

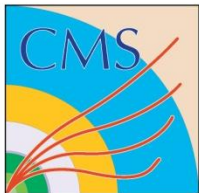
LHC- okno na fizykę poza Modelem Standardowym

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Fizyki Uniwersytetu Warszawskiego

i

Współpraca Compact Muon Solenoid



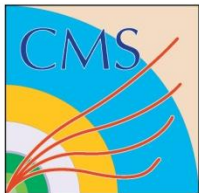
Literatura

Referat jest głównie oparty na wynikach pokazywanych na konferencji Fizyki Wysokich Energii Europejskiego Towarzystwa Fizycznego w lipcu 2009 w Krakowie. Transparencje referatów, zawierające znacznie więcej szczegółów można znaleźć pod adresem: <http://www.ifj.edu.pl/hep2009/>

Polecam także referaty na niniejszym Zjeździe:

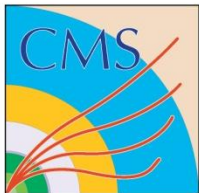
1. Barbara Wosiek (IFJ PAN): LHC – fizyka: pierwszy dzień, tydzień, miesiąc! (S-3.6)
2. Michał Turała (IFJ PAN): LHC status, maszyna i detektory (S-3.6)

oraz referaty na sesjach równoległych S-1.6, S-2.4, S-2.6, S-3.6



Plan

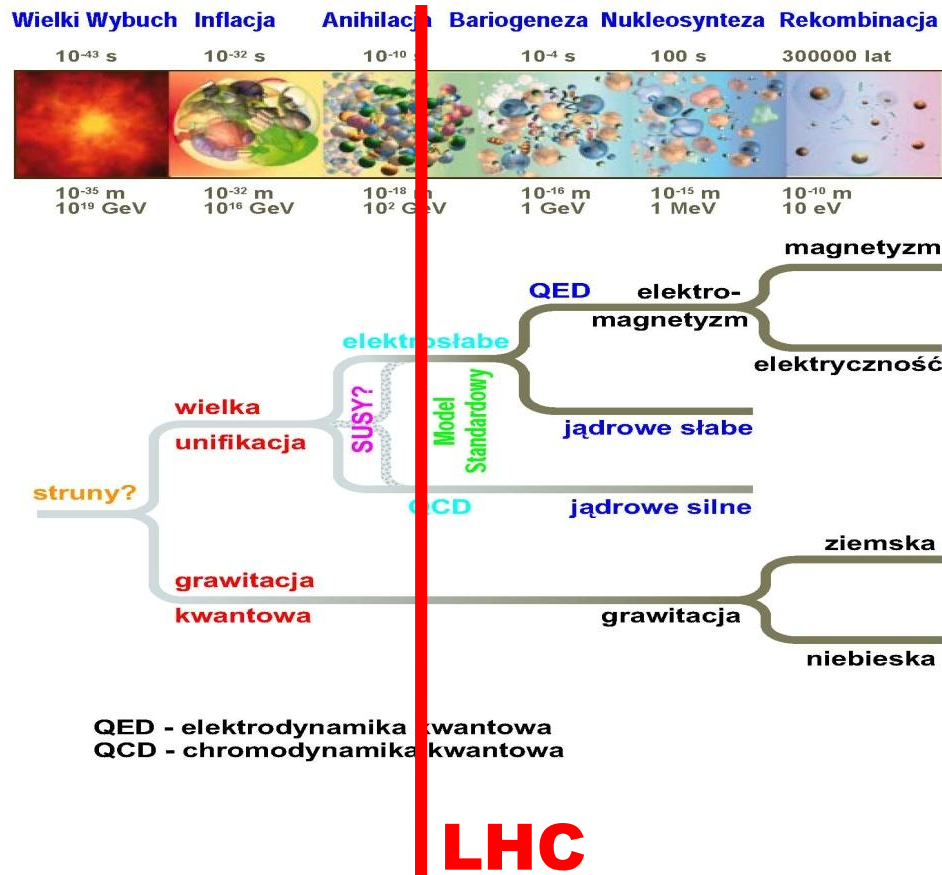
1. Large Hadron Collider –stan zderzacza i eksperymentów, plany na 2009-2011
2. Dodatek A: R. Heuer LHC status (RRB Plenary Oct. 12th)
3. Dodatek B: Wyniki CMS z naświetleń mionami kosmicznymi 2008-2009
4. Model Standardowy: co wiemy i czego nie wiemy
5. Fizyka Modelu Standardowego na początku pracy LHC
6. **BADANIE MECHANIZMU SPONTANICZNEGO ŁAMANIA SYMETRII I FIZYKA POZA MODELEM STANDARDOWYM W LHC**

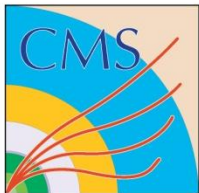


Gdzie jesteśmy na drodze poznania świata subjądrowego?

Unifikacja oddziaływań

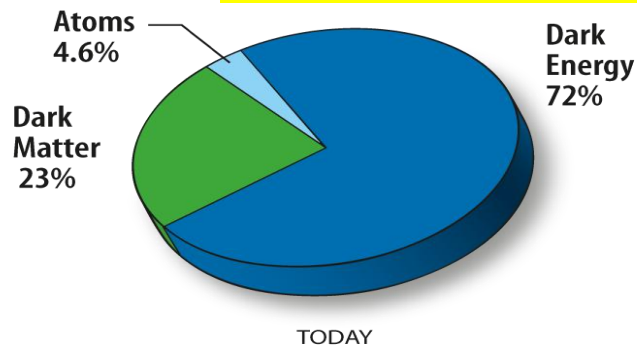
Fizyka Oddziaływań Elementarnych ma bliski związek z Kosmologią. Wielkie energie odpowiadają bardzo wczesnym etapom ewolucji Wszechświata.





Co wiadomo o składzie Wszechświata?

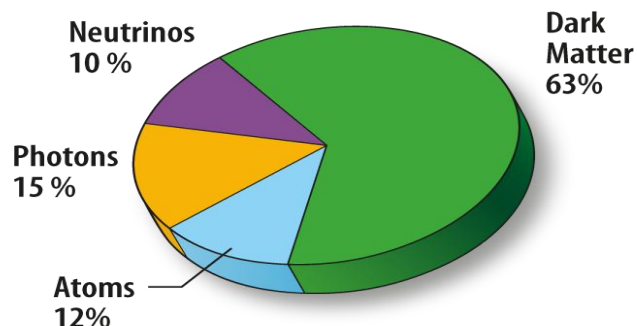
Universe now



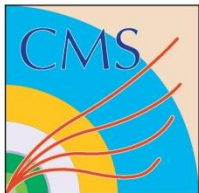
Model Standardowy i jego rozszerzenia opisują ok. 5% gęstości energii Wszechświata.

Być może odkryjemy (w LHC?) składniki **Ciemniej Materii** (Cząstki SUperSYmetryczne?).

Ciemna Energia, odpowiedzialna za przyspieszanie tempa ekspansji Wszechświata, pozostaje na razie niezrozumiała.

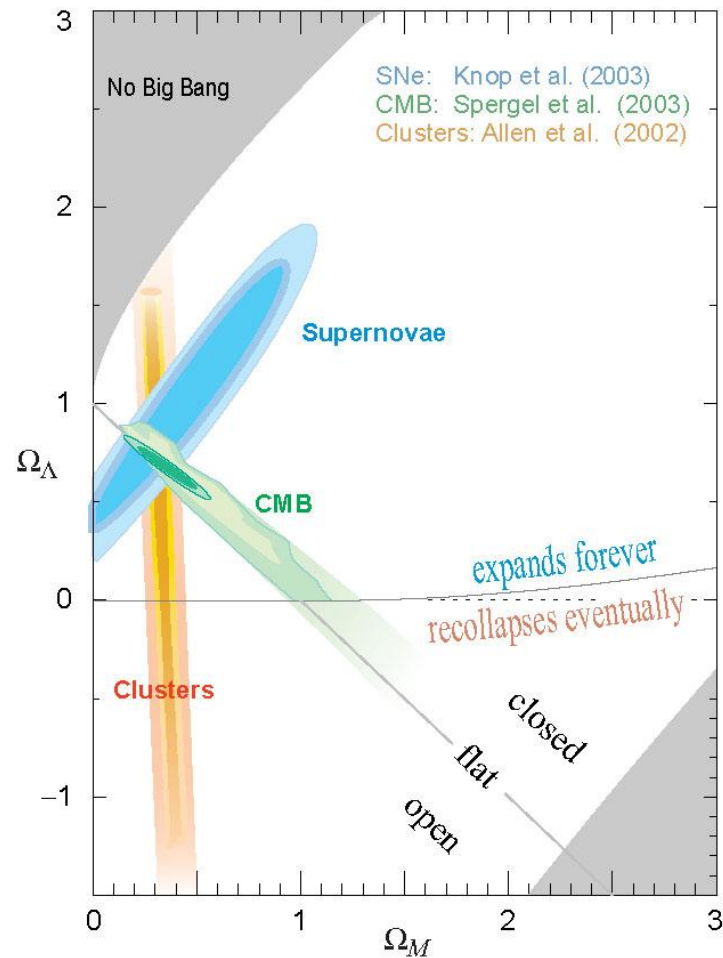


Universe 380 000 years old



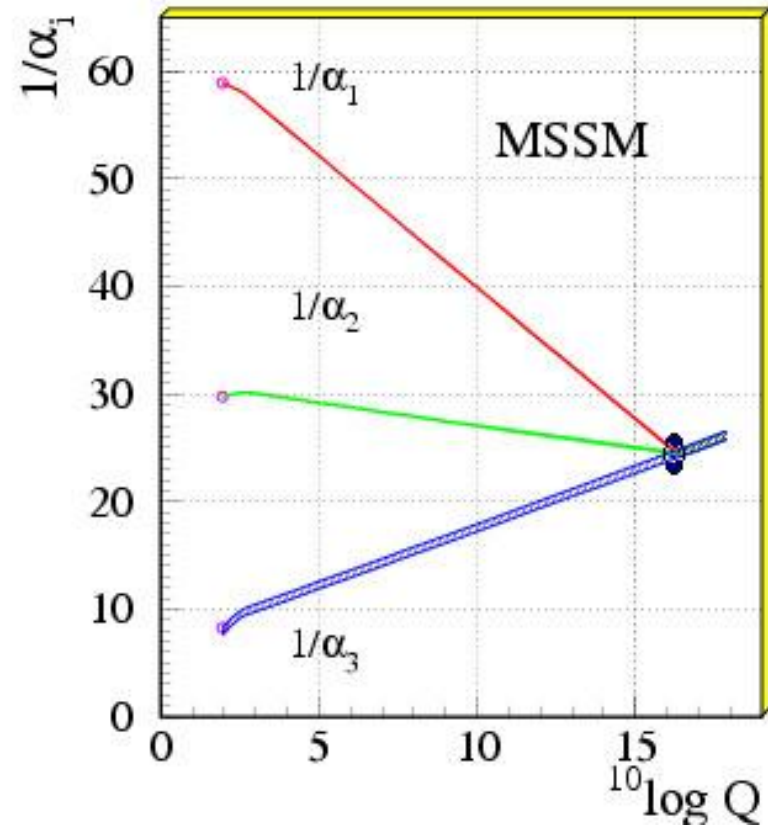
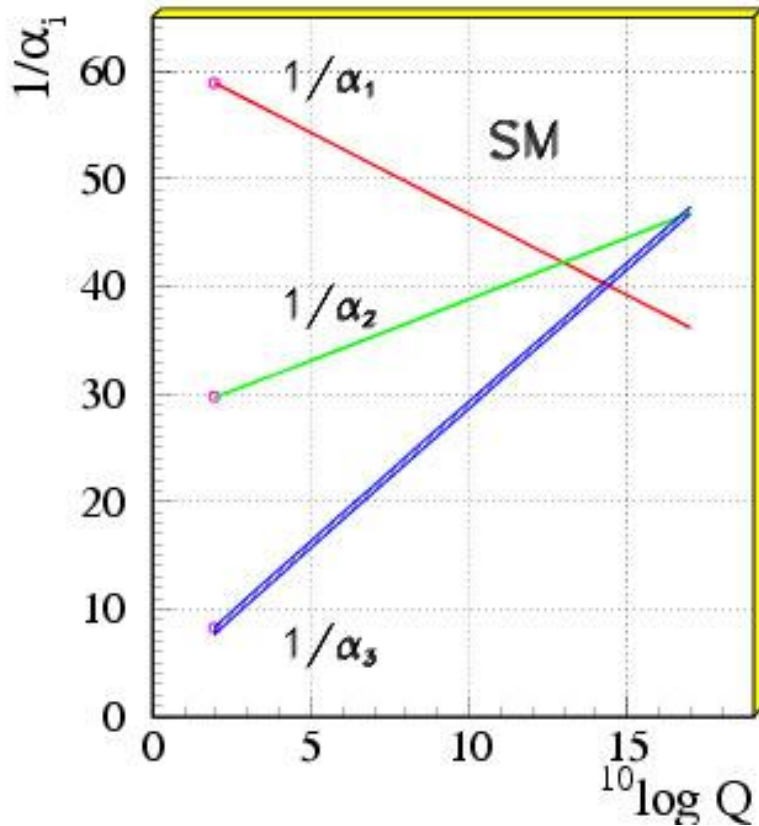
Gdzie jest ciemna materia?

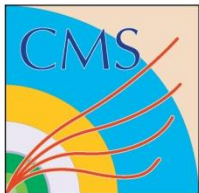
Materia barionowa $\sim 4-6\%$
Ciemna Materia $\sim 23\%$
Ciemna Energia $\sim 70\%$



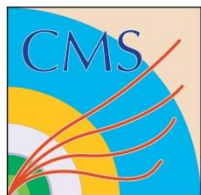


Czy oddziaływania unifikują się przy wysokich energiach?





1. LARGE HADRON COLLIDER - STAN ZDERZACZA I EKSPERYMENTÓW, PLANY NA 2009-2011



Wielki Zderzacz Hadronowy LHC

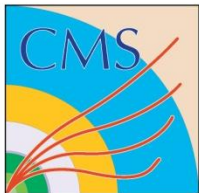


W tunelu LEP
W CERNie
k/ Genewy-
27 km obwodu

Uruchomiony
we wrześniu
2008. Uległ
awarii po 9
dniach.
Rozpocznie
ponownie pracę
w listopadzie. 2009.



ATLAS
ALICE
CMS
LHCb

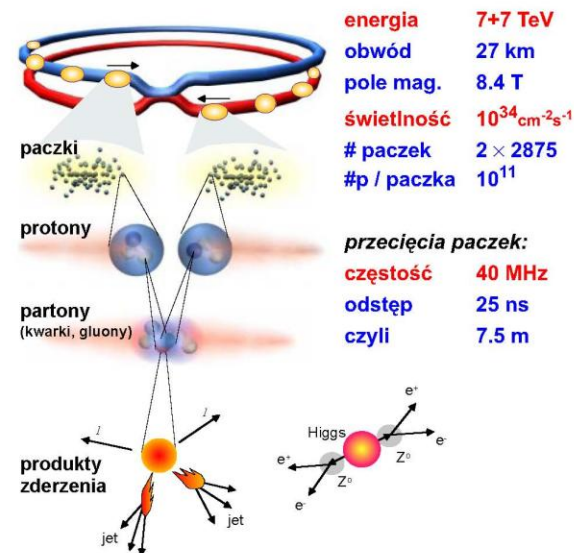


Zderzacz LHC



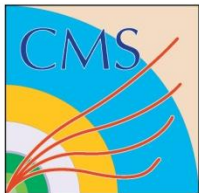
Wykorzystano istniejący tunel zderzacza e^+e^- LEP o obwodzie ok. 27 km.
Zbudowano pierścień magnesów nadprzewodzących dipolowych (~1300) zapewniający zamknięte orbity dla dwóch przeciwbieżnych wiązek protonów lub jonów (aż do jonów Pb).
Maksymalna indukcja B w dipolach to 8.4 T \rightarrow maksymalna energia wiązki p 7 TeV.

Zderzenia proton-proton w LHC



Przy nominalnej światłości w każdym przecięciu paczek zajdzie 10-20 zderzeń proton-proton.

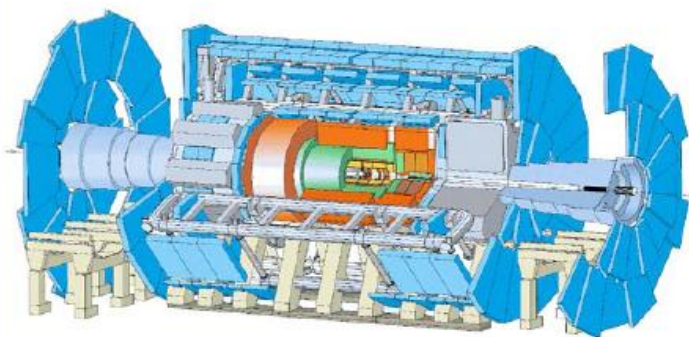
System kriogeniczny LHC jest największy na świecie.
Magnesy dipolowe pracują w temperaturze nadciełego helu 1.9 K



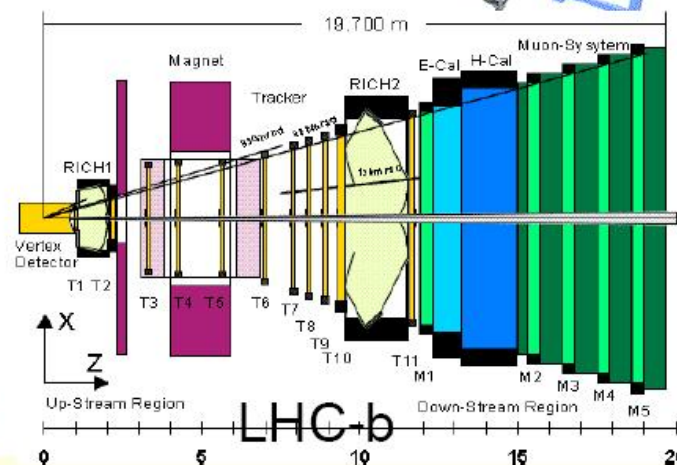
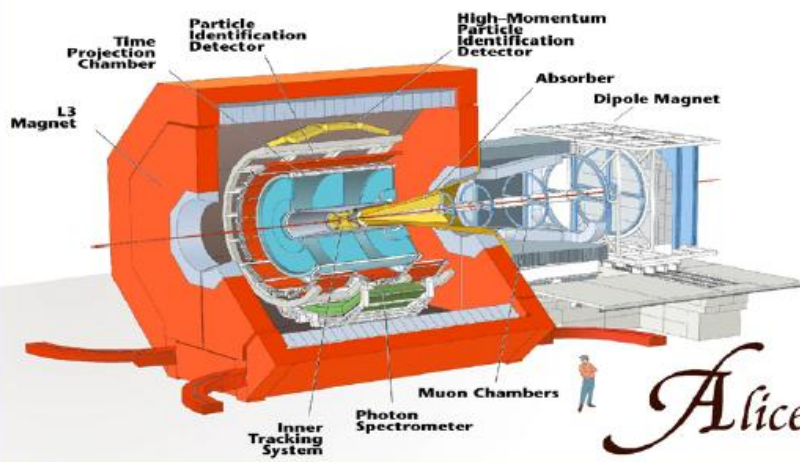
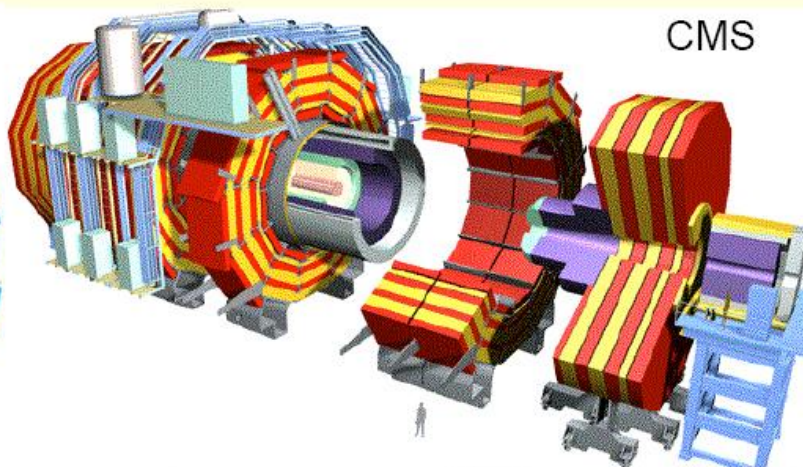
Przy LHC będą działać 4 eksperymenty

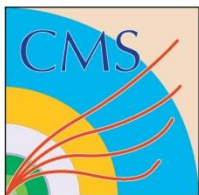


ATLAS



CMS

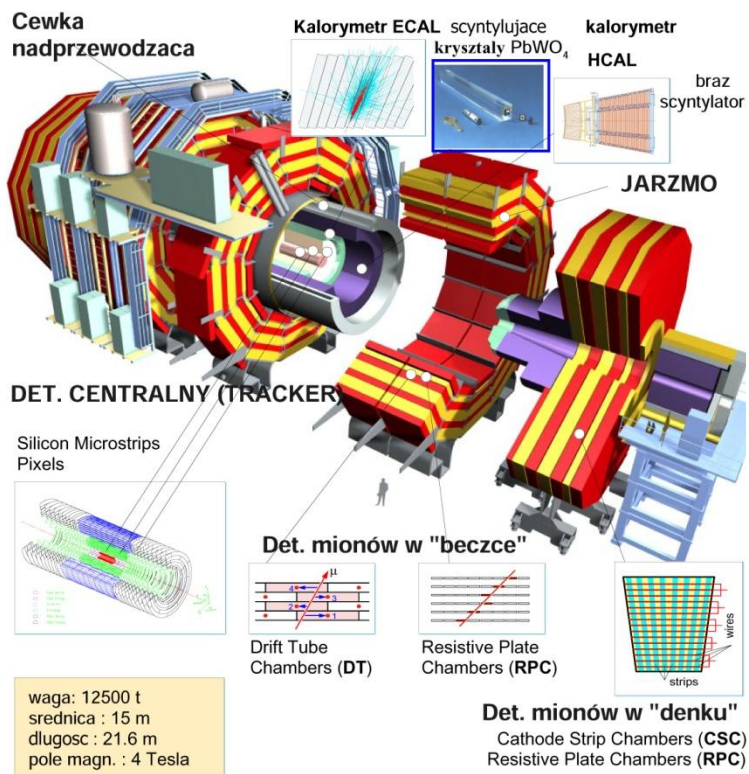




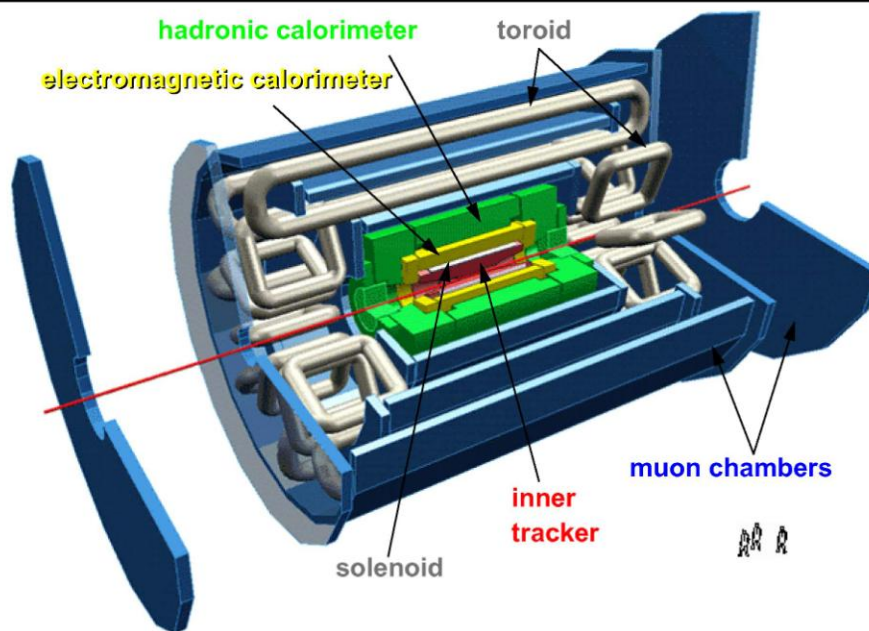
Eksperymenty „ogólnego przeznaczenia”

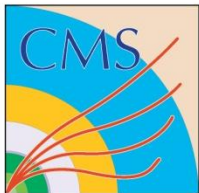


Detektor CMS i jego poddetektory

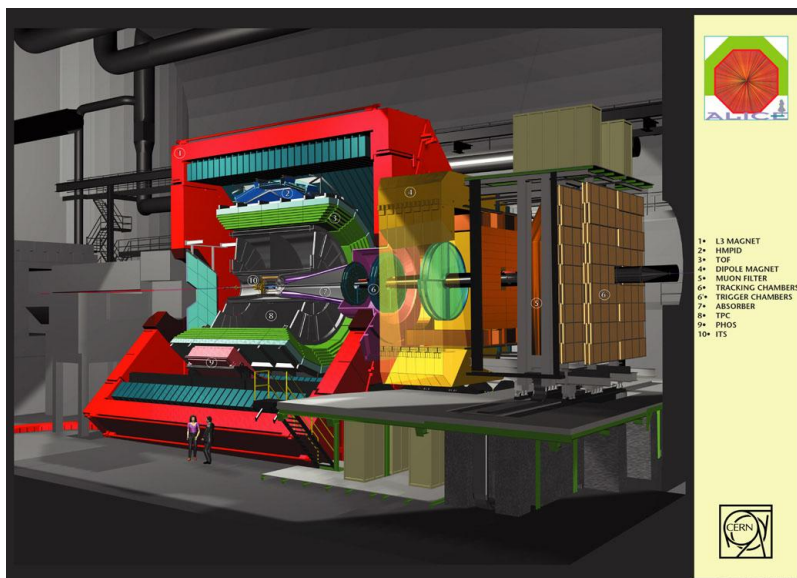


A Toroidal LHC ApparatuS (ATLAS)

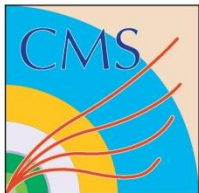




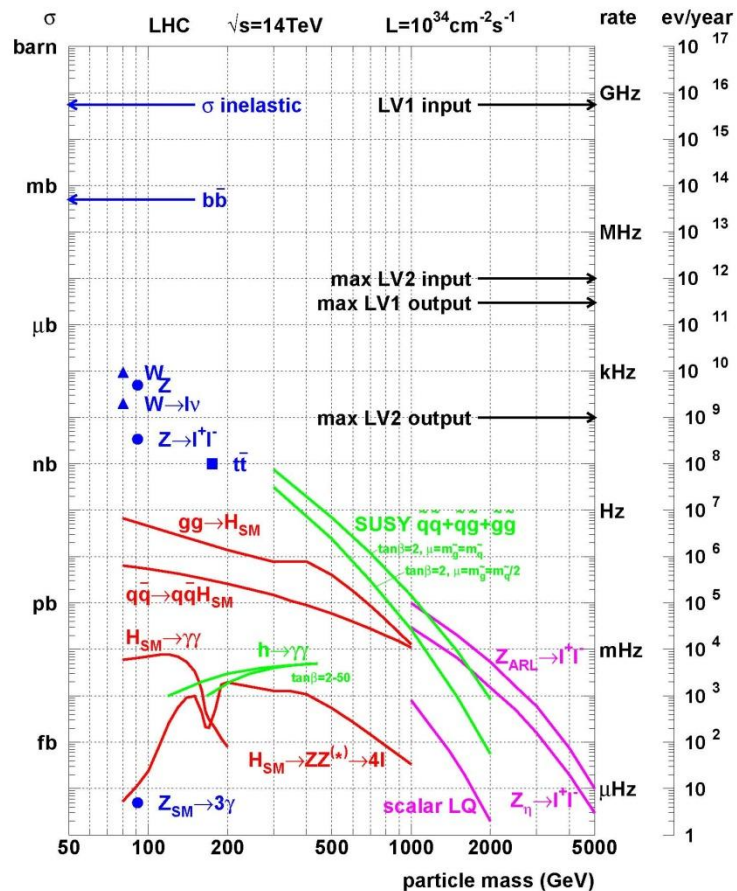
Eksperymenty dedykowane: ALICE i LHCb

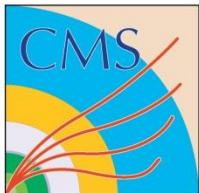


ALICE- zderzenia jonów (jader atomowych) wysokich energii
LHCb – badanie rozpadów cząstek zawierających kwarki b



Fizyka Poza Modelem Standardowym będzie trudnodostępna nawet w LHC



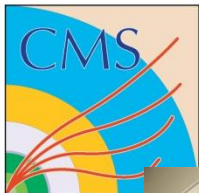


Wkład zespołów polskich

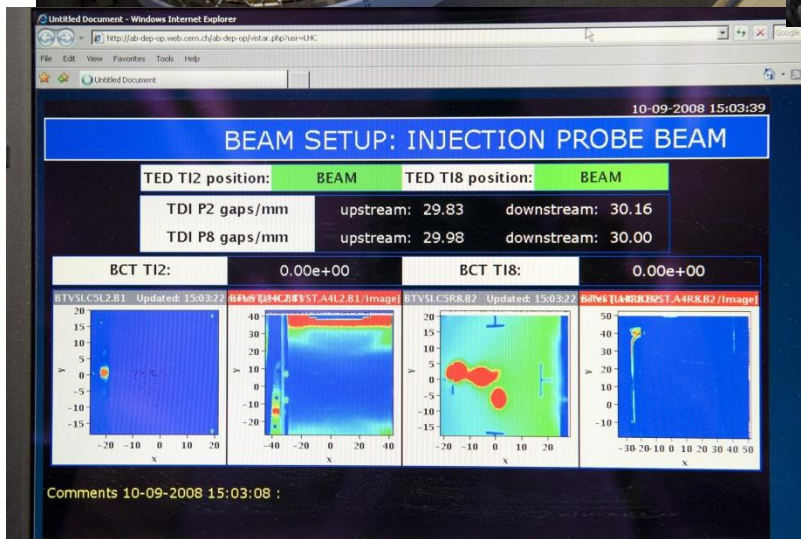
Polskie zespoły naukowe uczestniczą we wszystkich 4 eksperymentach przy LHC.

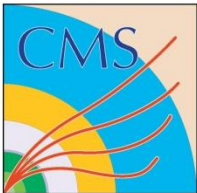
Wniosły znaczny wkład (~1% w każdym eksperymencie) aparaturowy w detektory i oprogramowanie.

Aktywnie uczestniczą w zdefiniowaniu i realizacji programów fizycznych, przygotowując analizy danych, uczestnicząc w integracji i kalibracji detektorów i systemów akwizycji oraz zbieraniu danych kosmicznych.

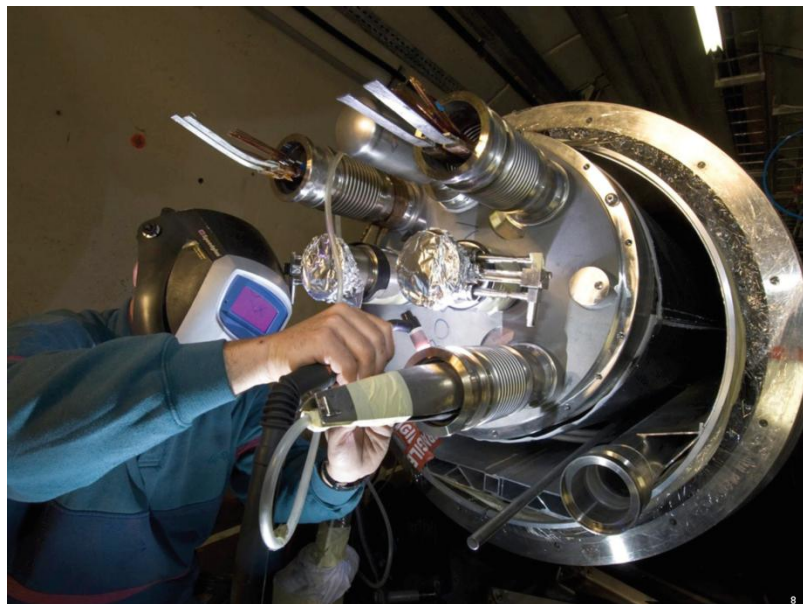


Start LHC: 10 września 2008



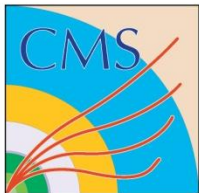


Awaria we wrześniu 2008



the blown-up connection between C24 and Q24

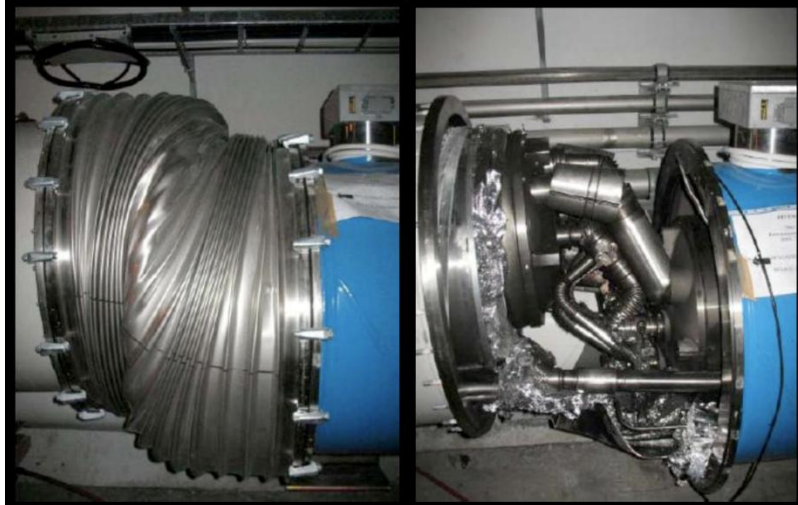




Fala nadciśnienia zniszczyła 10 magnesów i przesunęła 42



physical displacement of many magnets;
destruction of connections

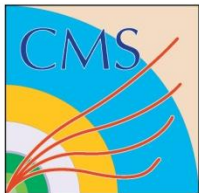


support jacks ripped out of concrete socket



Naprawa została zakończona. Ulepszono systemy kontroli, które są jeszcze instalowane i testowane.

Wiązki w LHC spodziewane są w połowie listopada 2009.



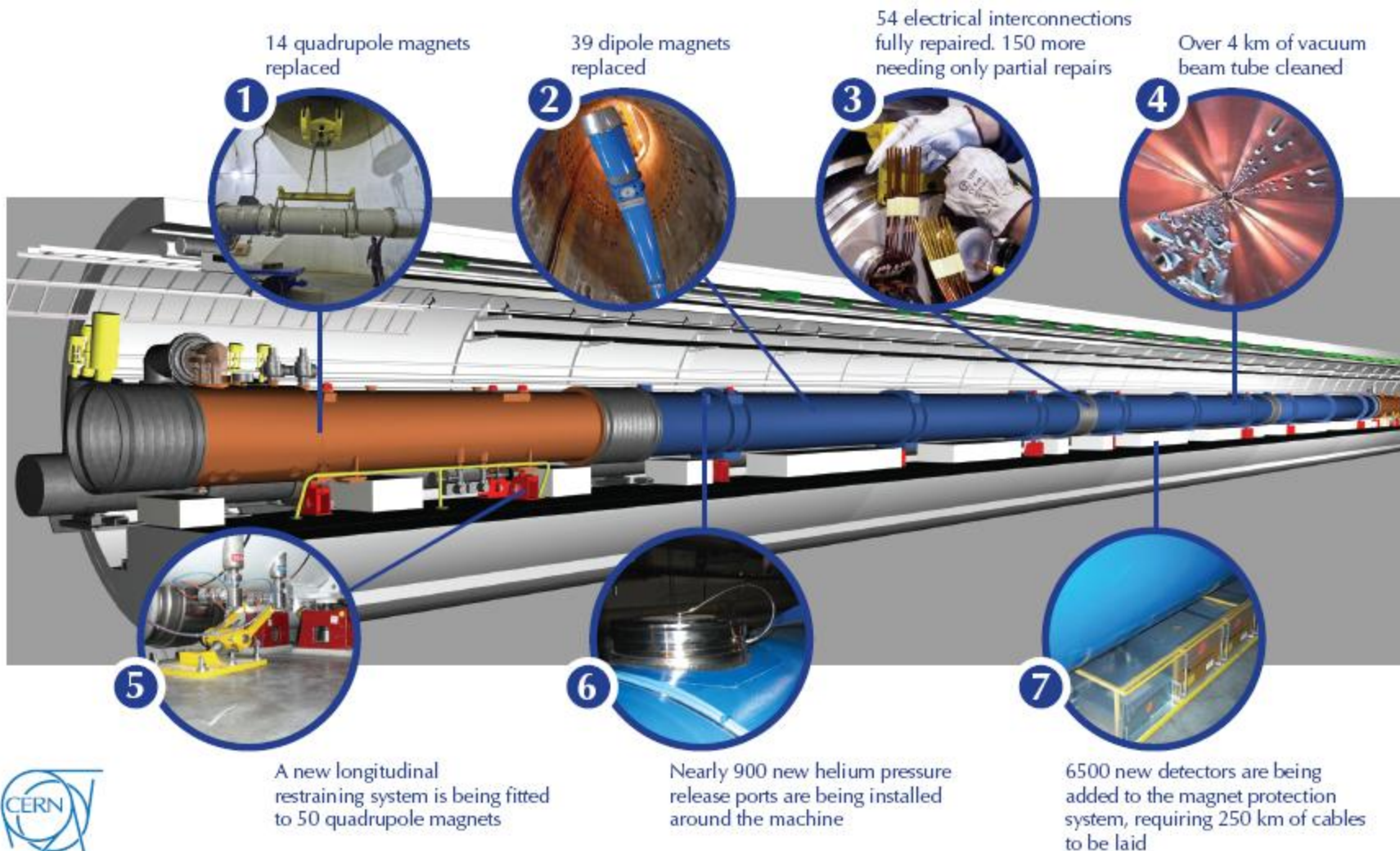
Dodatek A: LHC Status

12 October 2009

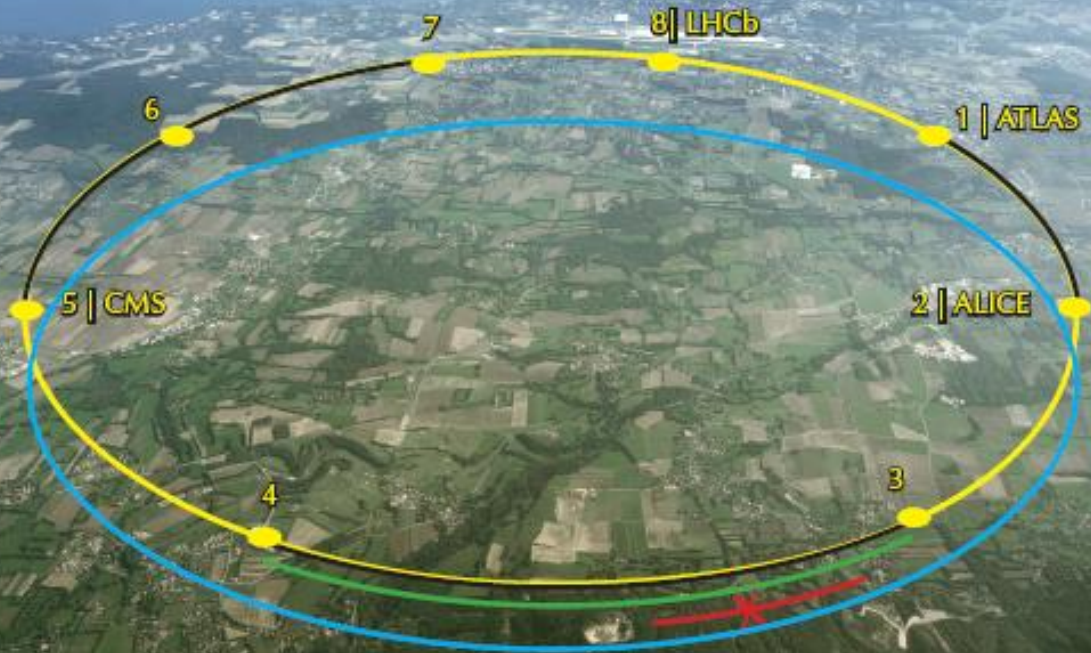
RRB Plenary

R.-D. Heuer

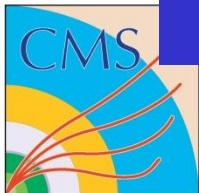
The LHC repairs in detail



Where the repairs are happening



- New pressure release ports fitted
- Upgrade of magnet protection system
- Cleaning of vacuum beam tube
- Dipole and quadrupole magnets replaced and electrical interconnections
- LHC ring
- X** Incident



Repair of QRL service module in S3-4

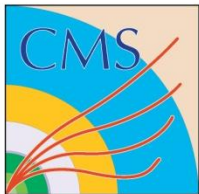


Before repair



After repair

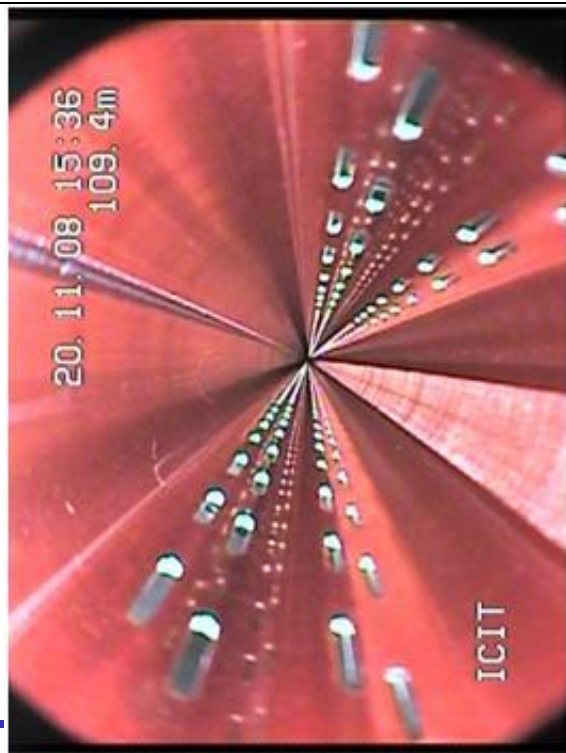
Q27



Beam vacuum recovery in sector 3-4

Beam Vacuum Contamination

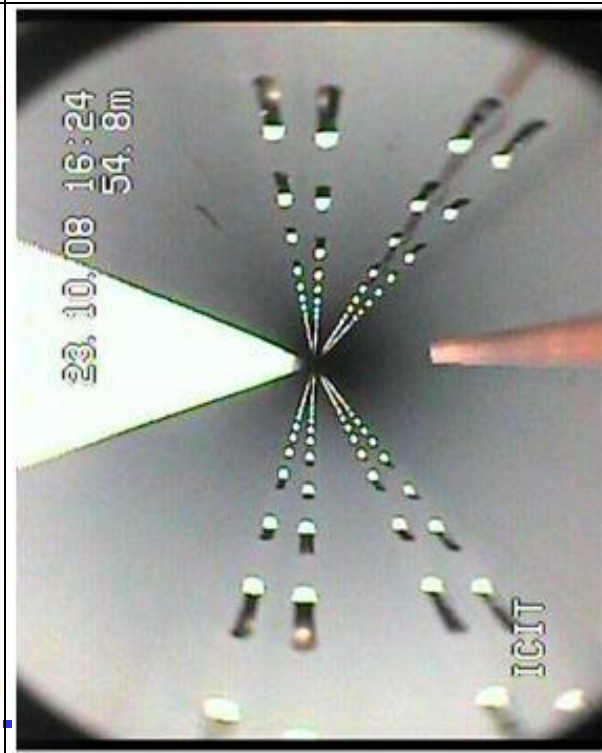
Beam Screen (BS) : The red color is characteristic of a clean copper surface

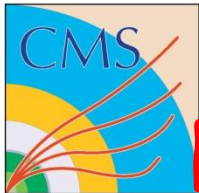


BS with some contamination by super-isolation (MLI multi layer insulation)



BS with soot contamination. The grey color varies depending on the thickness of the soot, from grey to dark.





Role of the Enhanced QPS System

To protect against the new 'problems' discovered in 2008

- The Aperture-Symmetric Quench feature in the Main Dipoles and
- Defective Joints in the Main Bus-bars, inside or in-between the magnets.

Reminder

QPS Upgrade also allows

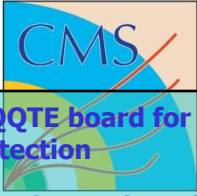
- precision measurements of the joint resistances **at cold** (sub-n Ω range) of every Busbar segment. This will allow complete mapping of the splice resistances (the bonding between the s.c. cables).
- To be used as the basic monitoring system for future determination of busbar resistances **at warm** (min. 80 K), to measure regularly the continuity of the copper stabilizers.



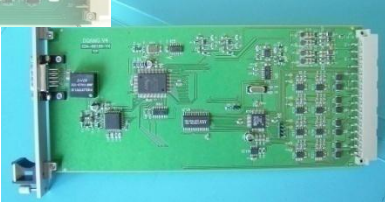
The nQPS project



For installation in
Phase 2



DQTE board for ground voltage detection
(total 1308 boards, 3 units/crate)



DQAMG-type S controller board
1 unit / crate, total 436 units

DQLPUS Power Packs
2 units / rack (total 872 units)

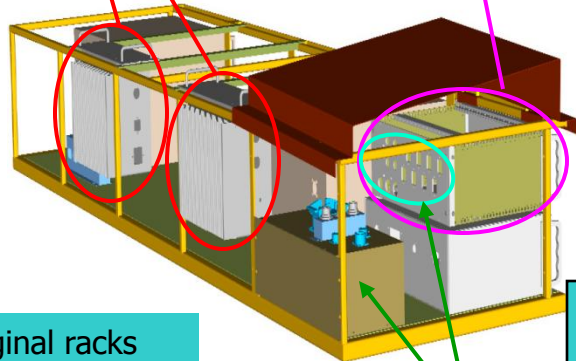


DQQBS board for busbar splice detection
5 such boards / crate, total 2180 units

DQLPU-type S crate
total 436 units



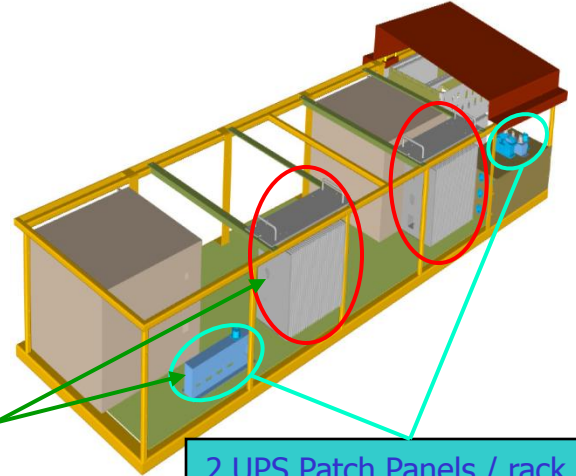
DQQDS board for SymQ detection
4 boards / crate, total 1744



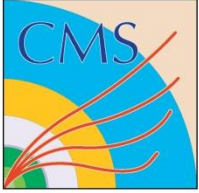
Original racks



'Internal' and 'external' cables for sensing, trigger, interlock, UPS power, uFIP (10'400 + 4'400)



2 UPS Patch Panels / rack & 1 Trigger Patch Panel / rack
total 3456 panel boxes



Splice Resistance Measurements



Good interconnect normal operation (1.9K)

Magnet

Magnet

copper bus bar 280 mm²

copper bus bar 280 mm²

current

interconnection (soldered)

superconducting cable

We must be sure that the joint between the sc cables is good.
Measurements of nano-Ohms at 1.9K



good interconnect, after quench (>10K)

Magnet

Magnet

copper bus bar 280 mm²

copper bus bar 280 mm²

interconnection

Non superconducting cable

Safe! Copper bus takes the current during the current decay following the quench



Bad interconnect, normal operation 1.9K

Magnet

Magnet

copper bus bar 280 mm²

copper bus bar 280 mm²

superconducting cable

interconnection

No problem while the sc cable remains superconducting



Bad interconnect, after quench

Current path is deviated through the sc cable (which is no longer sc). Depending on the current and length of this path, the cable can suffer thermal runaway

Magnet

Magnet

copper bus bar 280 mm²

copper bus bar 280 mm²

interconnection

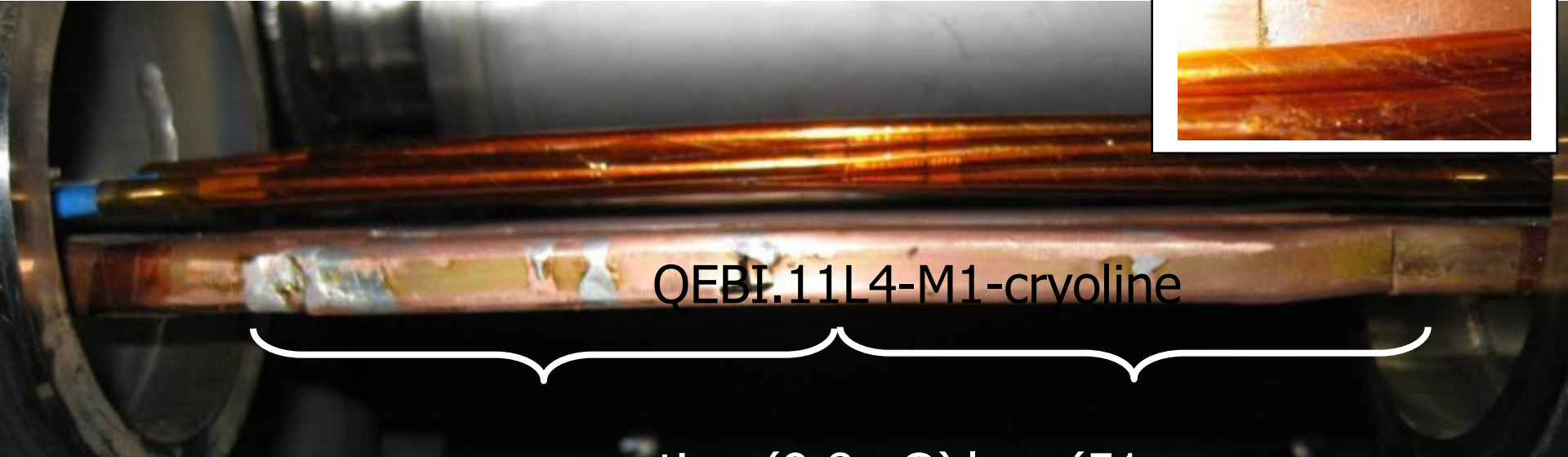
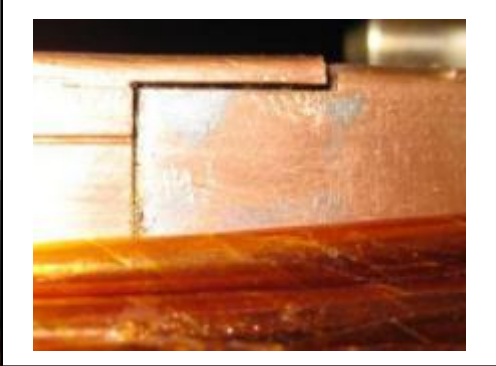
Non-superconducting cable

Danger of melting the sc cable then electrical arc

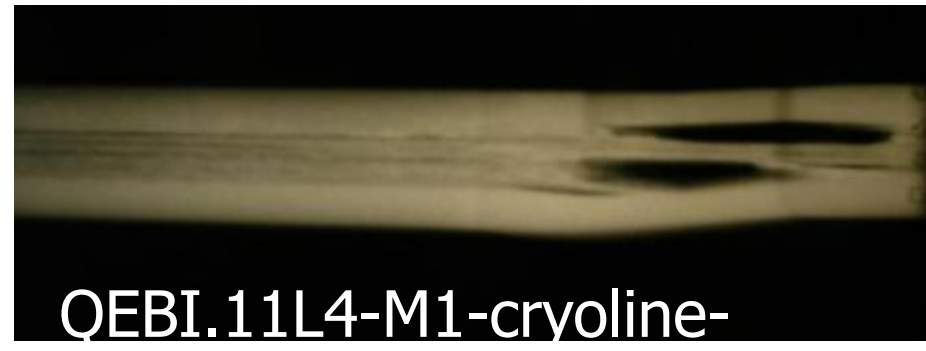
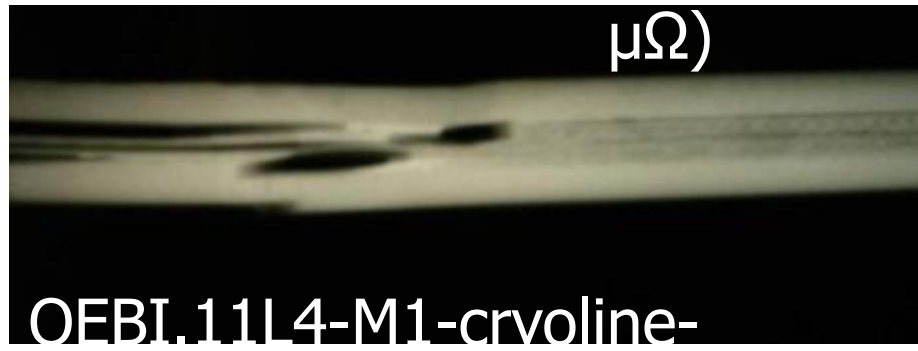
We must be ensure that the copper stabiliser is continuous
Measurements of micro-Ohms at warm



Sector 3-4 : QEBI.11L4-M1-cryoline before repair

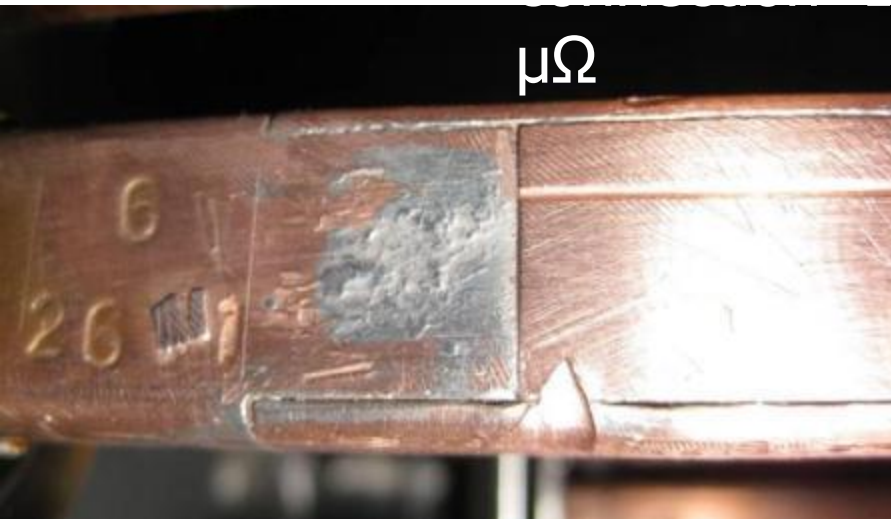
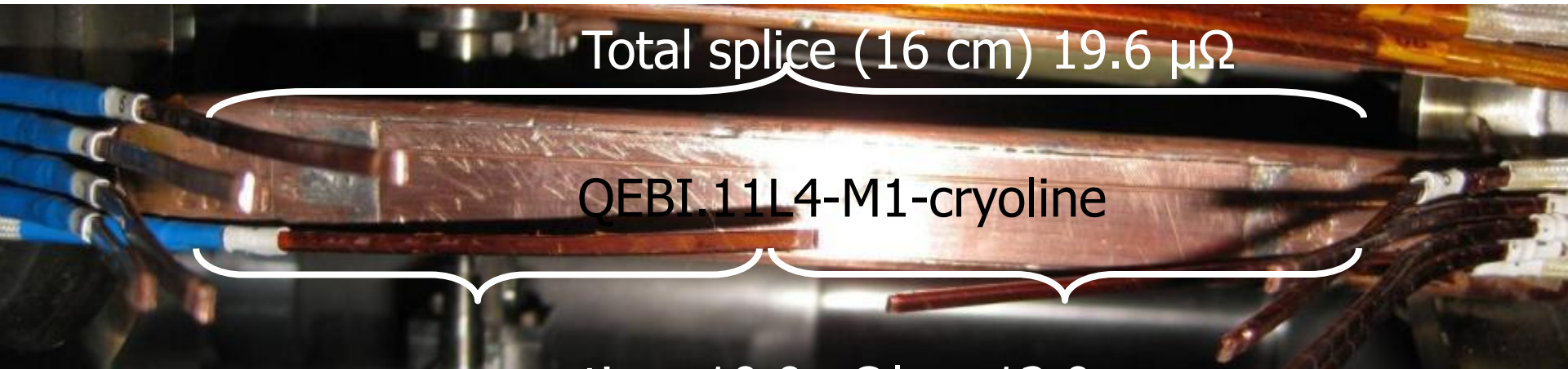


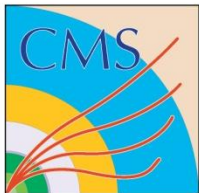
QEBI.11L4-M1-cryoline





Sector 3-4 : QEBI.11L4-M1-cryoline repaired





Number of splices in RB, RQ circuits

circuit	splice type	splices per magnet	number of units	total splices
RB	inter pole	2	1232	2464
RB	inter aperture	1	1232	1232
RB	interlayer	4	1232	4928
RB	internal bus	1	1232	1232
RB	interconnect	2	1686	3372
RQ	Inter pole	6	394	2364
RQ	internal bus	4	394	1576
RQ	interconnect	4	1686	6744
total				23912

~11 k splices: dipole, quadrupole



Non invasive splice resistance measurements

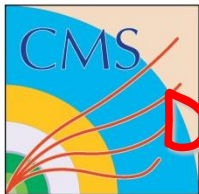
Summary of measurements performed on RB and RQ circuits

	Sector	Sector	Sector	Sector	Sector	Sector	Sector	Sector
Circuit	12	23	34	45	56	67	78	81
RB	300		300, 300	300, 300	300	300, 300		
RB		80		80			80	80
RQ	300		300	300	300	300, 300		
RQ		80		80			80	80, 80

Huge effort of dedicated measurement teams

About 35000 manual measurements

Over 400 kilometers walked in the tunnel



Decision on Initial Beam Operating Energy

(August 2009)

Highest measured value of excess resistance (R_{long}) in 5 sectors measured at 300K was $53\mu\Omega$.

Operating at 7 TeV cm with energy extraction times of 50s, 10s (dipoles and quadrupoles)

Simulations show that resistances of $\leq 120\mu\Omega$ are safe from thermal runaway under conservative assumed conditions of worst case conditions for the copper quality (RRR) and no cooling to the copper stabilizer from the gaseous helium.

Operating at 10 TeV cm with a dipole energy extraction time of 68 s

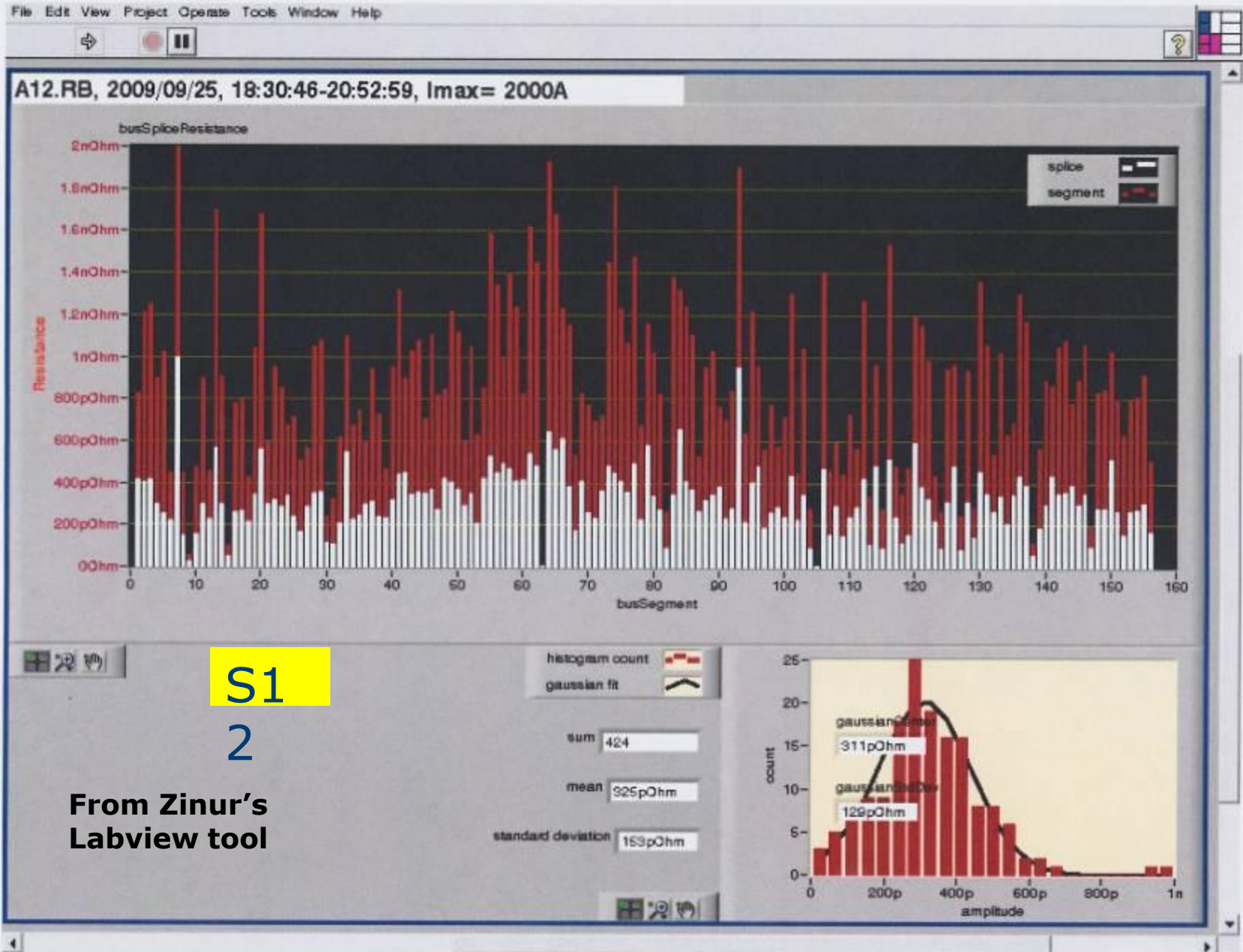
Simulations show that resistances of $\leq 67\mu\Omega$ are safe from thermal runaway under conservative assumed conditions of worst case conditions for the copper quality (RRR), and with estimated cooling to the stabilizer from the gaseous helium.

Decision: Operation initially at 7 TeV cm (energy extraction time of 50s, 10s) with a safety factor or more than 2 for the worst stabilizers. During this time

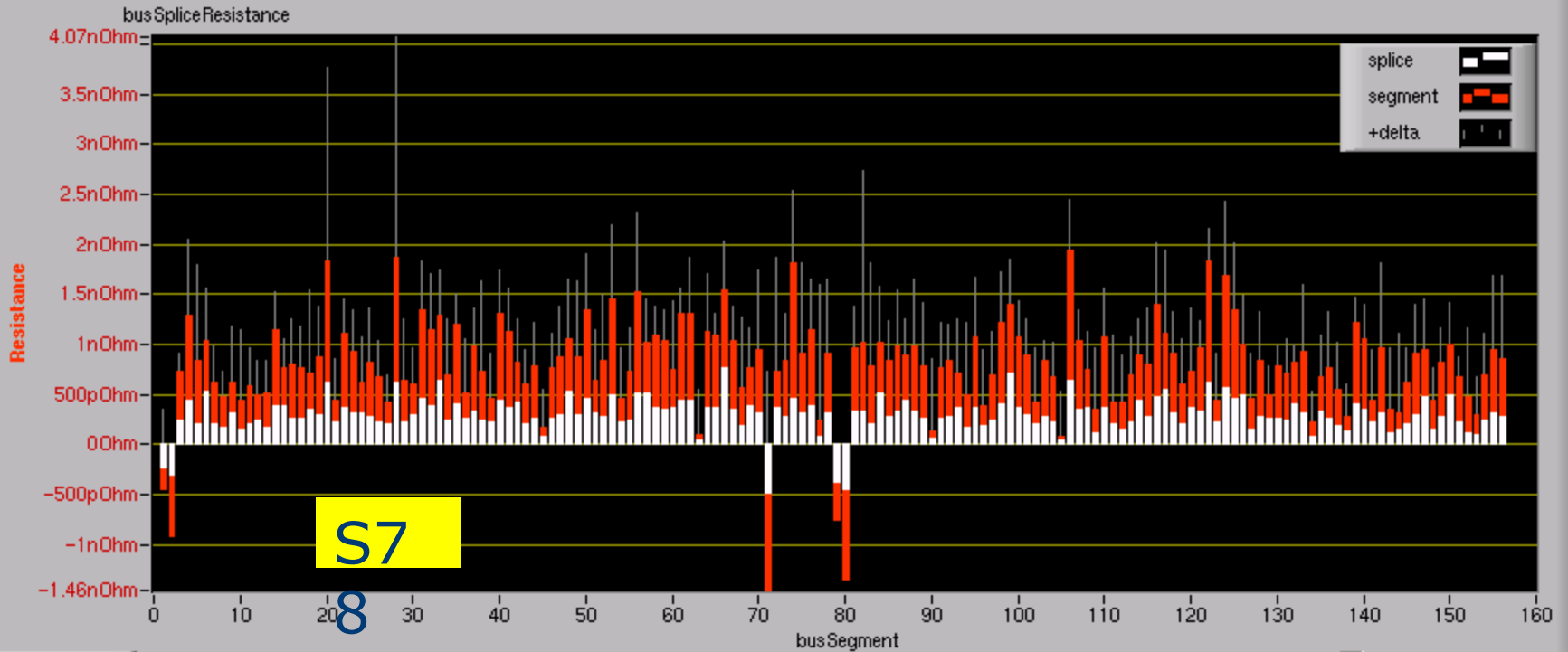
monitor carefully all quenches to gain additional information.

Continue simulations and validation of simulations by experimentation (FRESCA)

Then operate at around 10 TeV cm.



First Dipole Busbar Resistances from first scan to 2



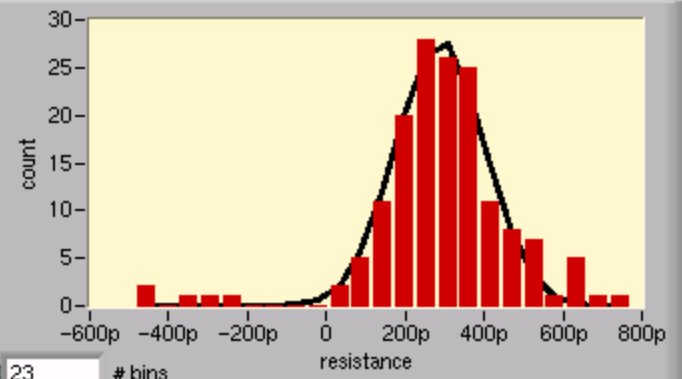
R_{excess} = R_{bus} - N_{splice} * R_{splice} show excess?

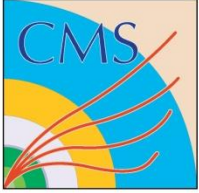
bus Segment Resistance Sorted

	signalName	spliceNum	resistance	deltaRes
78	DCBD.7R7.R	3	-9.16E-10	7.24E-10
79	DCBQ.7R7.L	2	7.49E-10	4.98E-10
80	DCBQ.8R7.L	3	1.35E-9	4.02E-10
81	DCBQ.9R7.L	3	-9.70E-10	4.16E-10
82	DCBQ.10R7.L	3	-1.01E-9	1.73E-9
83	DCBQ.11R7.L	4	-7.82E-10	1.02E-9
84	DCBB.12R7.L	2	-1.02E-9	5.52E-10
85	DCBB.A13R7.L	3	-8.35E-10	3.96E-10
86	DCRQ.13R7.L	3	-9.83E-10	5.55E-10

histogram count
gaussian fit

sum 424
mean 291pOhm
stdDev 179pOhm
gaussianCenter 288pOhm
gaussianStdDev 113pOhm





Since August 2009

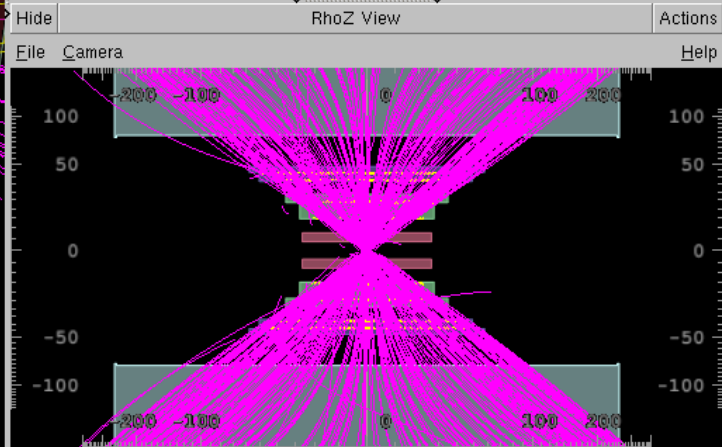
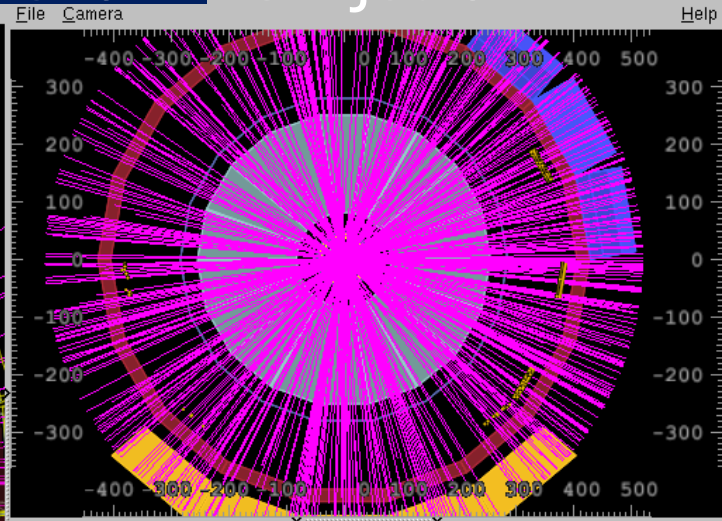
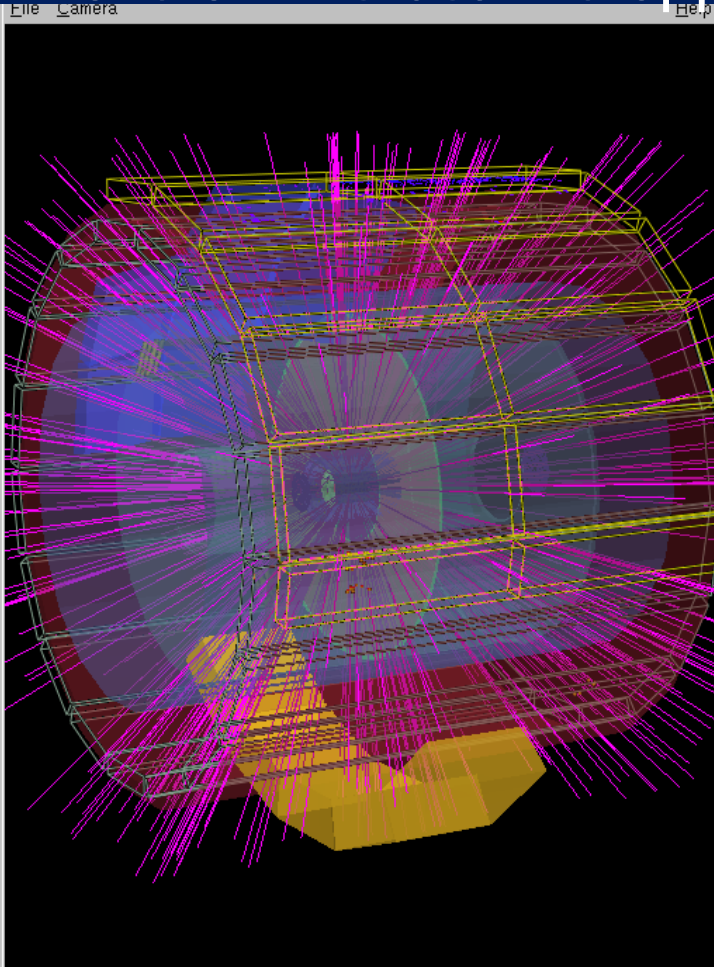
Start of re-establishment of spares situation as it was before the incident.

**Helium leak (flexible in the DFBs) in S45, S23, and S81.
All repaired.**

Super-insulation fire in S67 (minimum damage).

Magnet/bus-bar short to earth in S67 (detected and repaired).

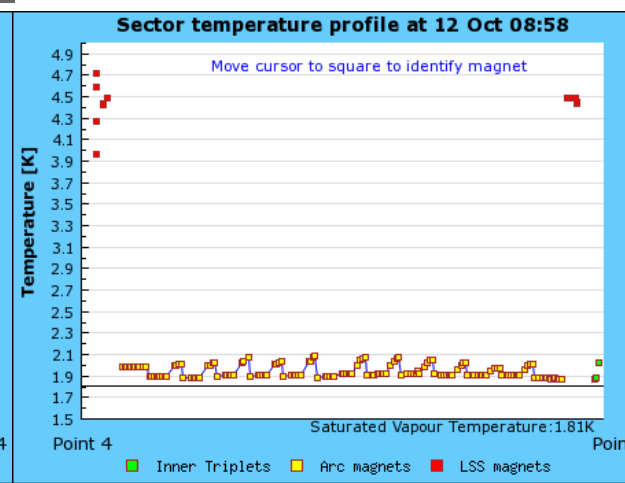
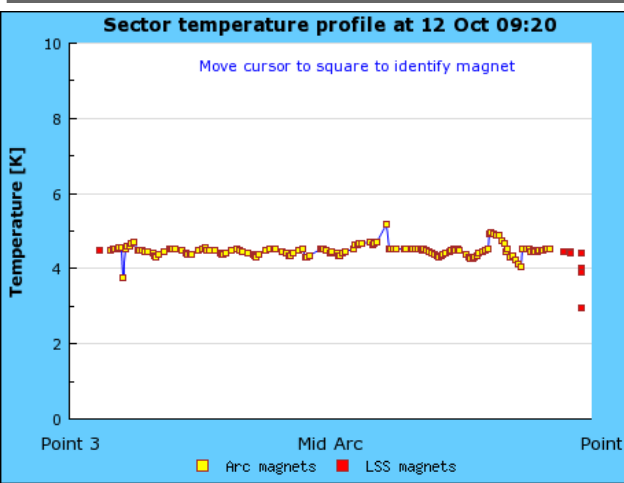
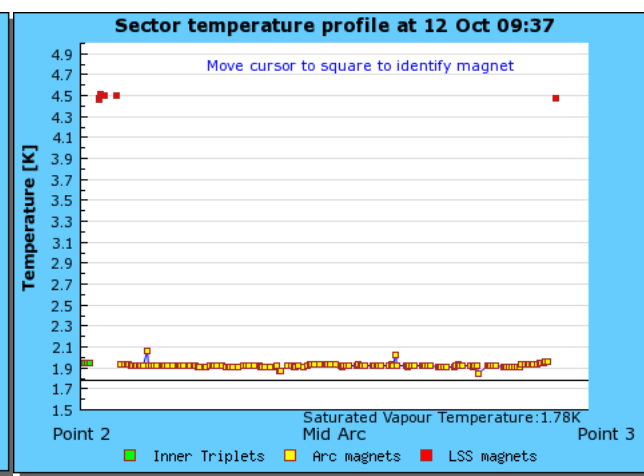
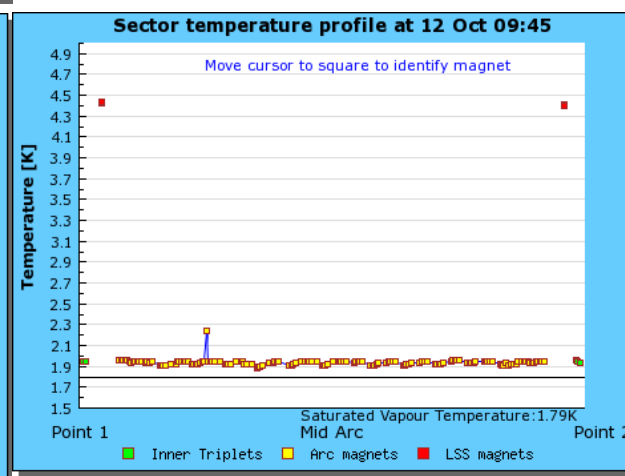
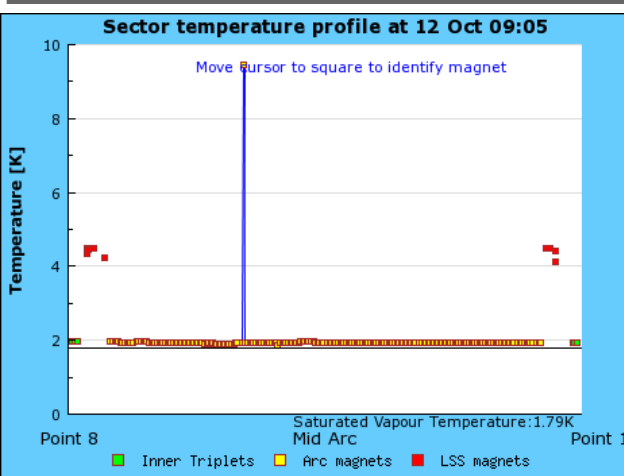
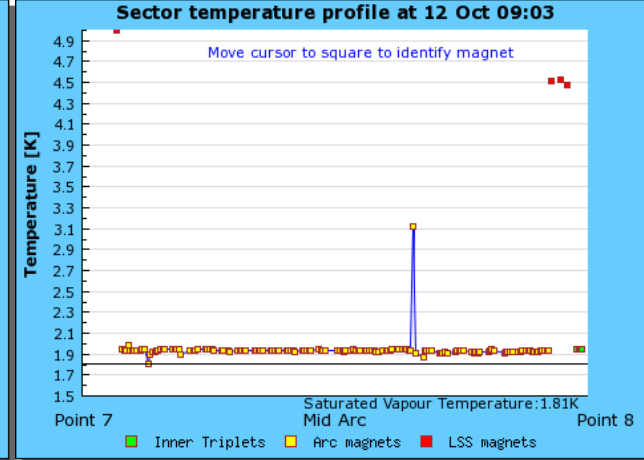
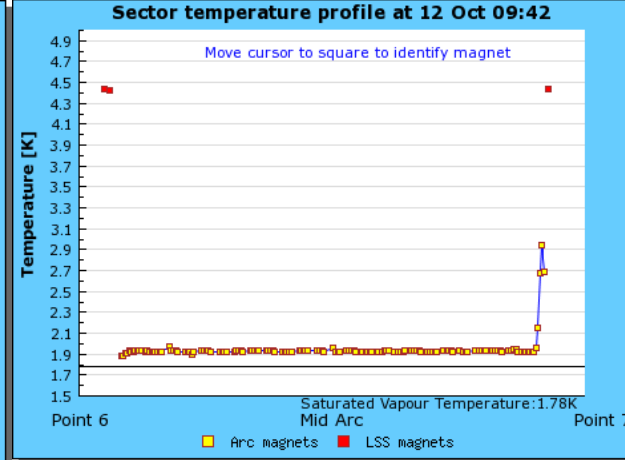
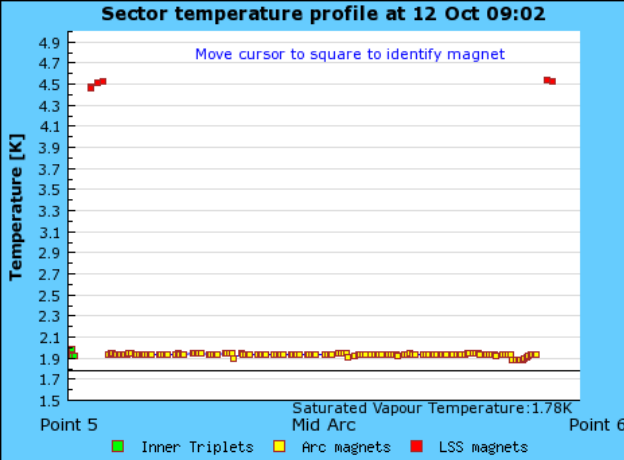
Sept.28: Ions on the beam stopper at LHC injector



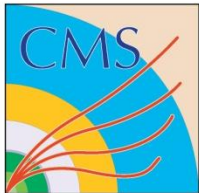
Style
Name
RhoPhi (0.0)::TEveProjectionManager
TEveElement
Show: Self Children
TEveProjection
Type: RPhi
Distortion: 0.00
FixedR: 300.0
FixedZ: 400.0
ScaleR: 0.00
ScaleZ: 0.00
CurrentZ: 0.00
TrackStep: 5.0
Distortion centre
CenterX: 0.000
CenterY: 0.000

Command EventCtrl
First Prev 9 /-1 Next Last Refresh Autoload Time: 10 COVID-ABCE-NOPF-CENT

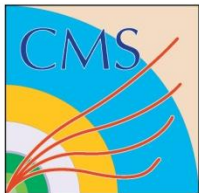
```
RAW event info: Run#: 87787 Event type: 7 (PHYSICS_EVENT) Period: 1 Orbit: 197d97 BC: ce  
Trigger: c  
Detectors: 8007f026 (ITSSDD ITSSDD TOP FMD TO VZERO ZDC ACORDE TRG EMCAL )  
Attributes:7f-0-30 Timestamp: 2009-09-28 12:41:15  
ESD event info: Run#: 87787 Event type: 7 (PHYSICS_EVENT) Period: 1 Orbit: 197d97 BC: ce  
Active trigger classes: COTID-ABCE-NOPF-CENT COVID-ABCE-NOPF-CENT COAID-ABCE-NOPF-CENT COEID-ABCE-NOPF-CENT  
Trigger: c ( COAID-ABCE-NOPF-CENT COEID-ABCE-NOPF-CENT )  
Event# in file: 9 Timestamp: 2009-09-28 12:41:15, MagField: 5.00e-14
```

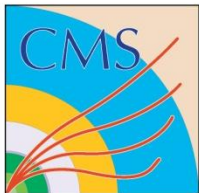
Cooldown
status
12.10.2009



-
- 7 Sectors at operating temperature
 - 2 Sectors splice resistances measured
 - Injection lines tested up to LHC for protons and ions
 - First injection mid November
 - Followed by collisions at injection energy
 - Collisions at 7 TeV
 - Towards 10 TeV in the course of 2010
 - Heavy Ion collisions at the end of the run in 2010
- Big thank you to everybody helping**



DODATEK B: WYNIKI CMS Z NAŚWIETLEŃ MIONAMI KOSMICZNYMI 2008-2009



Cosmic Run At Four Tesla 2008 i 2009



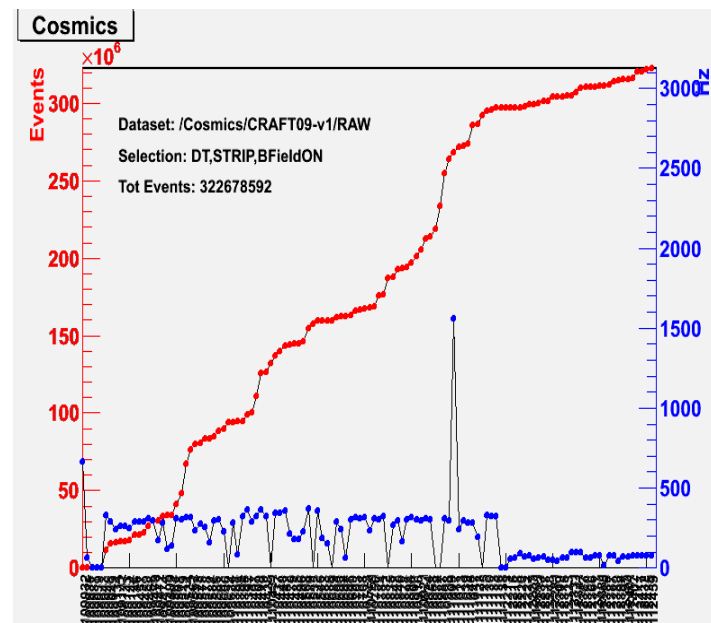
Zebrano niemal 1 bilion mionów.

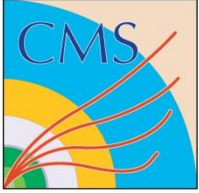
Bardzo dobra jakość zebranych danych.

Efektywność zbierania danych 80% (w czasie weekend'ów 85-90%) → dobrze wróży na przyszłość przy LHC.

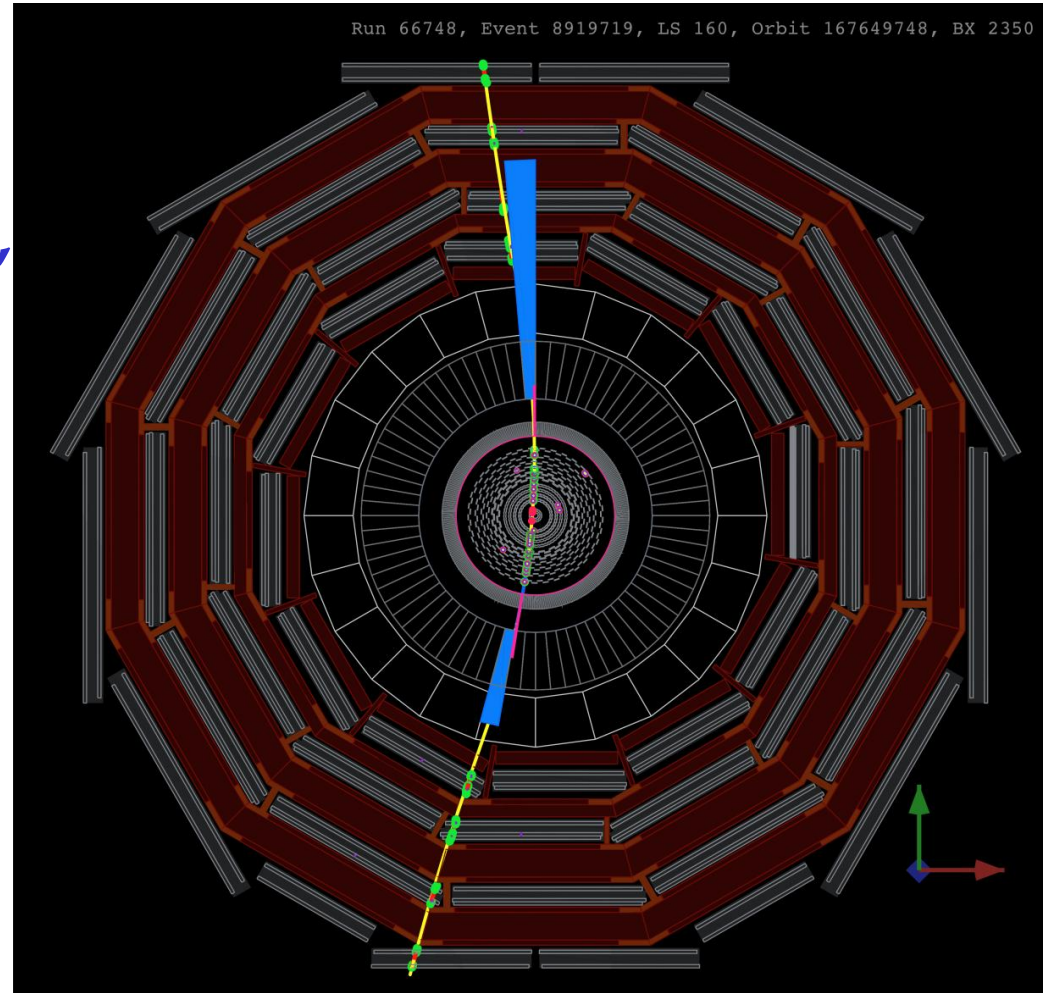
CRAFT09: Aug'09:

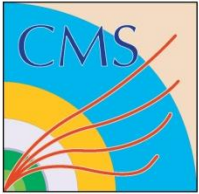
Collected 300M+ cosmic events with tracking detectors and field (3.8T).





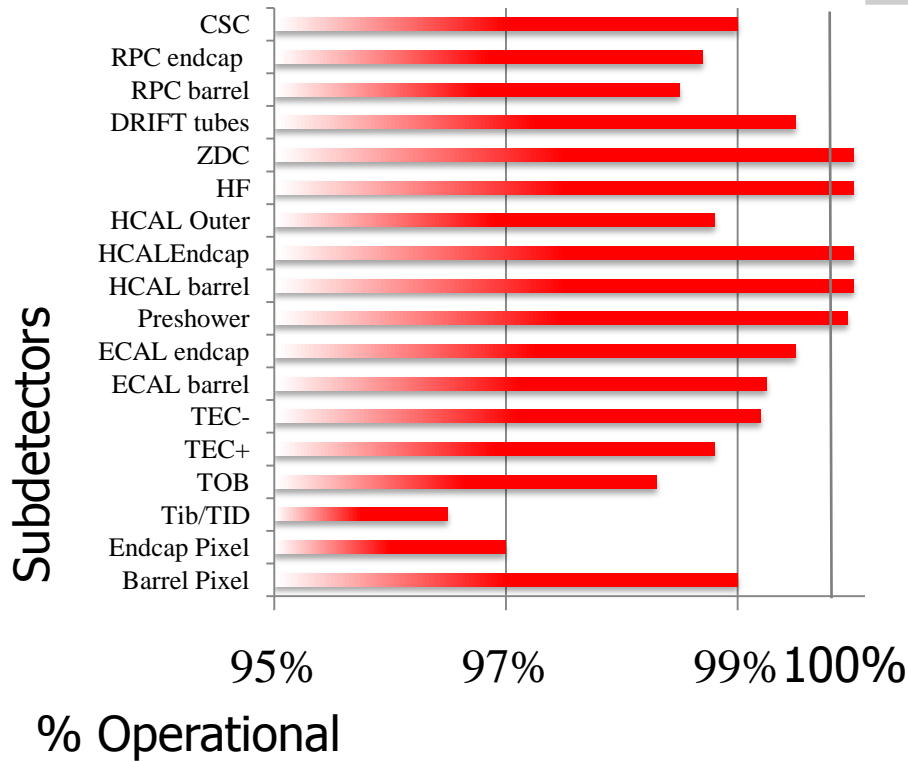
Przykład: typowy mion kosmiczny zostawia sygnały w Pixel Det., TK, ECAL, HCAL, DCh i RPC.



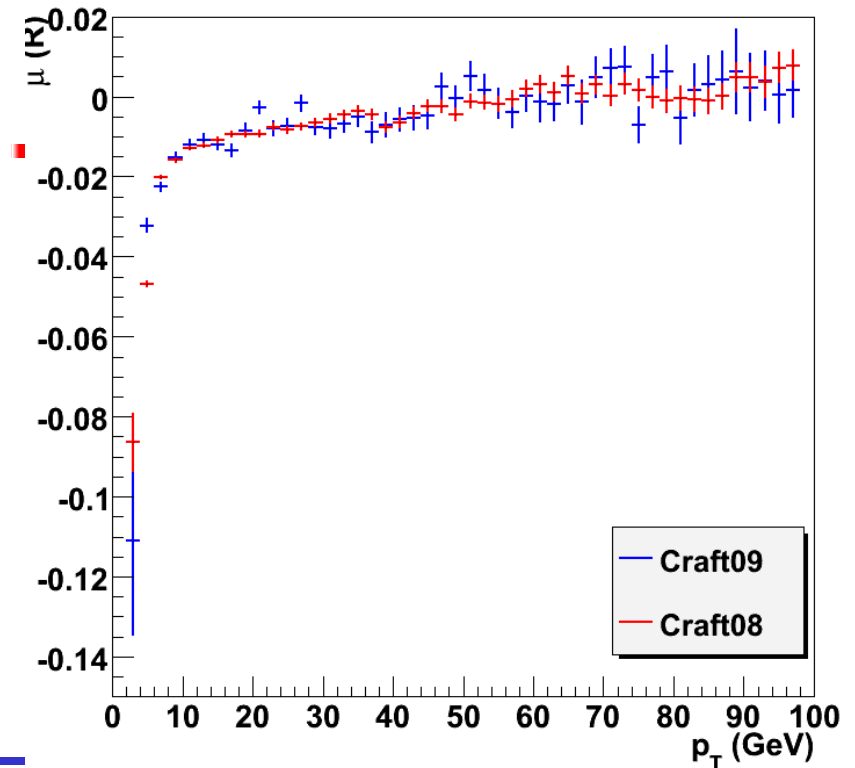


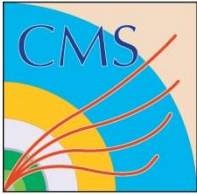
CRAFT09

P_T Comparison (B-Field): Stand-Alone Muons vs. Tracker Muons



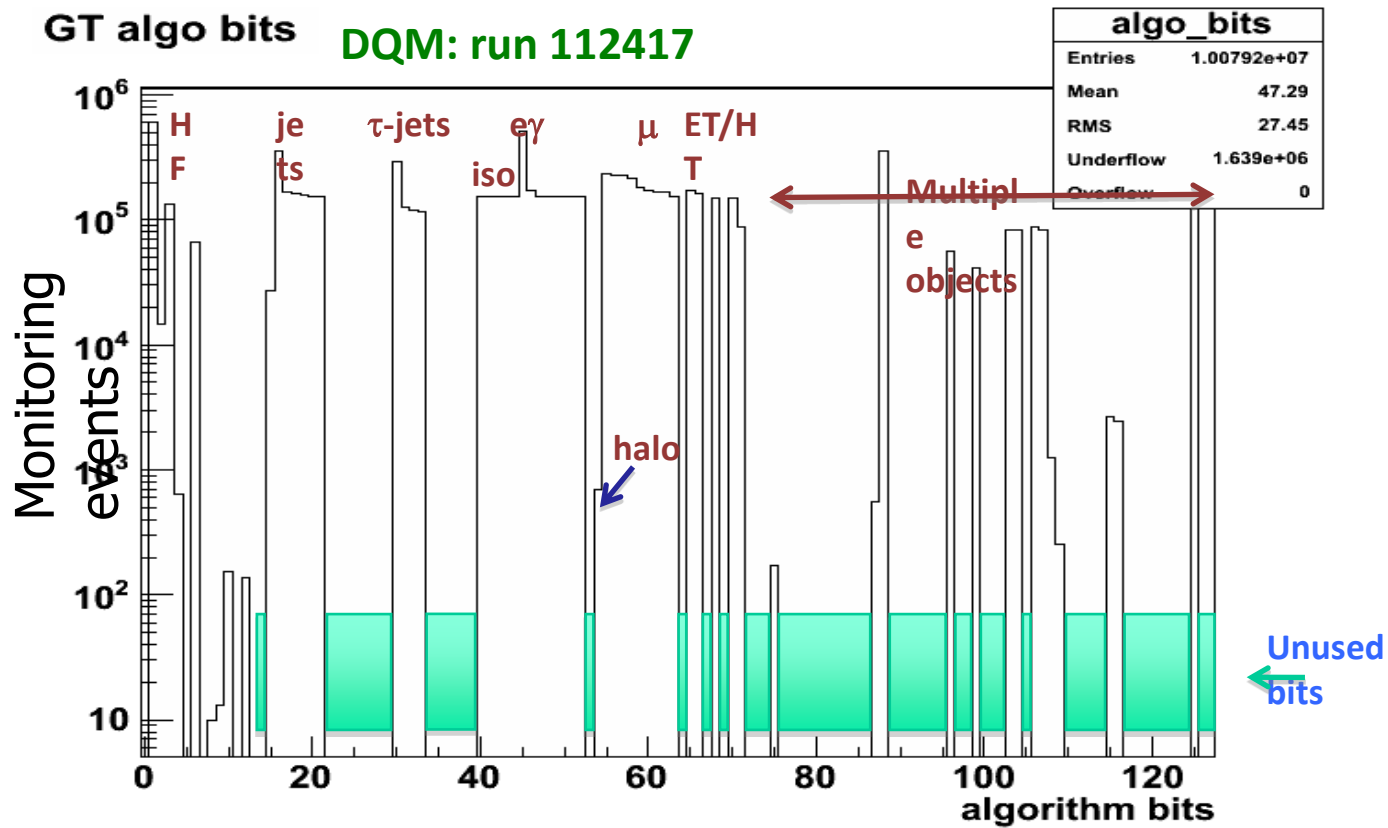
$$R = \frac{1 / p_T^{STA} - 1 / p_T^{TT}}{1 / p_T^{TT}}$$

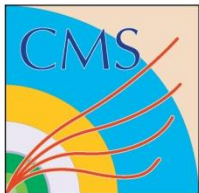




All L1 Triggers Operated During CRAFT09

Calorimeters thresholds set to low values to study noise





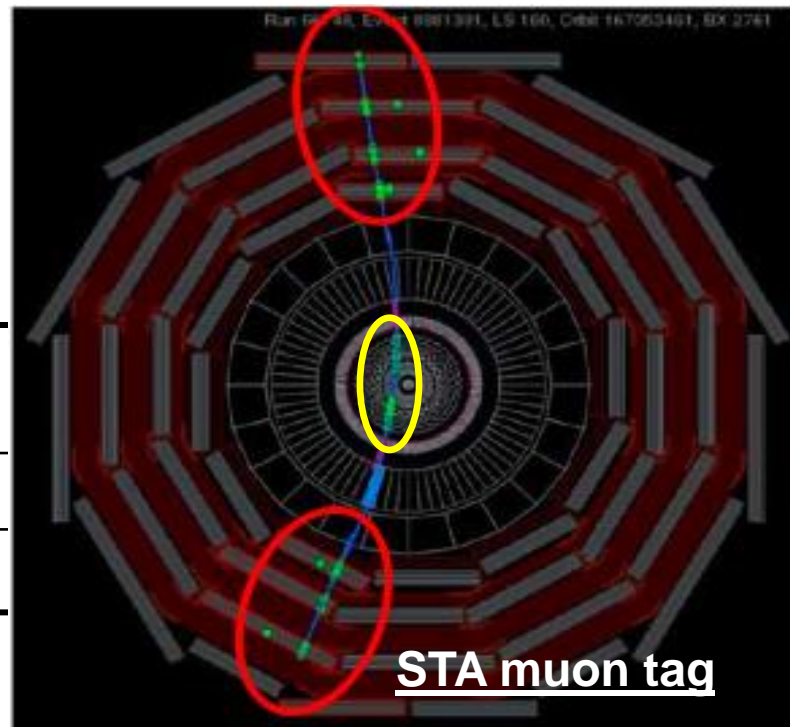
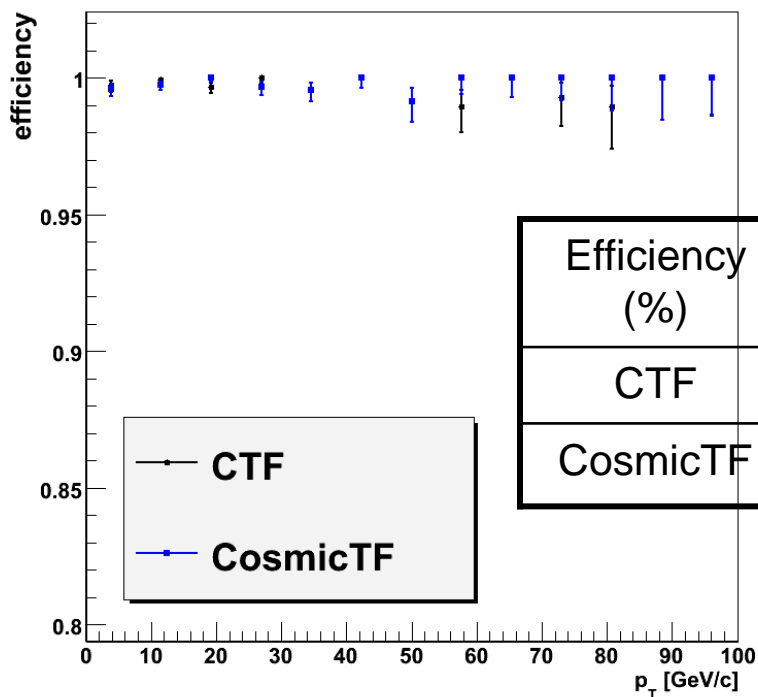
Detector Readiness: An Example

Cosmics Muon Track Finding Efficiency



Tag and Probe method

- Tag : Stand alone muons
- Probe : Tracker reconstructed muons

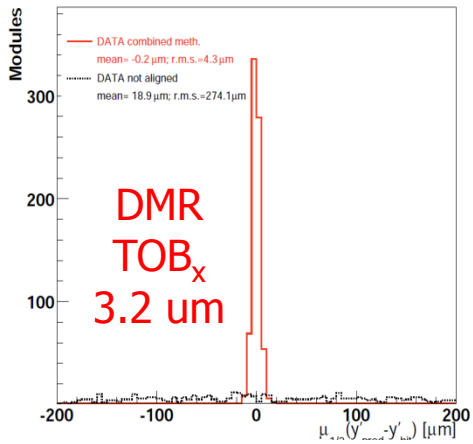


CRAFT08: Results

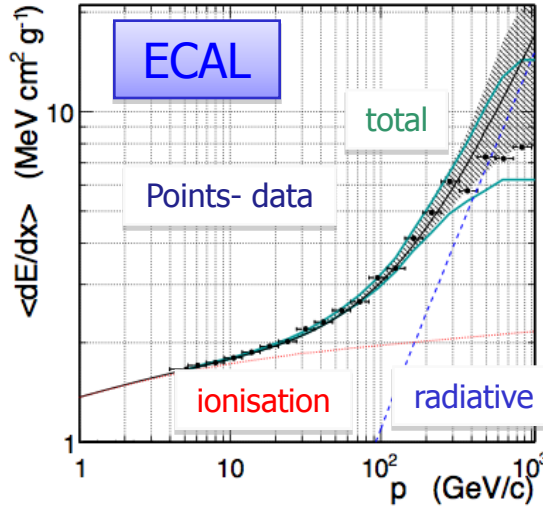
23 Papers will be submitted to JINST 1 Nov'09



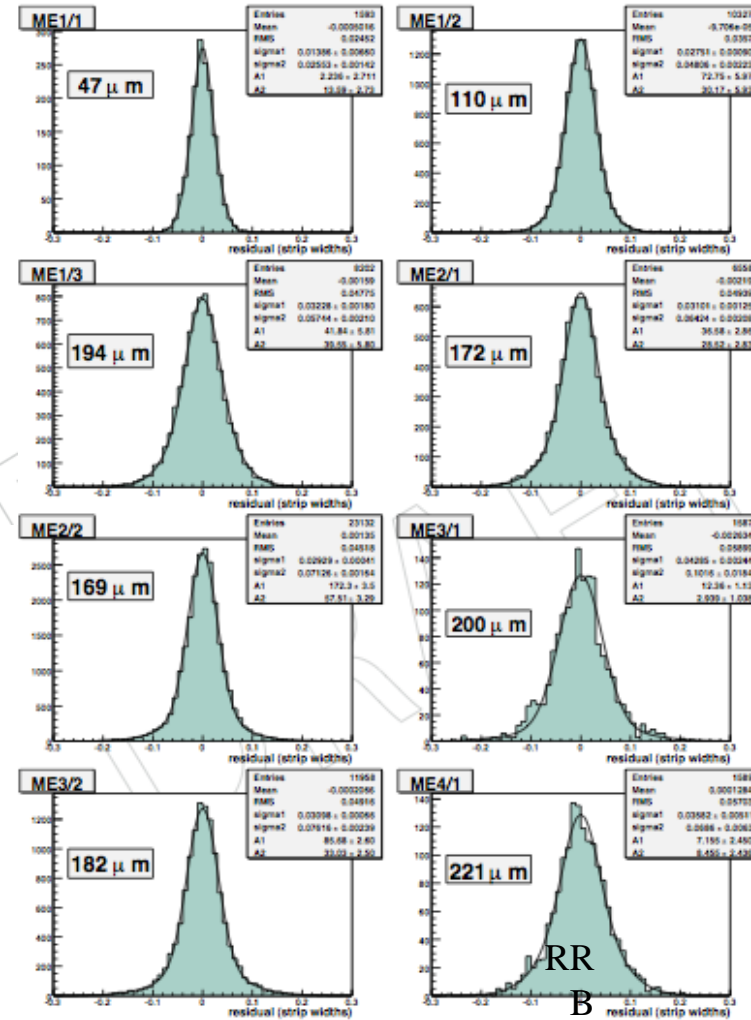
Alignment Si Trkr TOB Modules



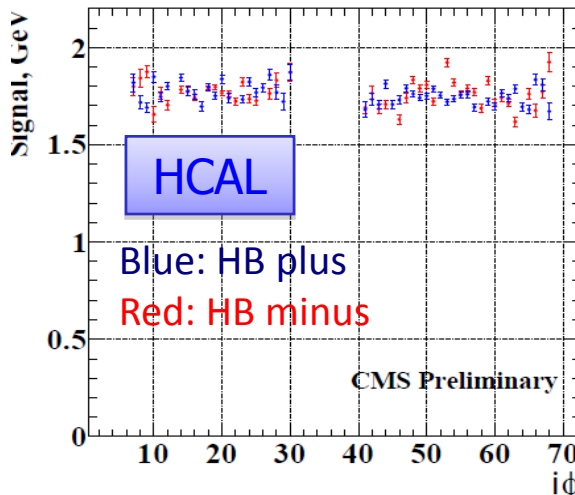
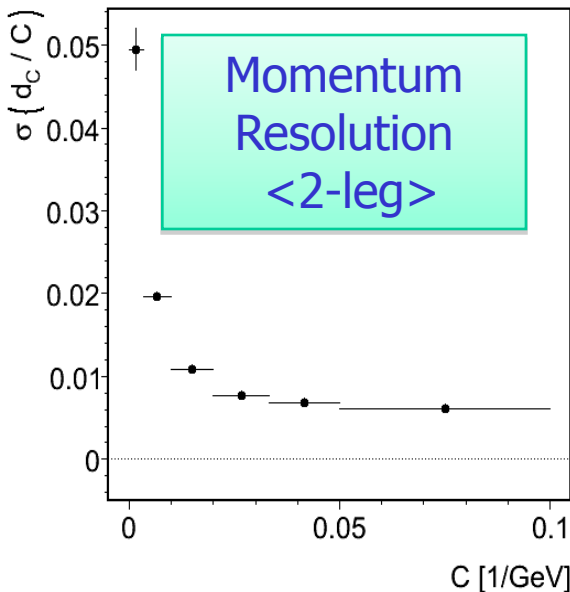
Energy deposited by muons



Endcap Muon Chambers Point Resolution



CMS Preliminary



CMS Preliminary



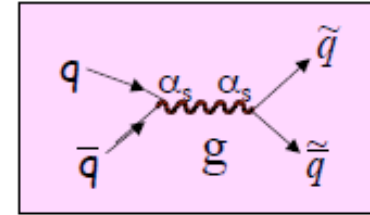
First discoveries ... Supersymmetry

ATLAS is ready...

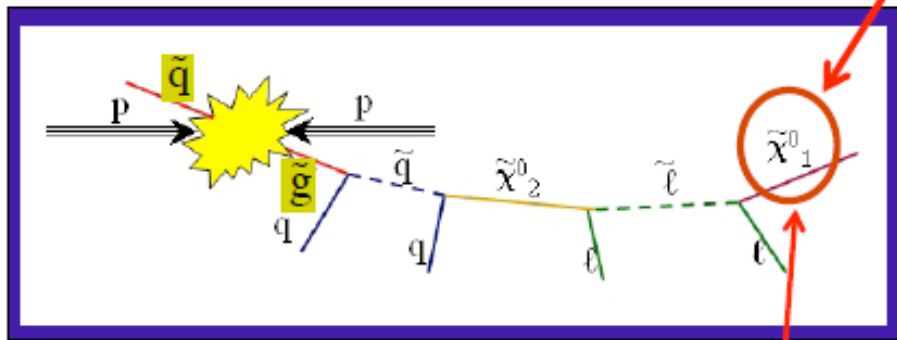
If it is at the TeV mass scale, it could be found "quickly" ... thanks to:

- Huge production cross-section for $\tilde{q}\tilde{q}, \tilde{g}\tilde{q}, \tilde{g}\tilde{g}$ production

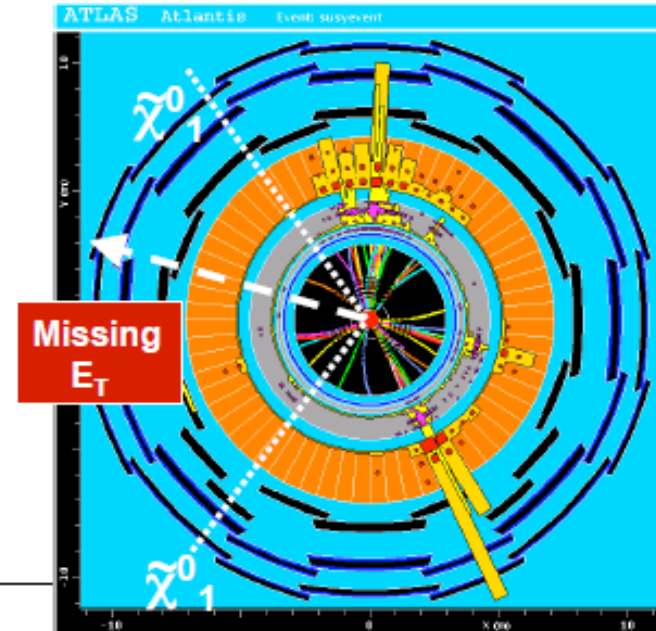
For $m(\tilde{q}, \tilde{g}) \sim 1 \text{ TeV}$
 expect 1 event/5 days at $L=10^{31} \text{ cm}^{-2} \text{ s}^{-1}$



- Spectacular final states (many jets, leptons, missing transverse energy)



dark matter candidate



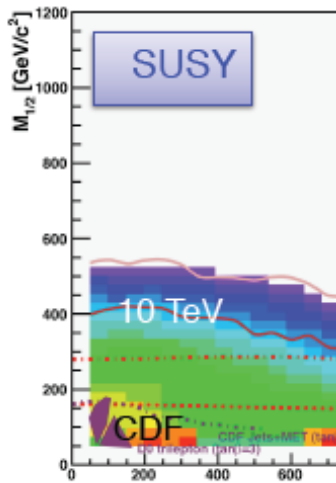


First Few Hundred pb⁻¹ @ 10 TeV

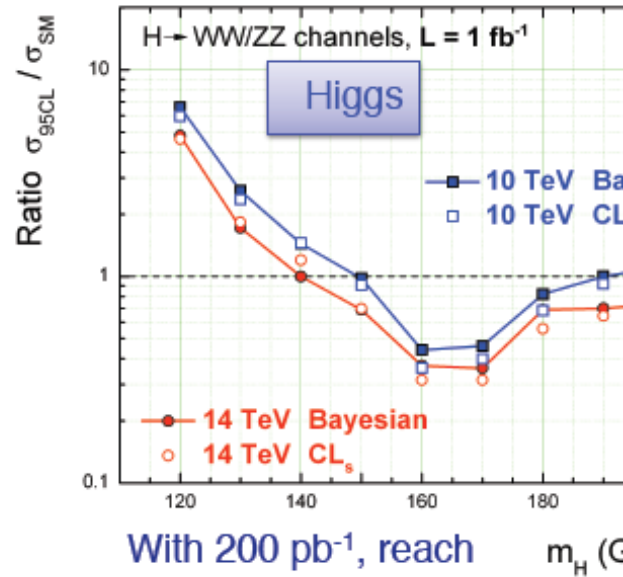


Signals and backgrounds are scaled from 14 TeV
Plots are indicative of CMS reach

CMS is ready...

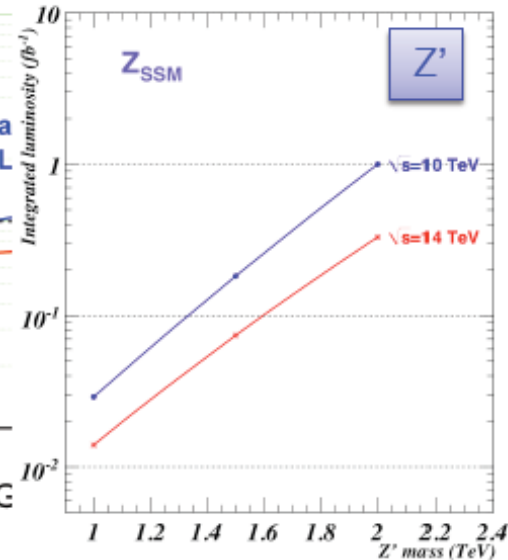


CMS Preliminary



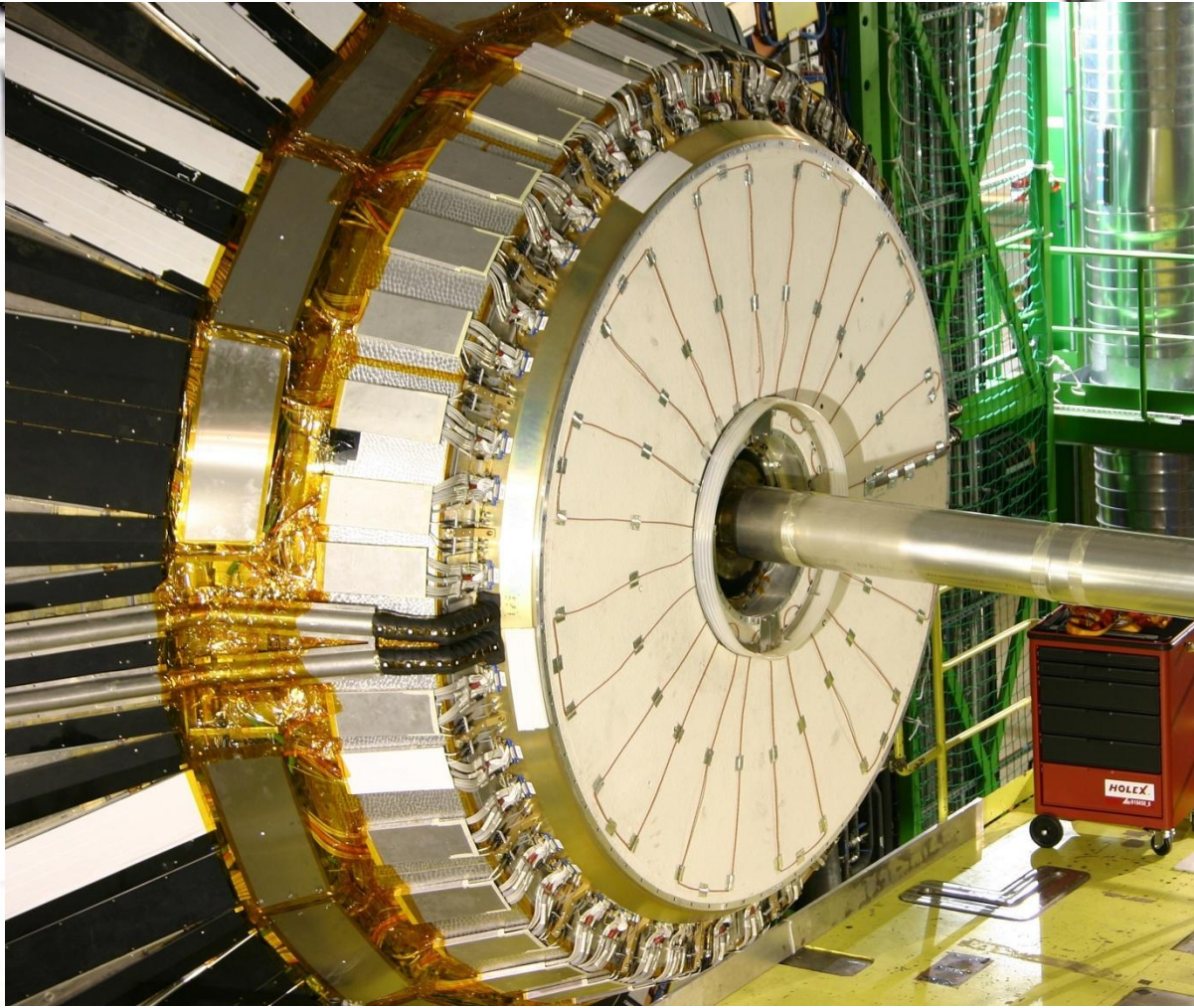
With 200 pb⁻¹, reach current Tevatron sensitivity for Higgs

T. Virdee EPS Jul09



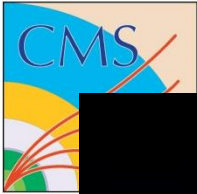


ES Installation Completed in April

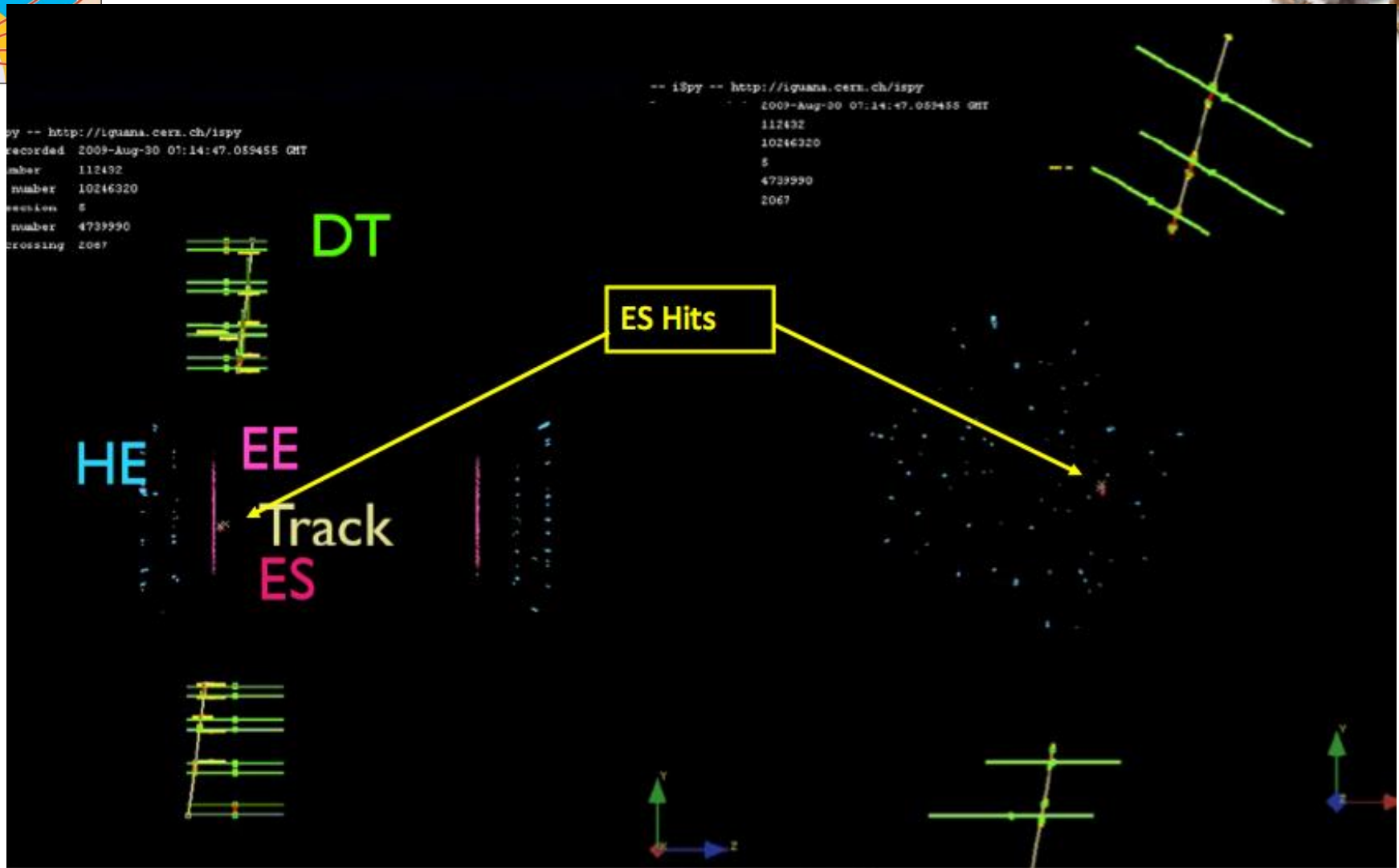


The two separate ES Dees

Installation completed in Apr'09



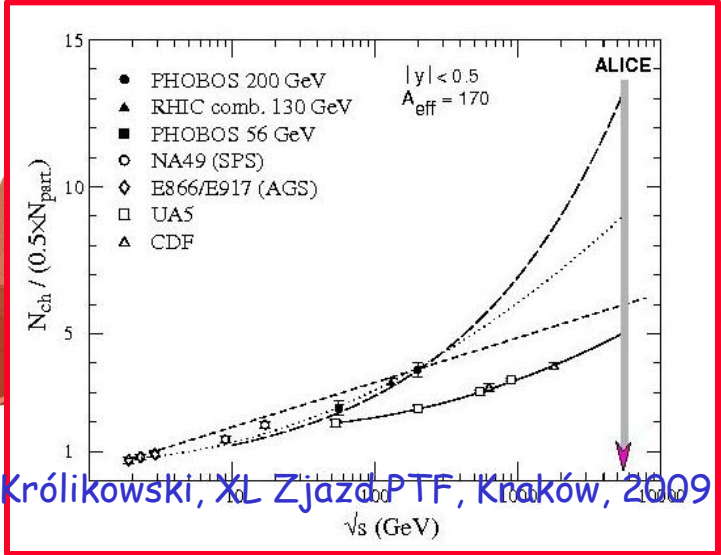
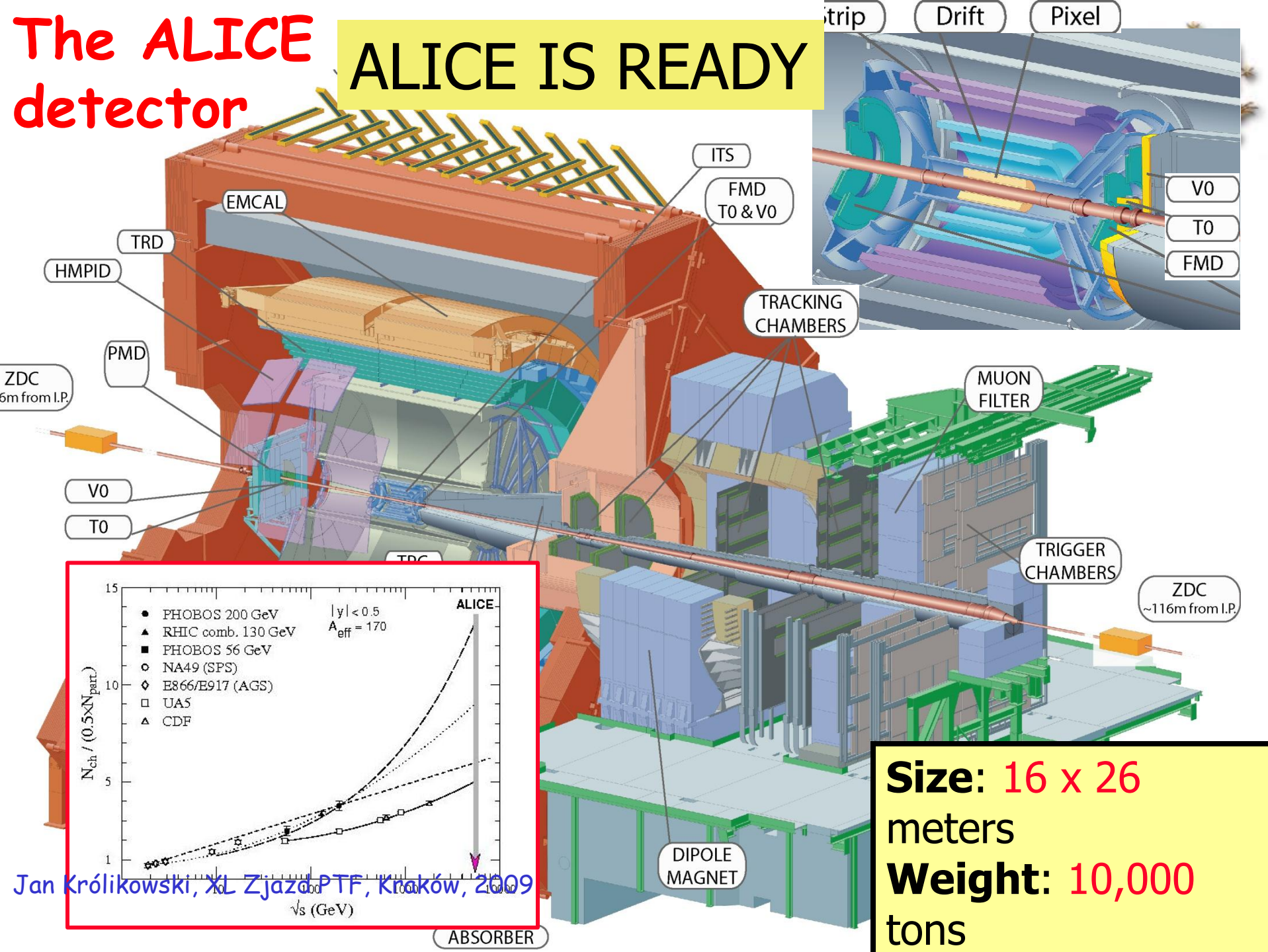
ECAL: Preshower.



Noise Performance is Excellent

The ALICE detector

ALICE IS READY

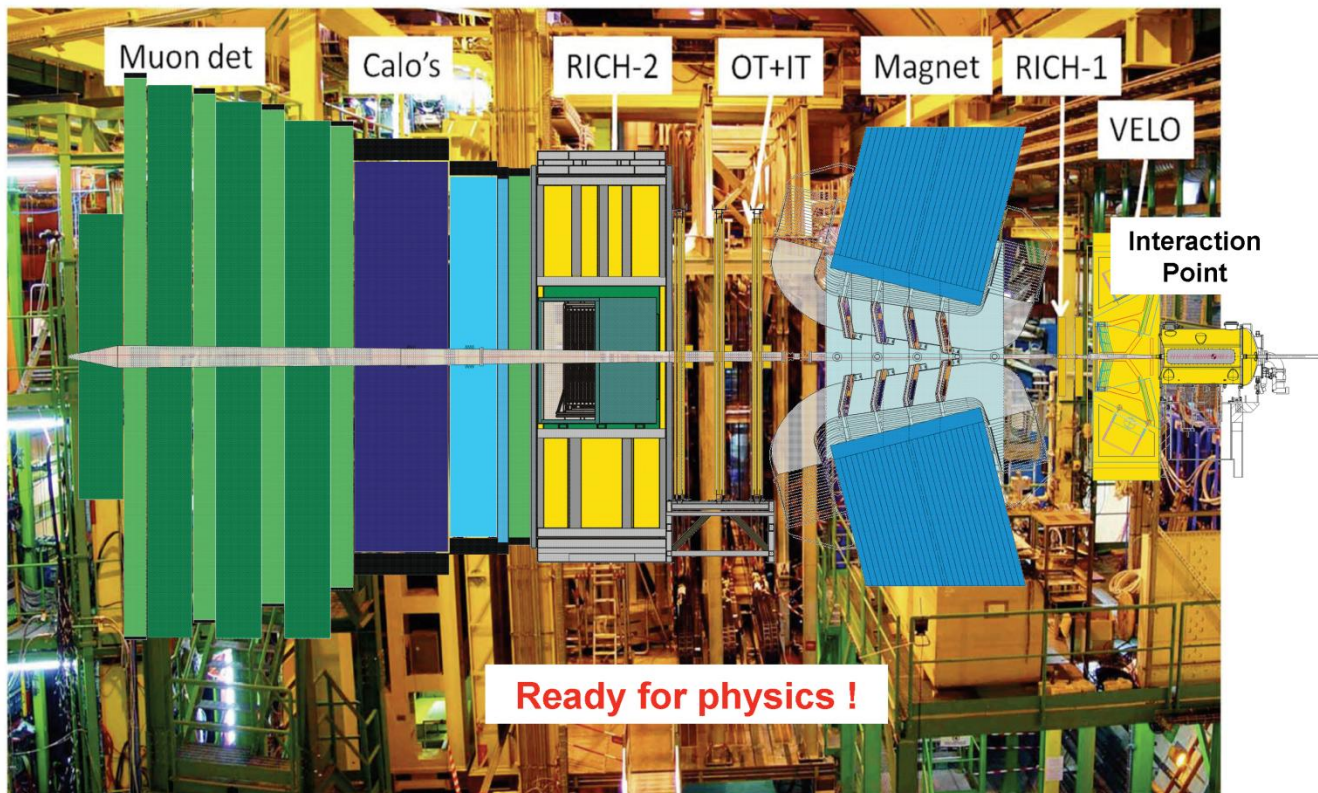


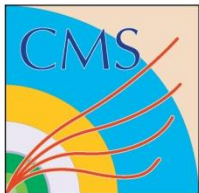
Size: 16 x 26 meters
Weight: 10,000 tons

Jan Królikowski, XL Zjazd PTF, Kraków, 2009



LHCb is ready

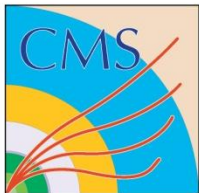




Plany na 2010-2011

- Po starcie pod koniec 2009 zbieranie danych przez 8-10 miesięcy. Cel: zebranie statystyki $\sim 200 - 250/\text{pb}$ zderzeń proton-proton. Energia **7 TeV** ($3.5+3.5$ TeV), potem może wyższa (10TeV) jeżeli zderzacz będzie dobrze działał. Pod koniec tego okresu: do kilku tygodni zbierania danych ze zderzeń ciężkich jonów.
- Długa przerwa (do 1 roku). Cel: ukończenie instalacji zaworów bezpieczeństwa w $\frac{1}{2}$ pierścienia. Być może wymiana połączeń dipole-kwadrupol.

Plany te mogą ulec zmianie w miarę napływu nowych danych o pracy zderzacza i detektorów



Zbieranie przypadków rzadkich

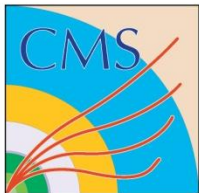
Eksperymenty przy zderzaczach polegają na starannym zbieraniu rzadkich przypadków.

Liczy się scałkowana świetlność eksperymentu:

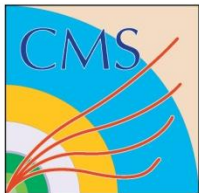
$$L = \int L(t) dt$$

Znaczoność sygnału: liczba przypadków sygnału mierzona w jednostkach błędu liczby przypadków tła:

$$\frac{N_{signal}}{\sqrt{N_{background}}} \propto \sqrt{\int L dt}$$

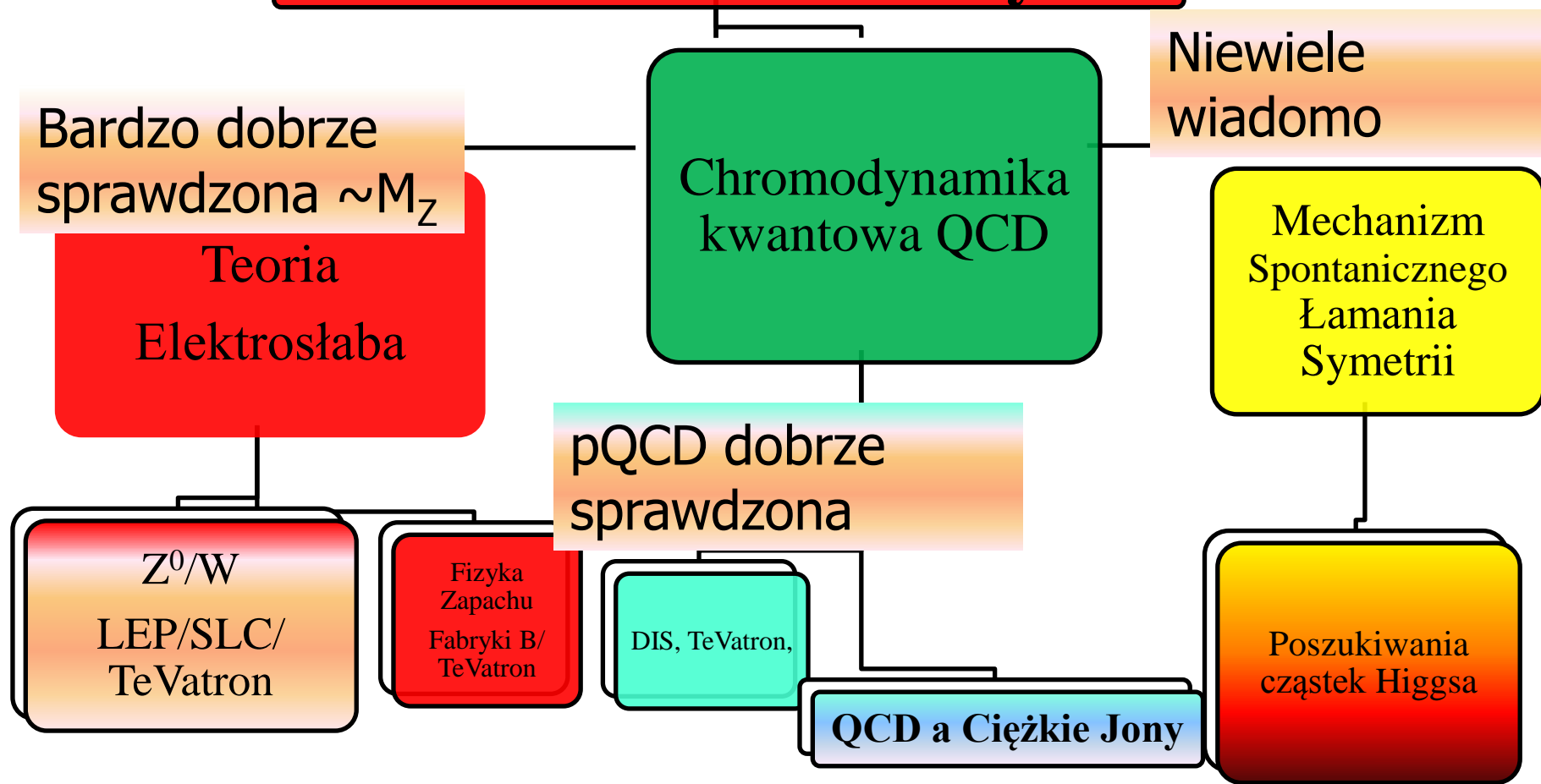


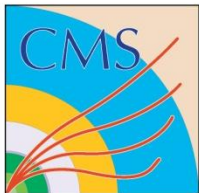
2. MODEL STANDARDOWY: CO WIEMY I CZEGO NIE WIEMY



Model Standardowy

Model Standardowy





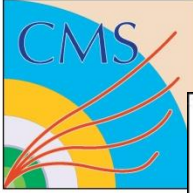
Oddziaływania elektrosłabe

LEP/ SLC/ TeVatron

Zgodność doświadczenia z teorią $\sim 10^{-3}-10^{-5}$



July 2008



Fizyka zapachu

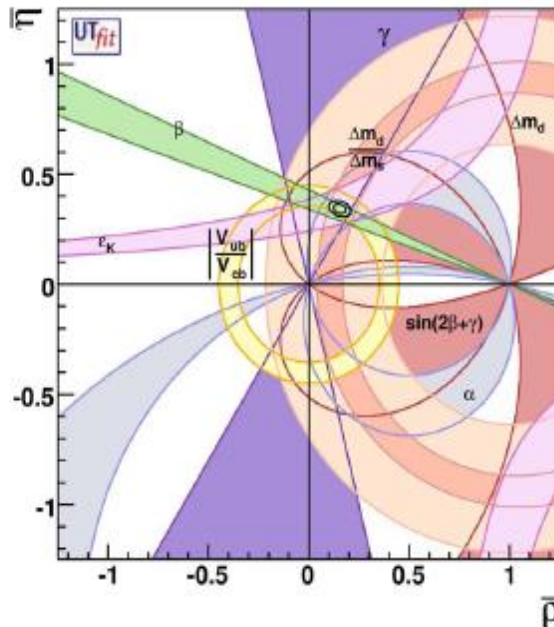


Unitarity Triangle Fits

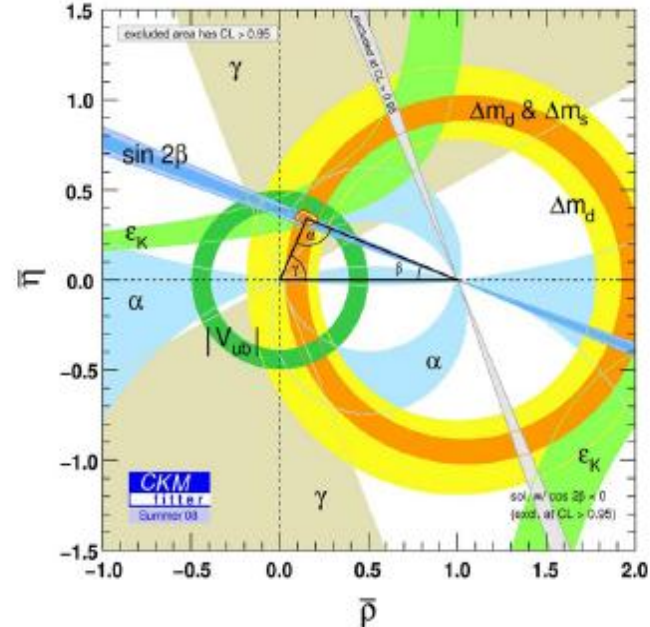
(Icons of Flavour Physics)

Buras HEP_EPS_09

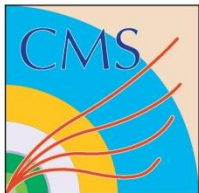
UT fit



CKM fitter

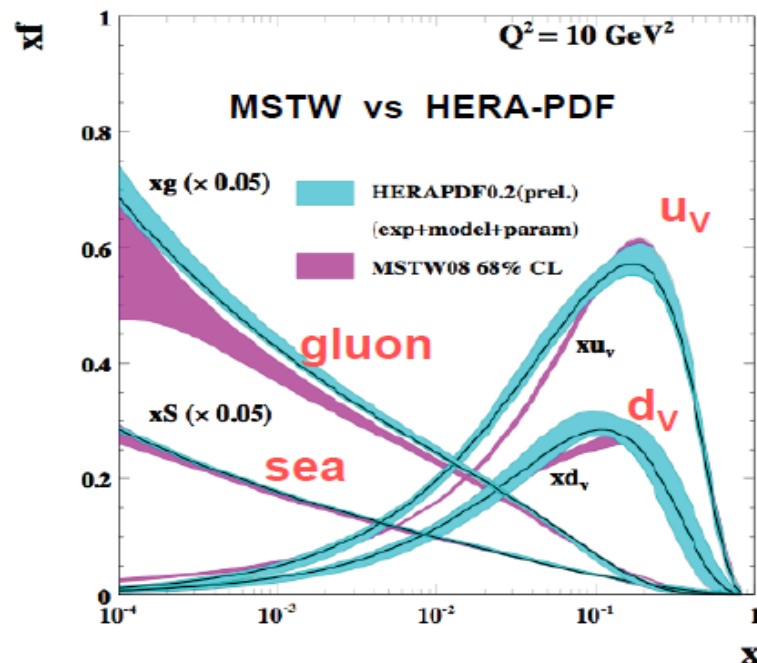
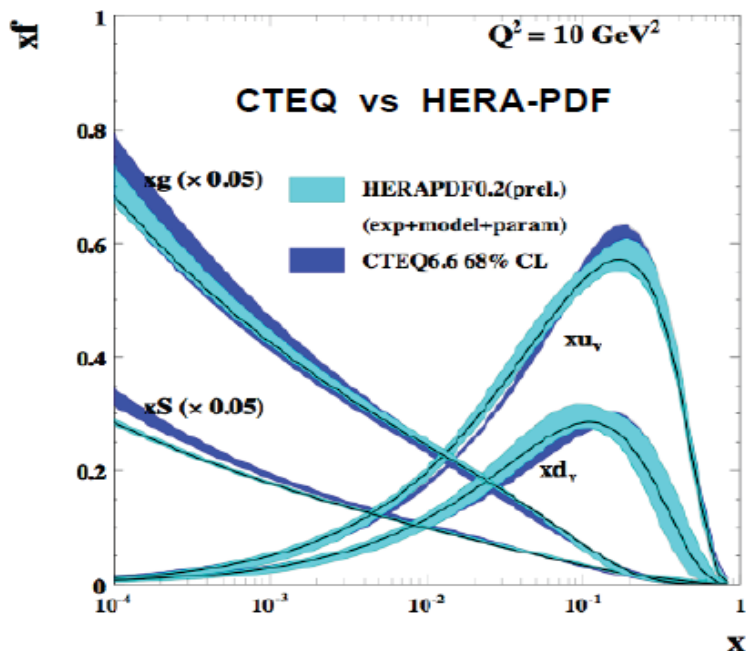


Impressive success of CKM model, "no deviation" from Standard Model!



Perturbacyjna Chromodynamika kwantowa

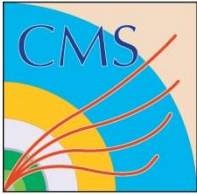
QCD Fits of Parton Densities I



Errors reflect different treatment of experiments, model uncertainties, α_s , ...

Schleper
HEP_EPS_09

HERA-PDFs: significantly increased accuracy,
some differences compared to previous analyses

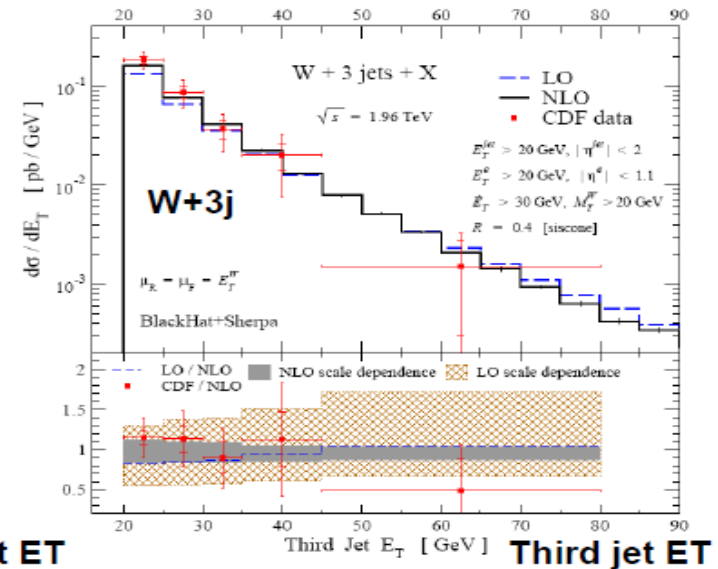
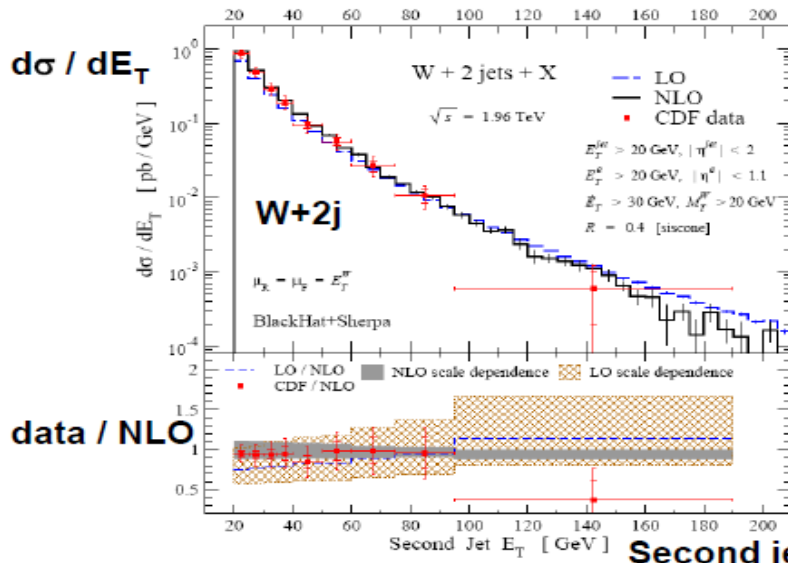


Multi-Leg NLO

New techniques for multi-leg NLO calculations (see talk by Anastasiou)

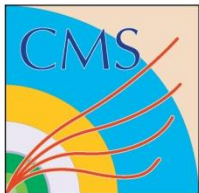
- full NLO for W+3jet at Tevatron
- Much reduced scale uncertainty (~10%)
- NLO: SisCone CDF: JETCLU 0.32 fb⁻¹
- First successful test of NLO automation, much more precise data to come

Berger et al, arXiv:0907.1984

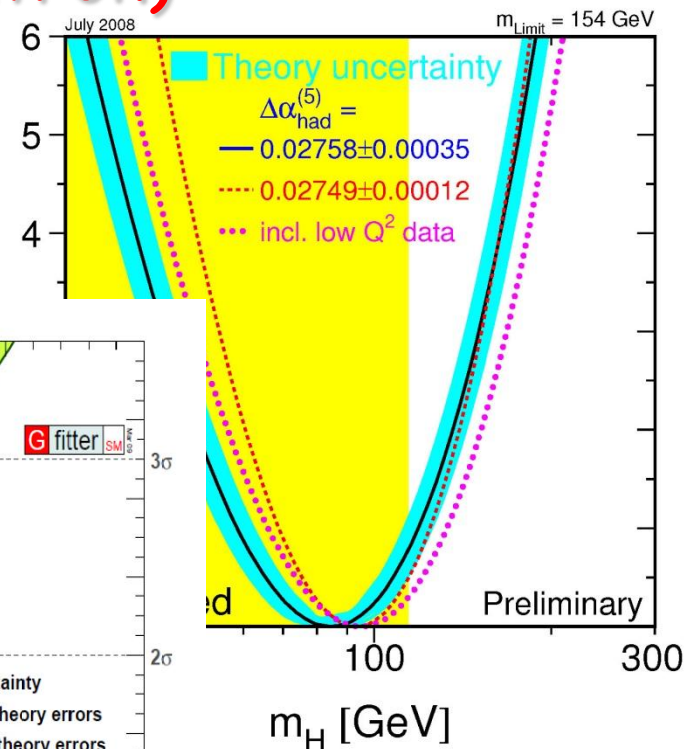
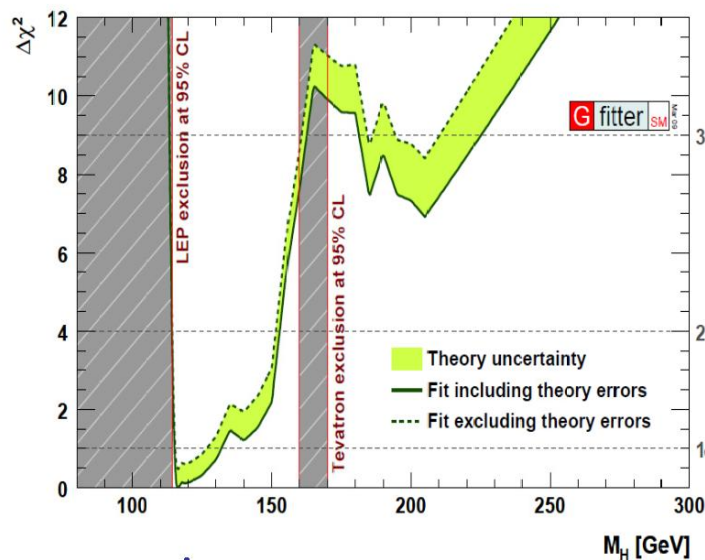
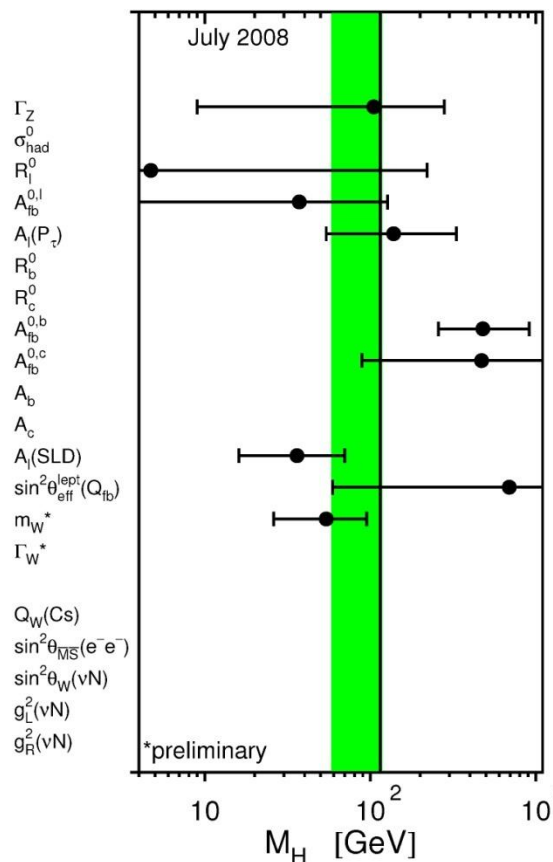


Schleper

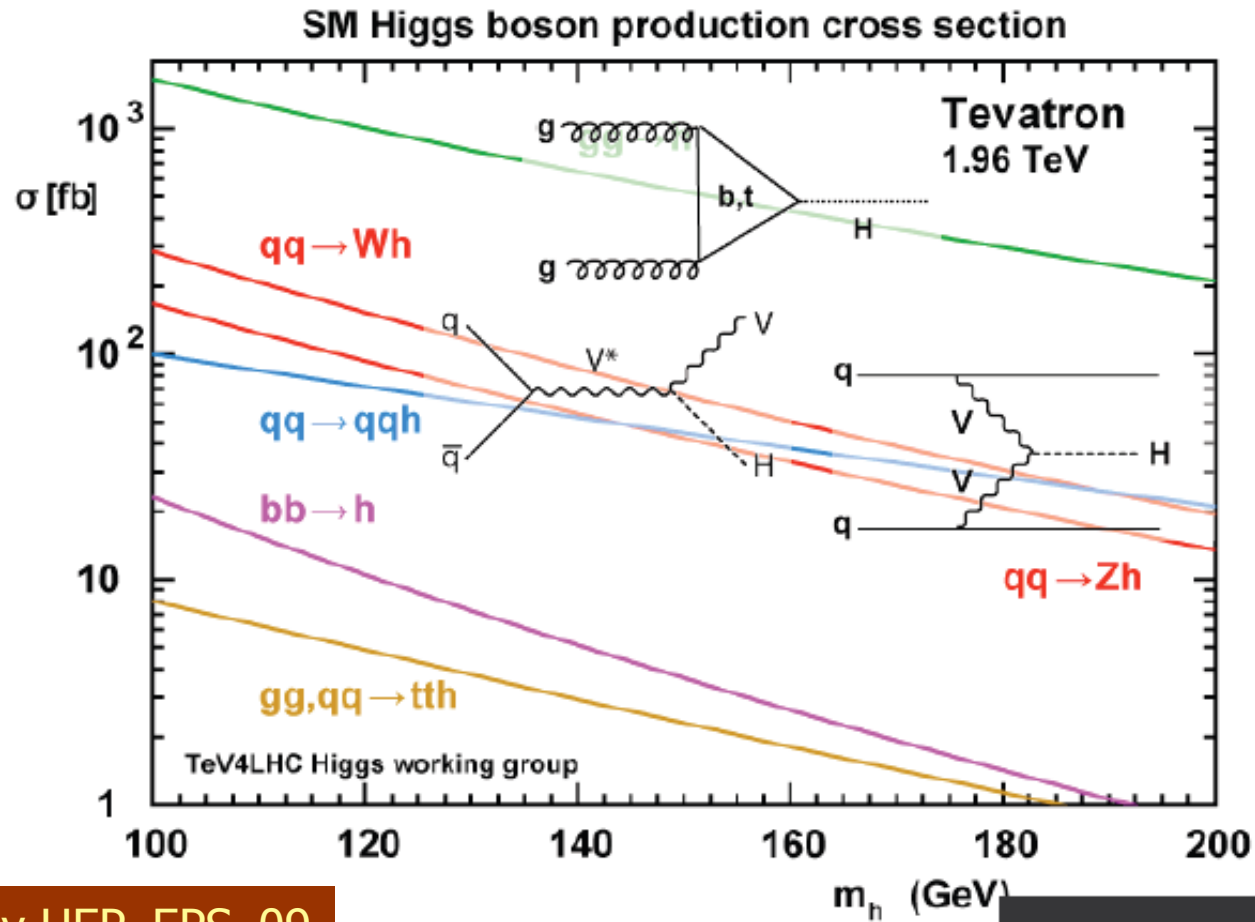
TH/EXP challenge, very important for LHC!



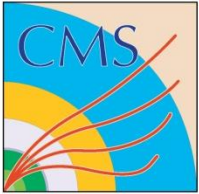
Więzy dla cząstek Higgosa (LEP/SLC/TeVatron)



Higgs production at Tevatron/LHC

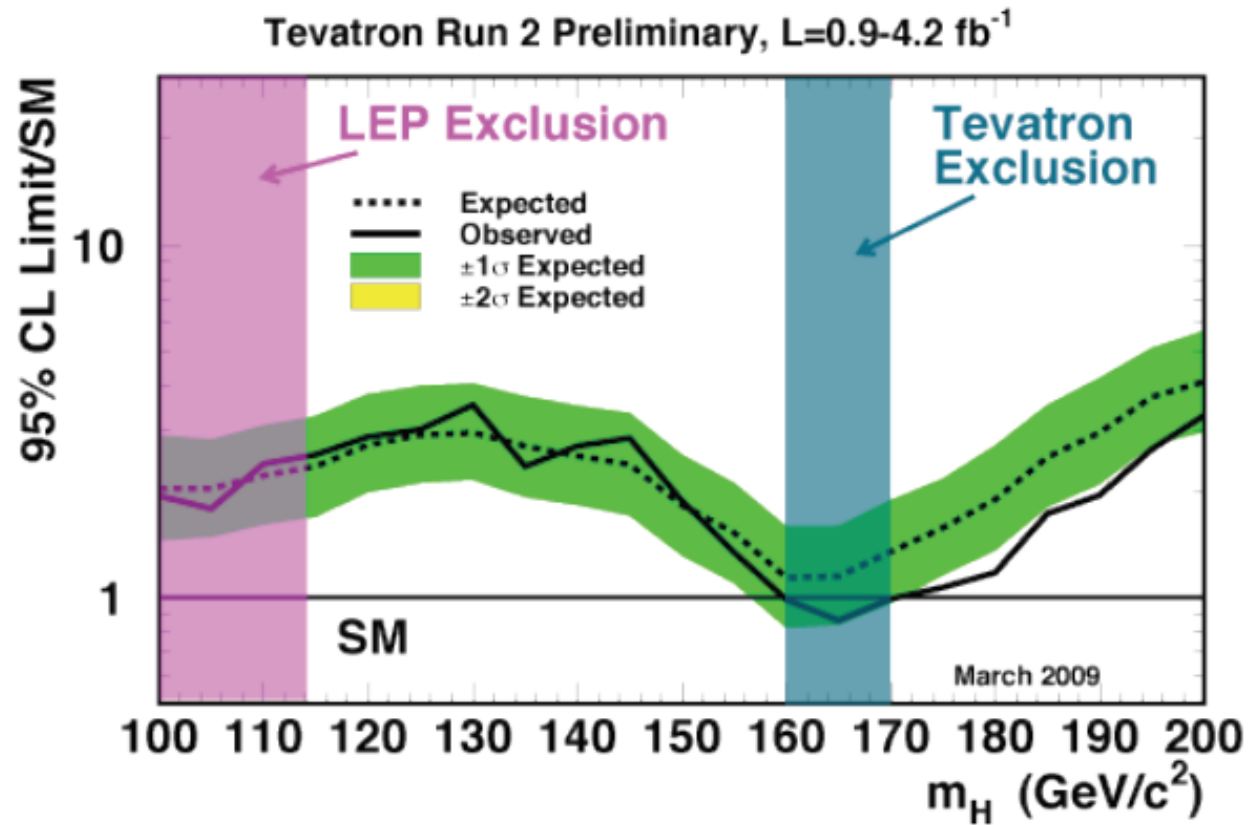


Conway HEP_EPS_09



Limit on "Higgs Cross Section"

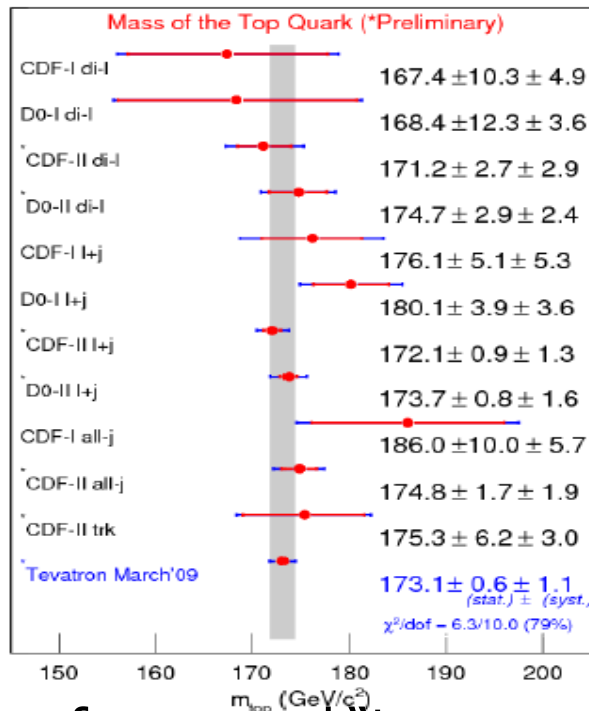
Conway





Top Quark Mass Measurement

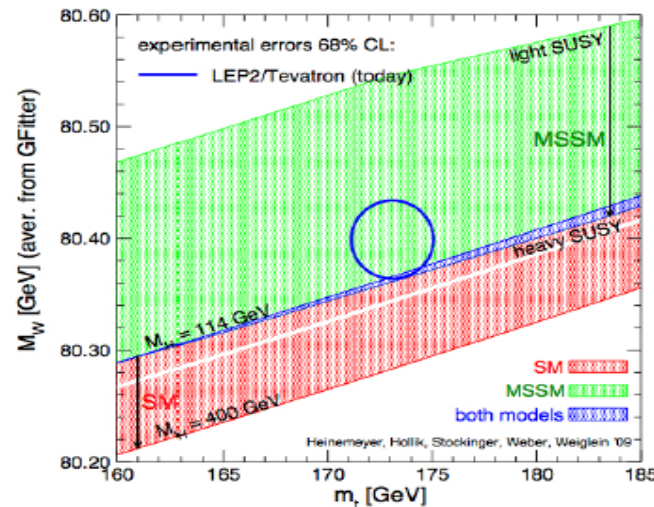
arXiv:0903.2503



$$m_{top} = 173.1 \pm 1.3 \text{ GeV}$$

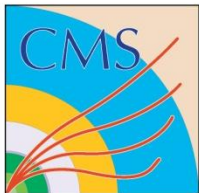
Heinemeyer et al.

±0.75%



Meaning of measured "top mass"? Precision is important – new physics in top-Higgs system?

Schwanenberger
HEP_EPS_09



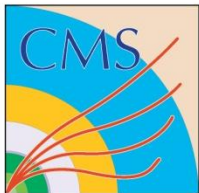
Brak sygnałów niezgodnych z MS



Badania obecnie koncentrują się na:

1. Precyzyjnych pomiarach pQCD
2. Spontanycznym Łamaniu Symetrii (Higgs, top...)
3. Zderzeniach (Ultrarelatywistycznych) Ciężkich Jonów i teoriach nieperturbacyjnych
4. Fizyce zapachu (sprzężenia W do kwarków i leptonów)

Mimo wielu sukcesów Model Standardowy
nie jest teorią ostateczną



Jedynie wątpliwości są natury teoretycznej



2. Bounds on the Higgs mass through the quartic coupling

The physical Higgs mass is set by the quartic coupling, which is a **running** parameter

$$m_h^2 = 2\lambda_4 v^2$$

$$16\pi^2 \frac{d}{d \log Q} \lambda_4 = 24\lambda_4^2 - (3g'^2 + 9g^2 - 12y_t^2) \lambda_4 + \frac{3}{8} g'^4 + \frac{3}{4} g'^2 g^2 + \frac{9}{8} g^4 - 6y_t^4 + \dots$$

- For a **too heavy** Higgs, the first term dominates and drives λ_4 to a Landau pole at large energy scales

TRIVIALITY BOUND

$$m_h^2 \lesssim \frac{4\pi^2 v^2}{3 \log(\Lambda/v)}$$

largest scale of validity of the theory (cutoff scale)

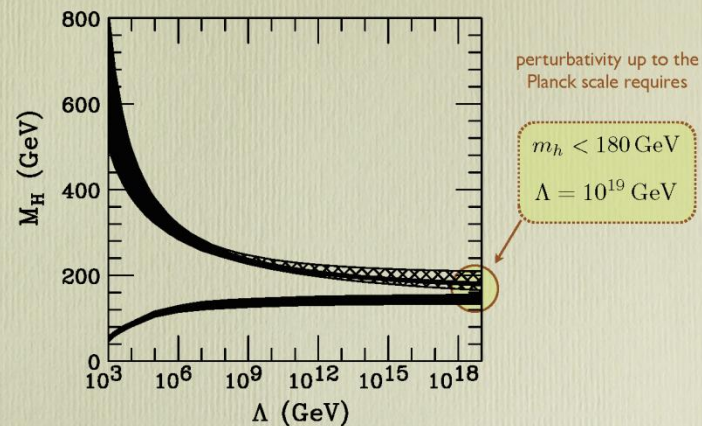
- For a **too small** Higgs, the last term dominates and drives λ_4 negative at large energy scales

VACUUM STABILITY BOUND

$$m_h^2 \gtrsim \frac{3y_t^4 v^2}{4\pi^2} \log(\Lambda/v)$$

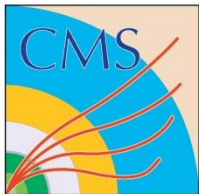
Poprawki pętlowe do masy higgsów

Problem hierarchii



from: T. Hambye, K. Riesselmann Phys Rev, D55 (1997) 7255

Contini Krakow 2009



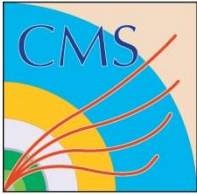
Teoretycy proponują dwie klasy rozwiązań:



Istnieje elementarna ale bardziej skomplikowana teoria (t. pola?) unifikująca oddziaływania przy znacznie wyższych energiach.

SUSY, GUT,...

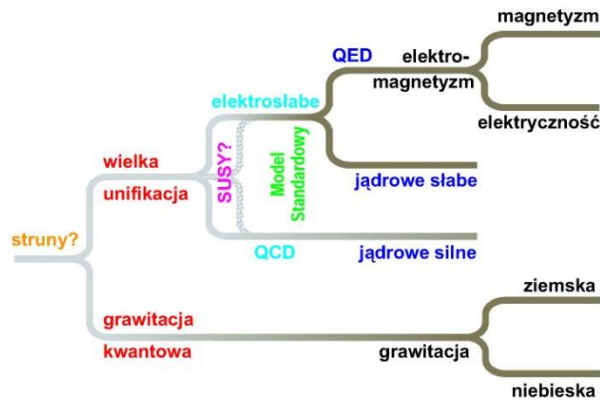
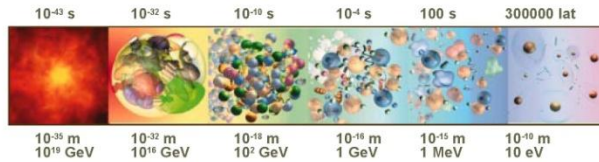
Rozwiązaniem jest teoria złożona, zaś MS jest jej efektywnym przybliżeniem. **(dodatkowe wymiary, struny, nowe silne oddziaływania).**



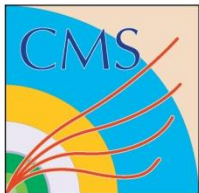
Wielkie unifikacje

Unifikacja oddziaływań

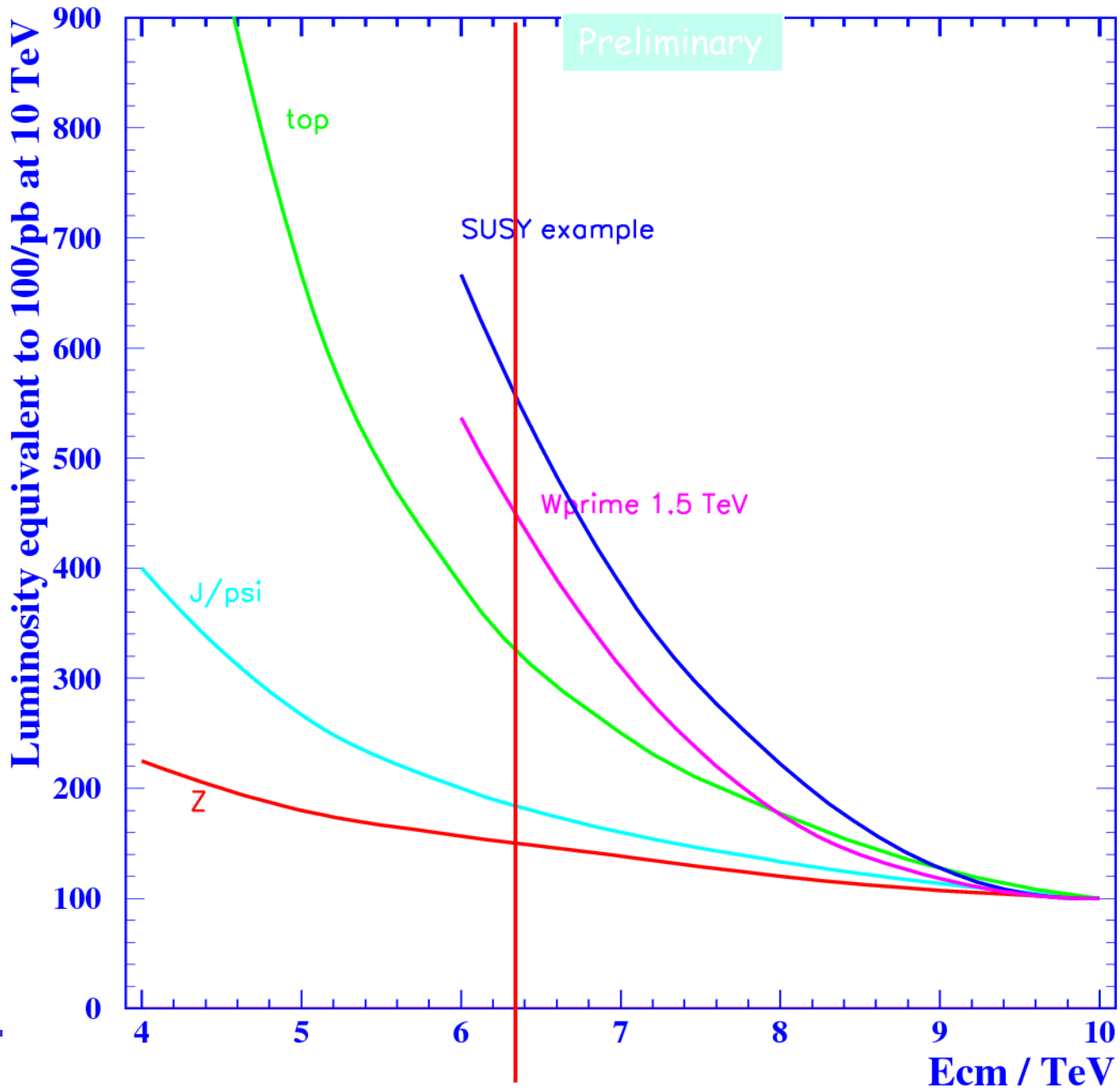
Wielki Wybuch Inflacja Anihilacja Bariogeneza Nukleosynteza Rekombinacja

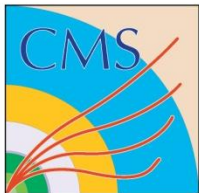


QED - elektrodynamika kwantowa
QCD - chromodynamika kwantowa



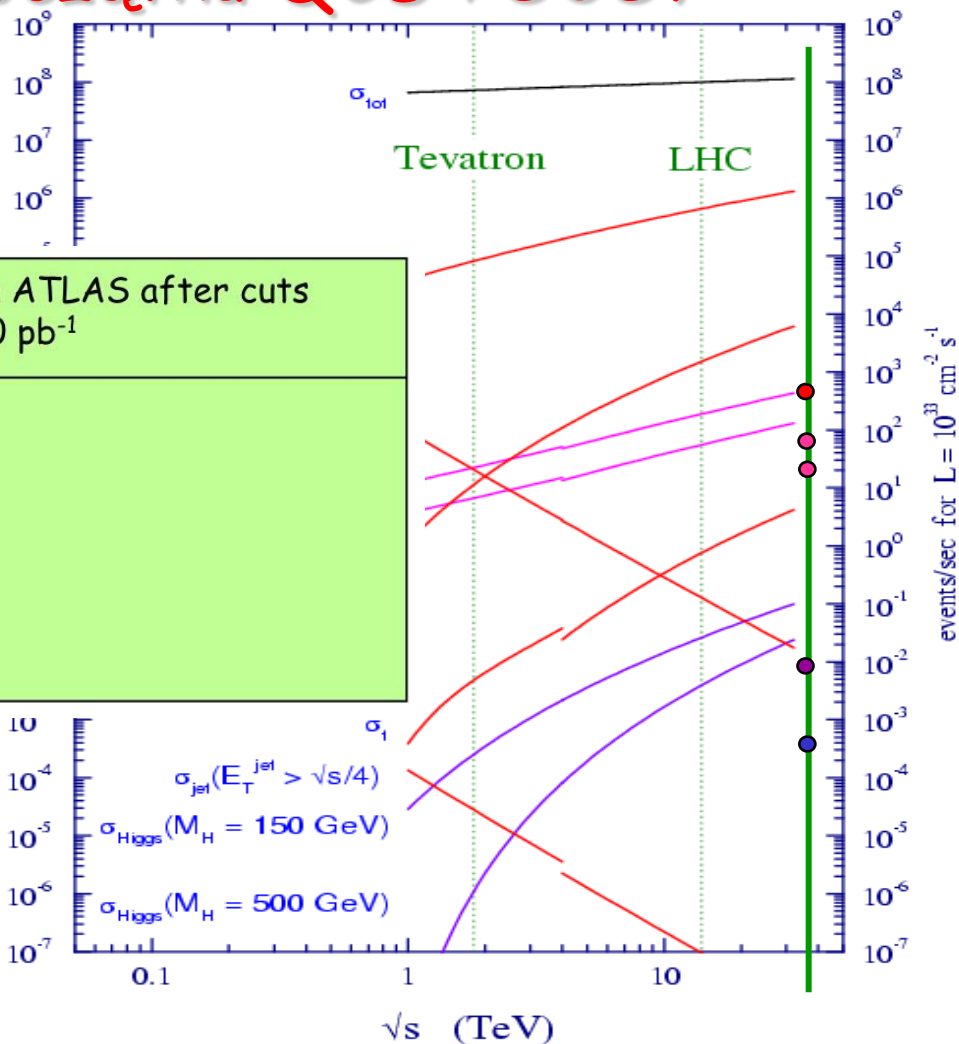
3. FIZYKA MODELU STANDARDOWEGO NA POCZĄTKU PRACY LHC





ATLAS: Na początku QCD i SUSY

pp



events/sec for $L = 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$

Channels (examples ...)	Expected events in ATLAS after cuts $\sqrt{s} = 10 \text{ TeV}, 100 \text{ pb}^{-1}$
$J/\psi \rightarrow \mu\mu$	$\sim 10^6$
$Y \rightarrow \mu\mu$	$\sim 5 \cdot 10^4$
$W \rightarrow \mu\nu$	$\sim 3 \cdot 10^5$
$Z \rightarrow \mu\mu$	$\sim 3 \cdot 10^4$
$t\bar{t} \rightarrow Wb Wb \rightarrow \mu\nu + X$	~ 350
QCD jets $p_T > 1 \text{ TeV}$	~ 500
$\tilde{g}, \tilde{q} \quad m \sim 1 \text{ TeV}$	~ 5

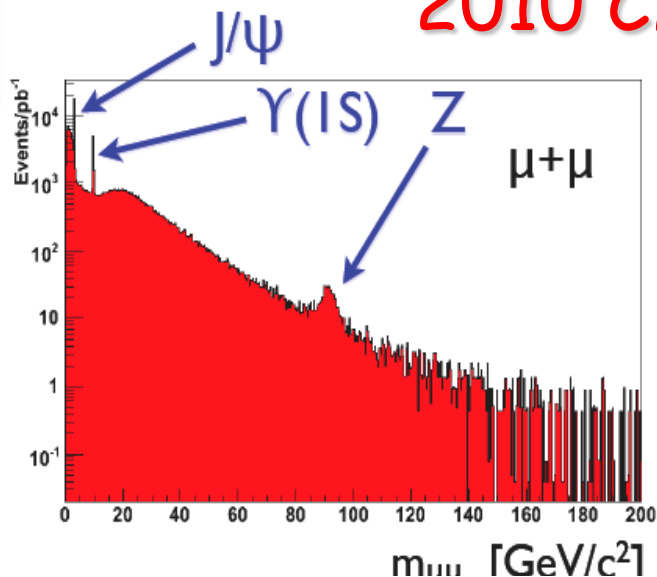
Przy 7 TeV- nieco niższe



2010 CMS Physics Programme

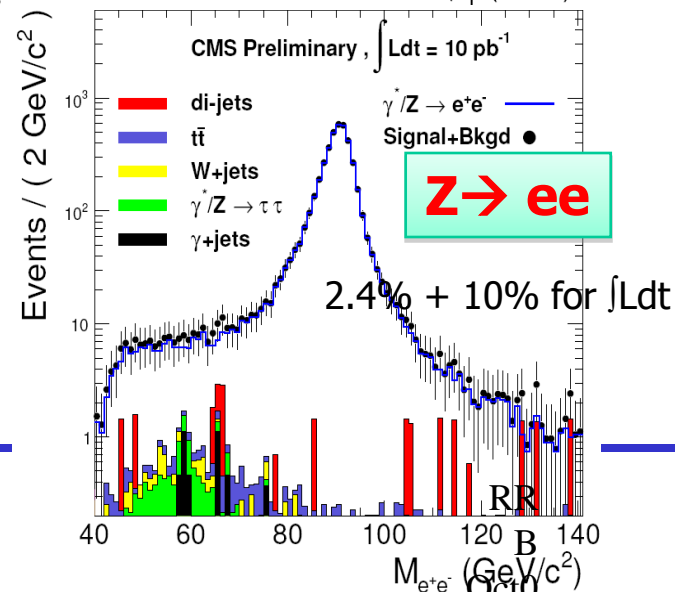
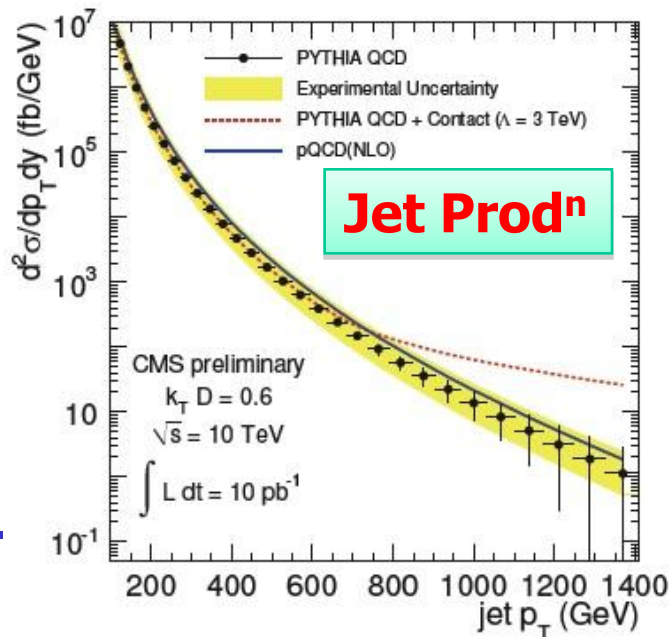
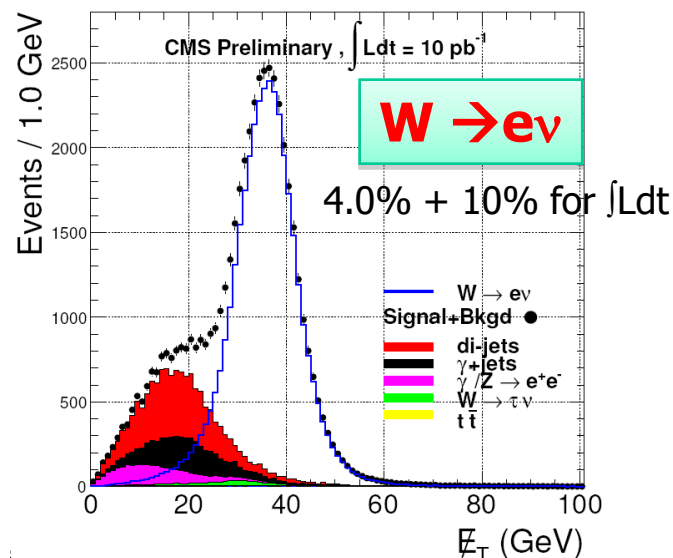
10 pb⁻¹ at 10 TeV

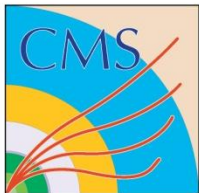
Already systematics dominate



Examples of First Analyses

Use data driven methods e.g. "tag and probe" method to work out efficiencies from "data"





Model Standardowy w LHC

- **Pomiary procesów MS przy nowych wyższych energiach są niezbędne dla:**
 - zrozumienia tła do procesów wykraczających poza MS.
 - Lepszego zrozumienia MS, w szczególności różnych przewidywań QCD przy wyższych energiach
- **Kalibracja i zrozumienie aparatury w LHC będzie wymagało obfitych procesów MS np. **produkcji W i Z oraz topu** jako wzorców.**
- **Szczególne znaczenie poznawcze zderzenia ciężkich jonów**



Day 1 Physics (10^5 events): Elliptic Flow



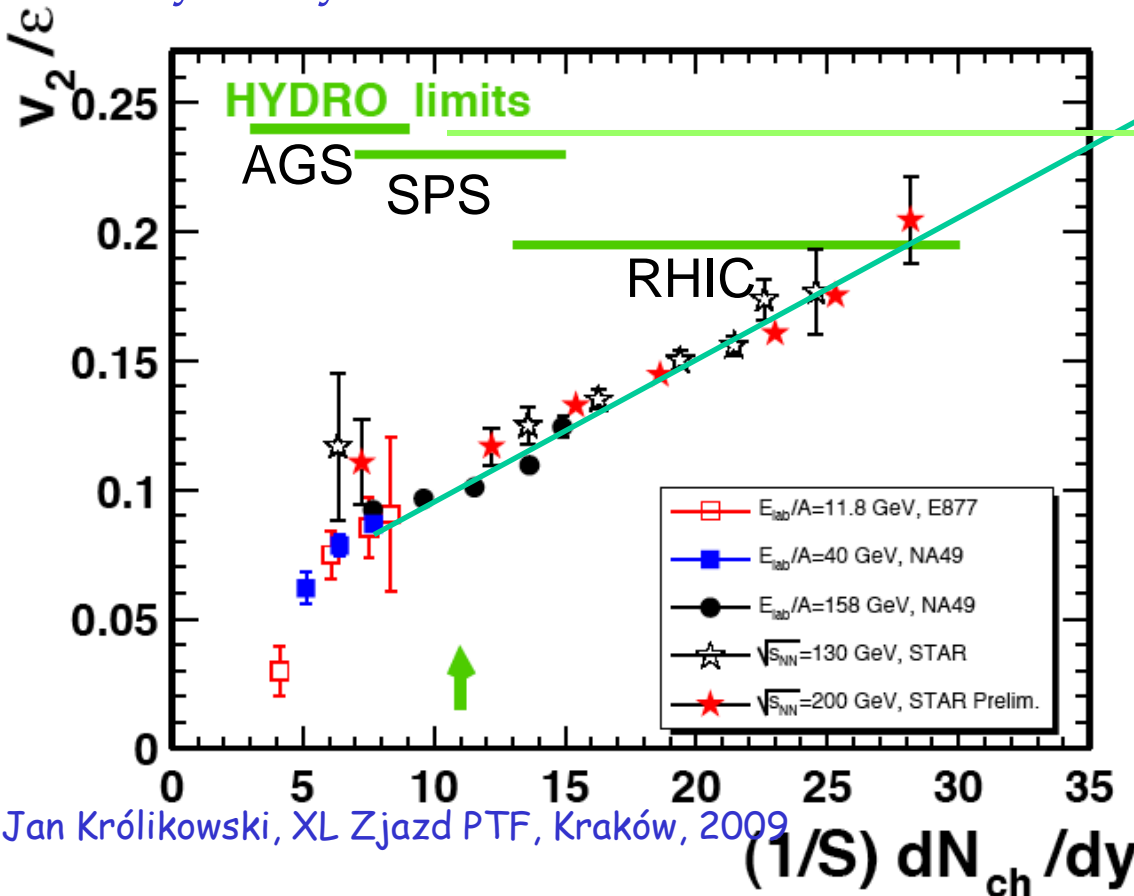
One of the first answers from LHC

Experimental trend & scaling predicts large increase of flow

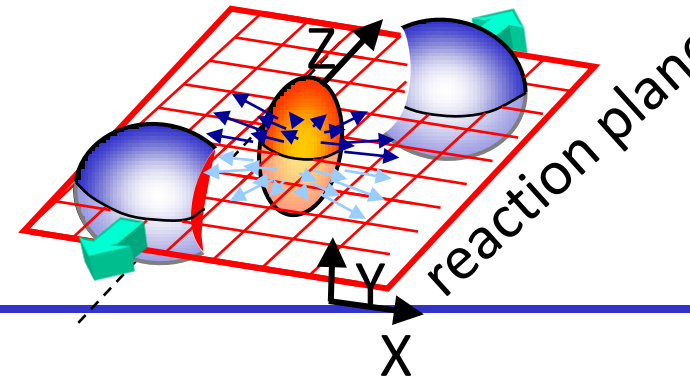
Hydrodynamics: modest rise

Ciężkie Jony
w LHC

L
H
C

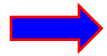


eccentricity vs. particle multiplicity in overlap region



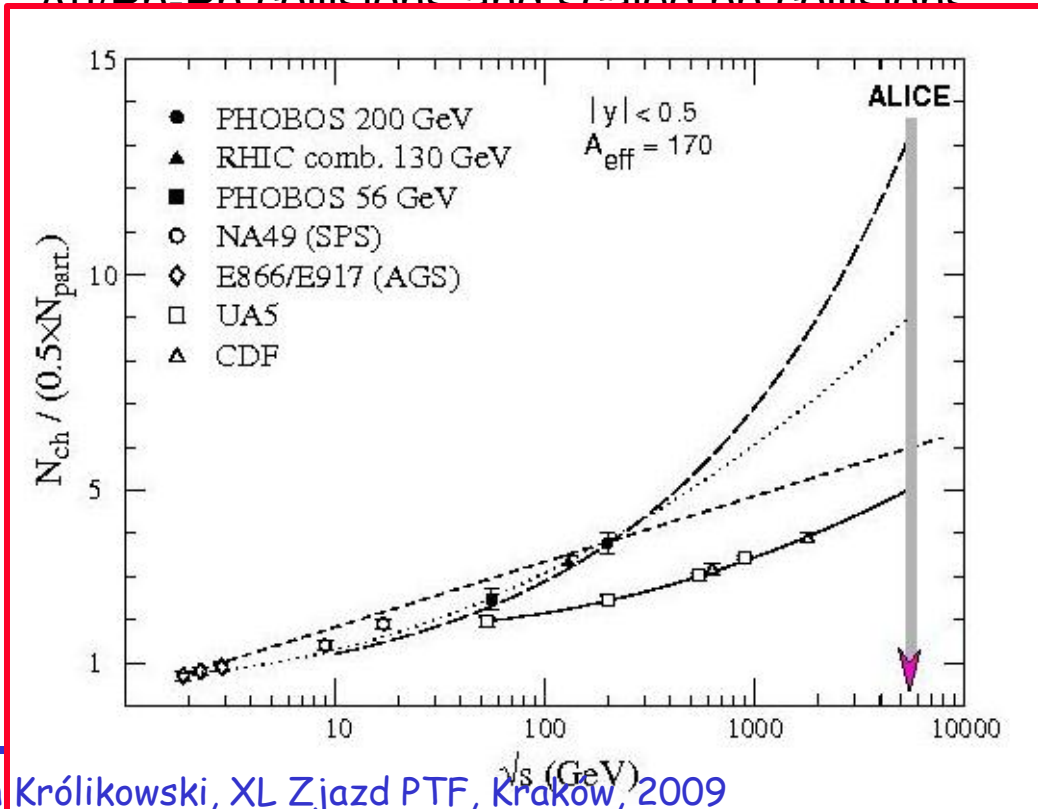


Physics of 'The First 3 Minutes': Multiplicity



First estimate of energy density
Saturation, CGC ?

integrated multiplicity distributions from Au-
Au/Pb Pb collisions and scaled pp collisions



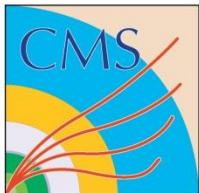
$dN_{ch}/dy = 2600$

saturation model
Eskola hep-ph/050649

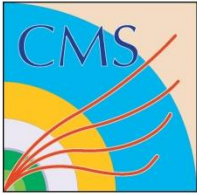
$dN_{ch}/dy = 1200$

$\ln(\sqrt{s})$ extrapolation

Before RHIC, predictions for
the LHC were considerably
higher, ranging up to
 $dN_{ch}/dy=8000$

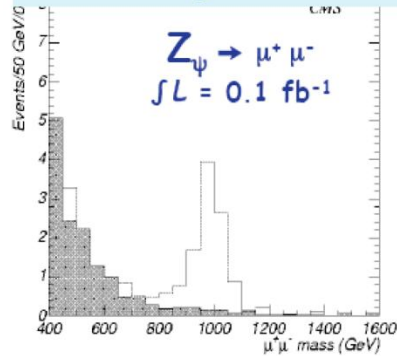


4. BADANIE MECHANIZMU SPONTANICZNEGO ŁAMANIA SYMETRII I FIZYKA POZA MODELEM STANDARDOWYM W LHC

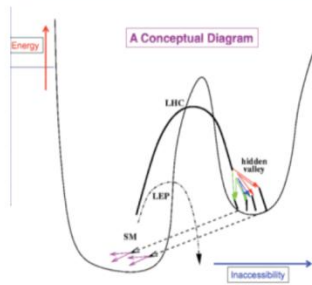


Galeria procesów BSM

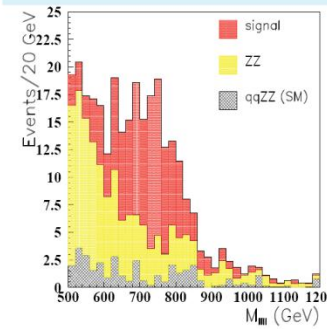
New Gauge Bosons?



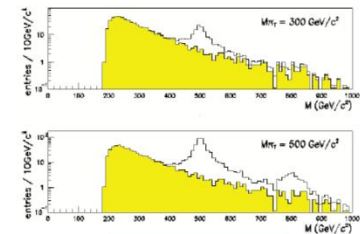
Hidden Valleys?



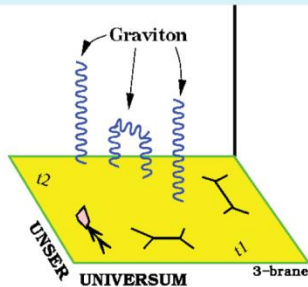
ZZ/WW resonances?



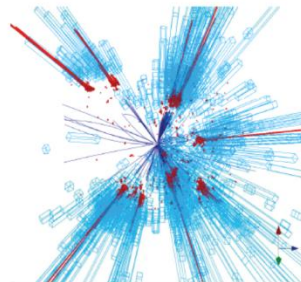
Technicolor?



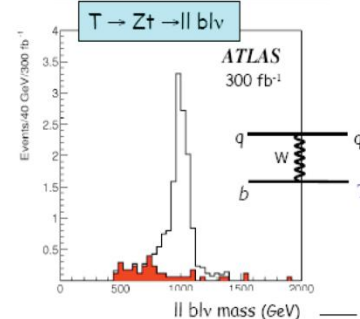
Extra Dimensions?



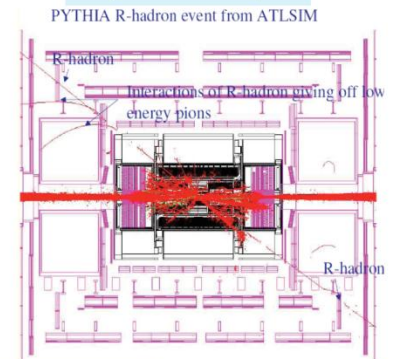
Black Holes???

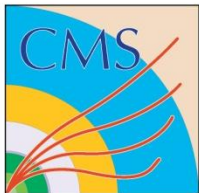


Little Higgs?

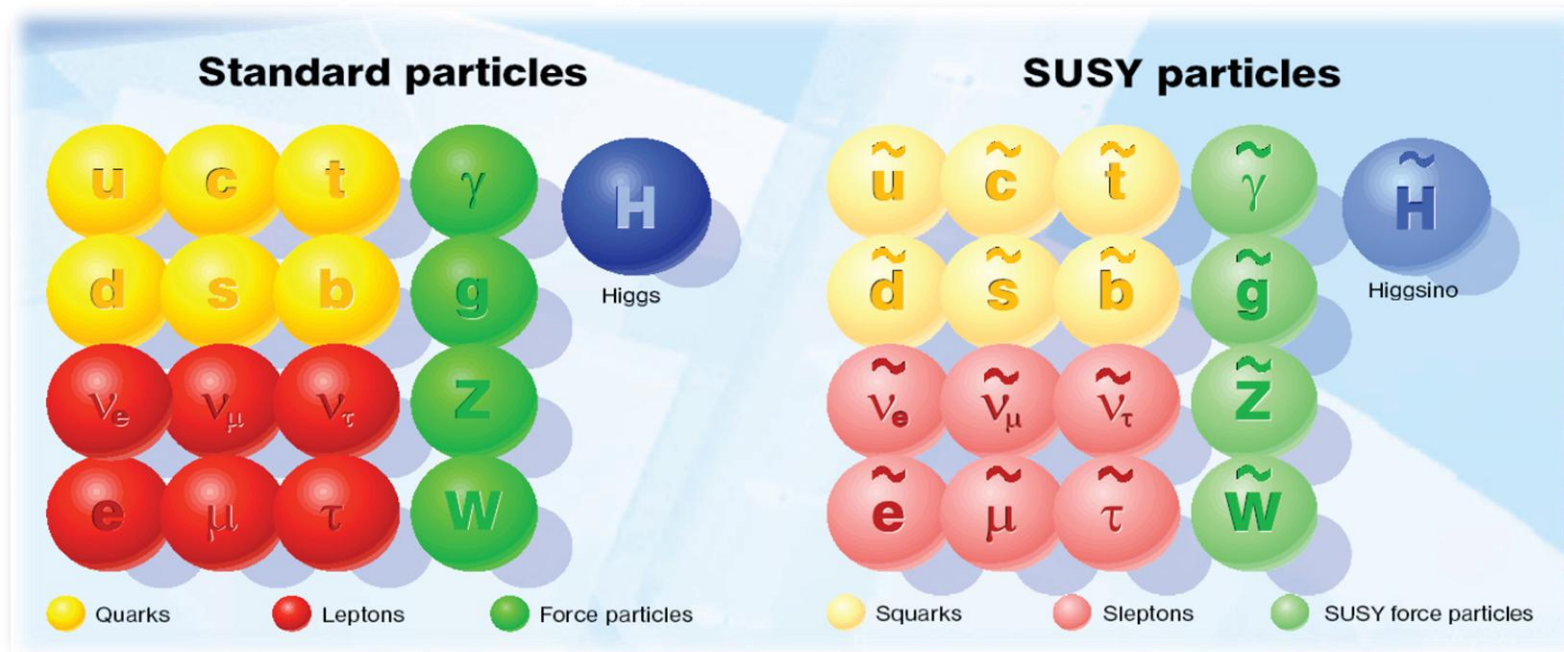


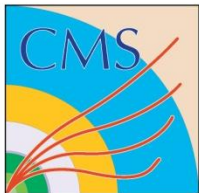
Split Susy?



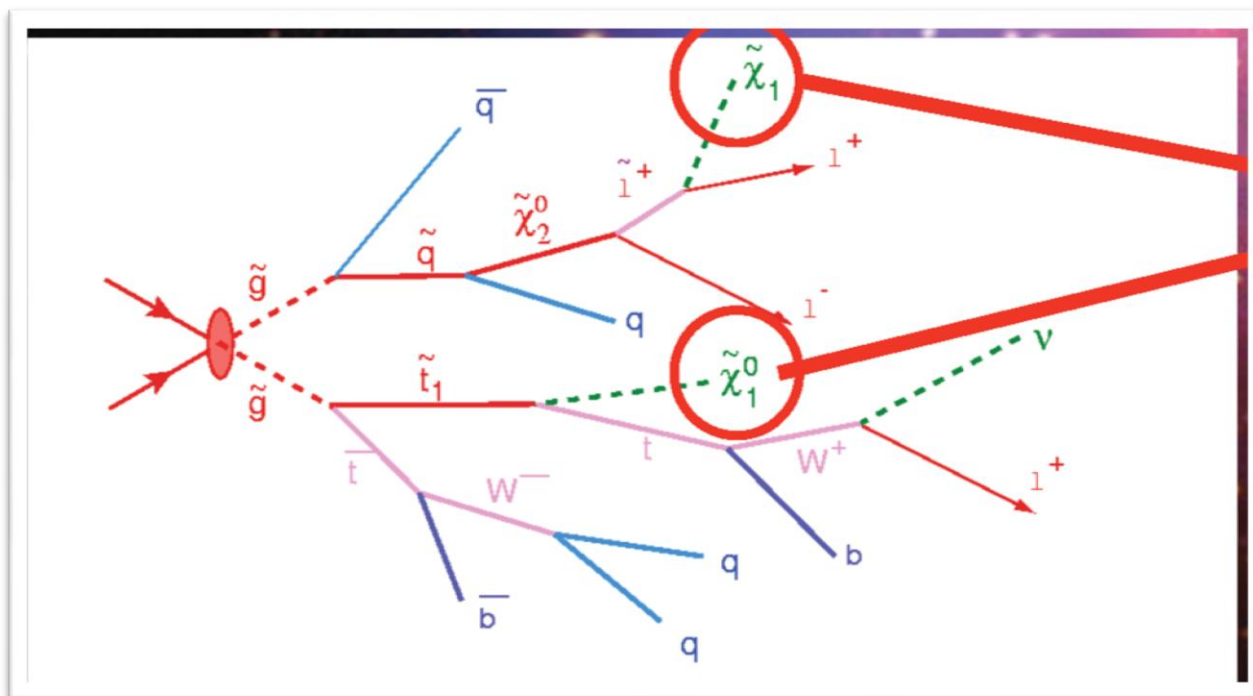


Najbardziej atrakcyjna: SUSY





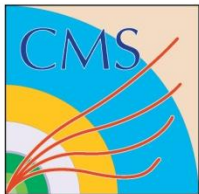
Produkcja supercząstek w LHC



Neutralina-
kandydaci na
Ciemną Materię

Niektóre z
tych
procesów
już przy
10/pb

Rozpady kaskadowe: wiele leptonów/ dżetów (b) i
Brakująca Energia Poprzeczna $E_{T \text{ Miss}}$



Poszukiwania SUSY

SUSY- rozpady kaskadowe

Typowa sygnatura hadronowa:

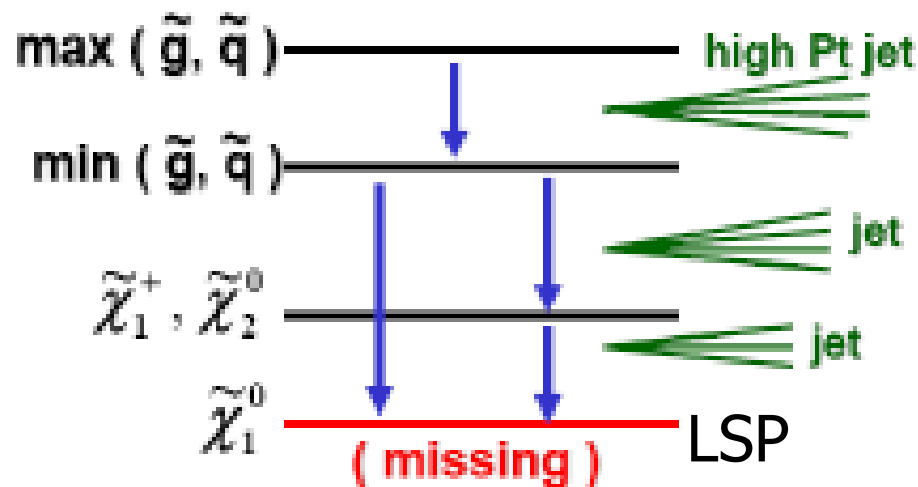
- Duża brakująca E_T (≥ 200 GeV)
- Dżety ($N \geq 3$)

Typowa sygnatura leptonowa:

- Naładowane leptony ($N = 1, 2, 3, 4$)
- Brakująca E_T

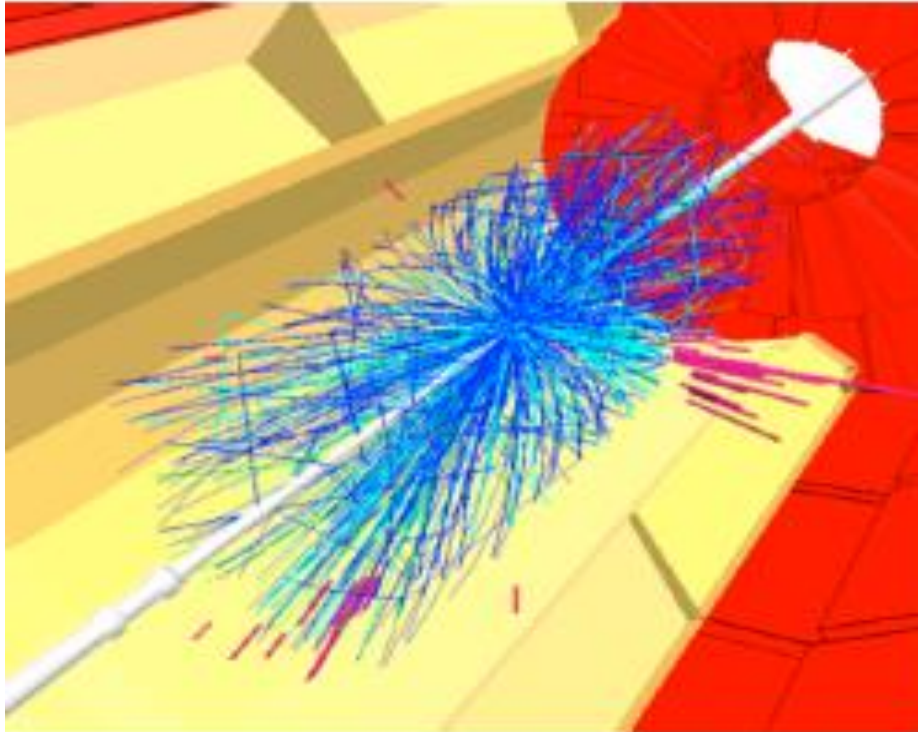
Typowe tła:

- Dżety hadronowe z QCD
- Top/ W/Z + Dżety (hadronowe and leptonowe)

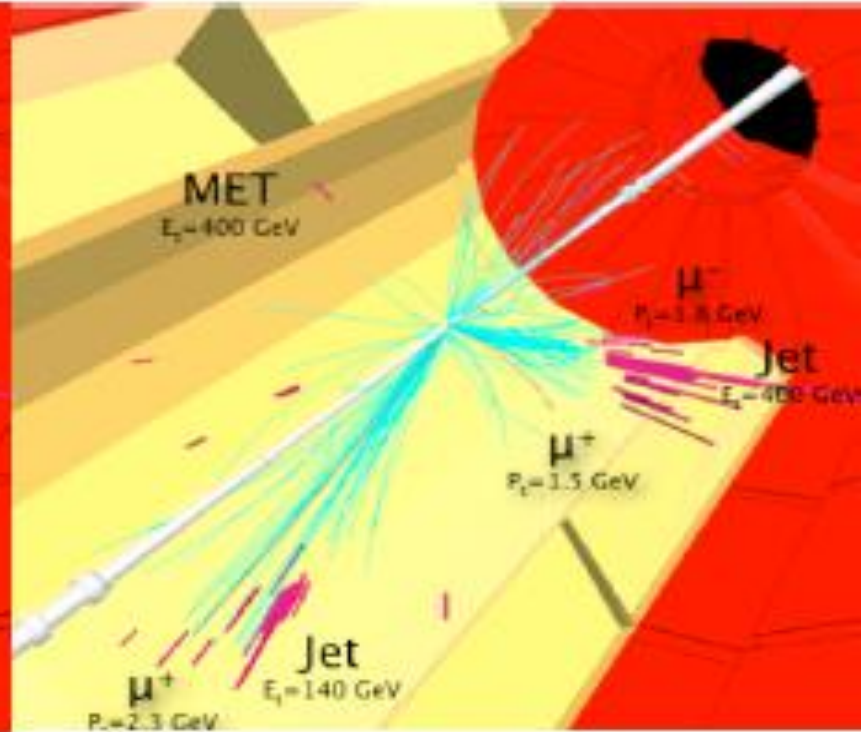




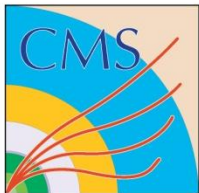
Example: 1.9 TeV gluino in the CMS detector



All charged tracks+E



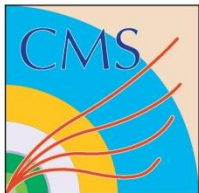
After reconstruction



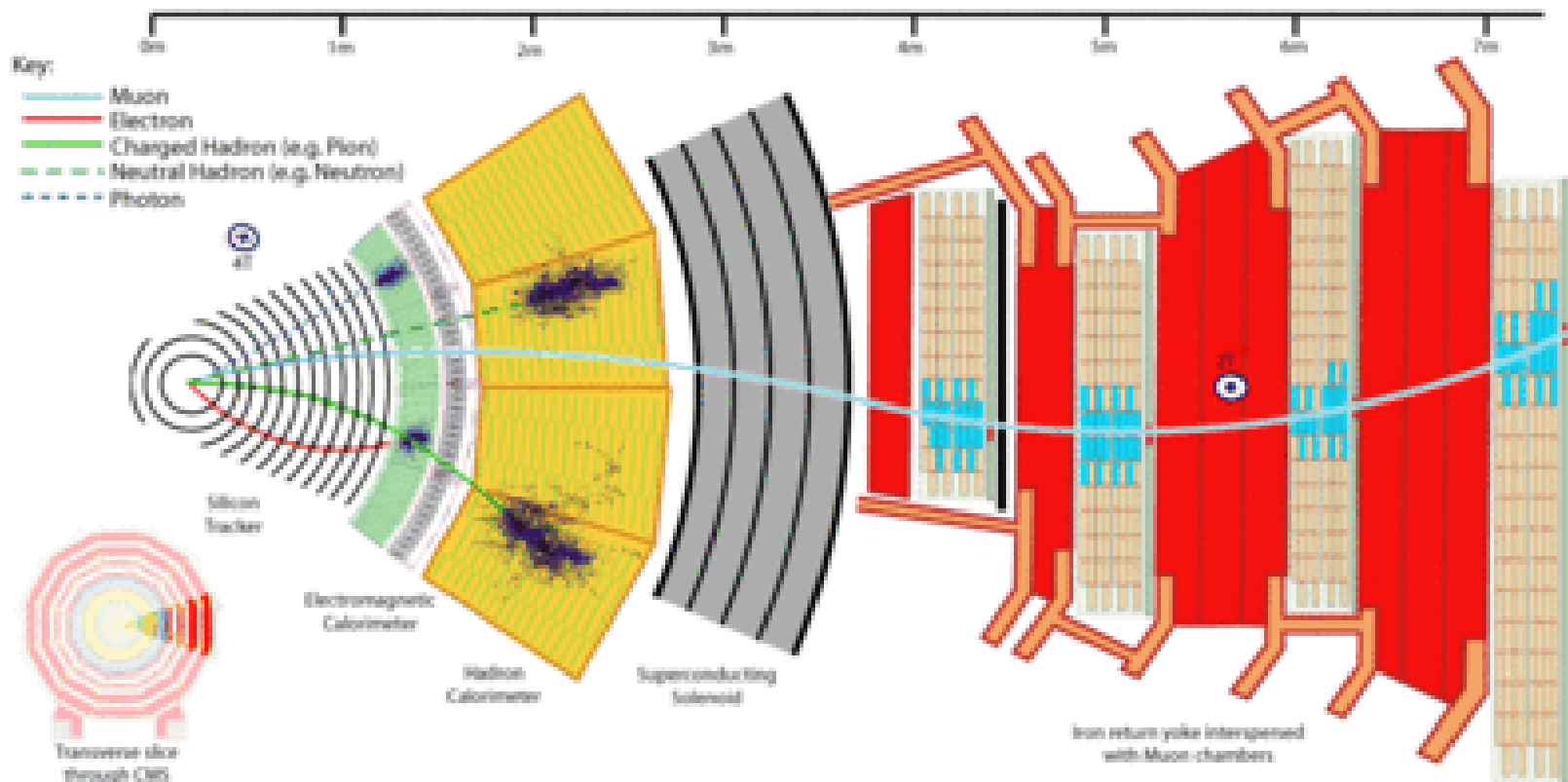
Wymagania dla detektorów

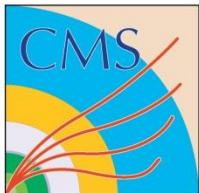
- Duża granularność- rekonstrukcja (kierunki i energie) wielu obiektów
- Hermetyczność- dobry pomiar $E_{T \text{ Miss}}$
- Dobra identyfikacja leptonów naładowanych: elektronów, mionów i taonów
- Duża stabilność pracy układu wyzwiania
- Identyfikacja dżetów b

Odkrycie SUSY możliwe już dla 100 /pb



Detekcja Cząstek w CMS





Badania Mechanizmu Spontanicznego Łamania Symetrii

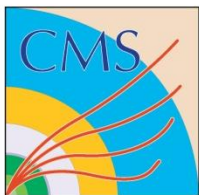


1. Mechanizm Higgsa

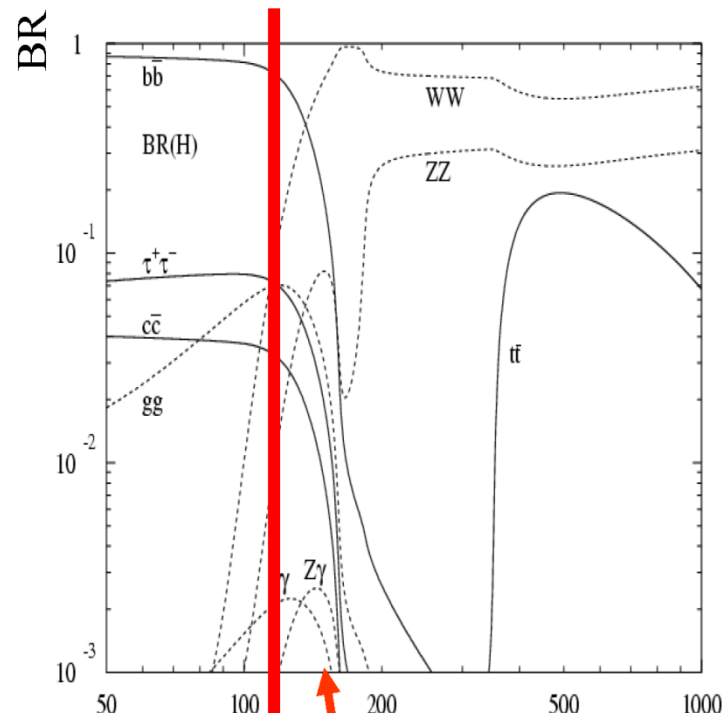
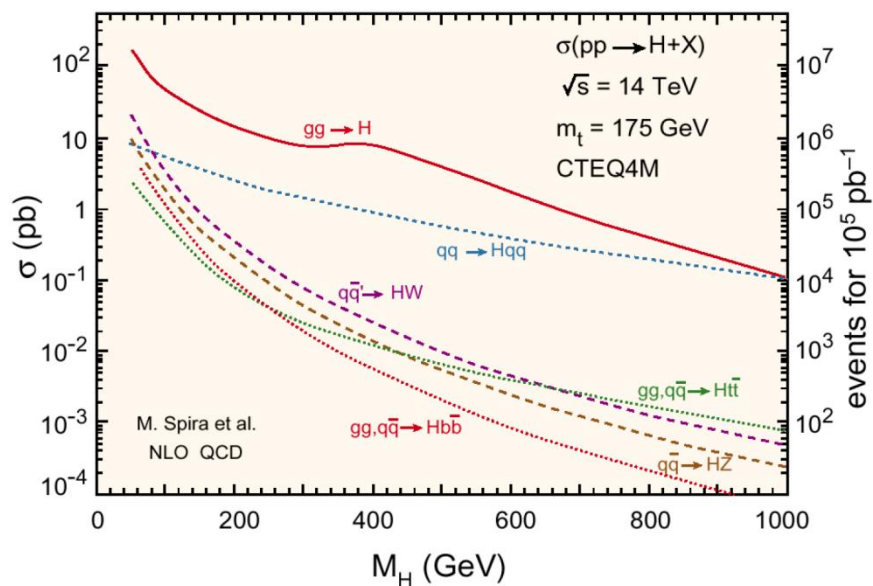
lub

2. coś bardziej skomplikowanego?

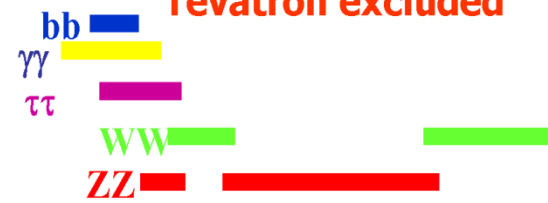
1. Odkrycie wymaga $\mathcal{L} > 10$ /fb, wykluczenie $\mathcal{L} \sim 1$ /fb
2. Coś bardziej skomplikowanego $\mathcal{L} > 30$ /fb

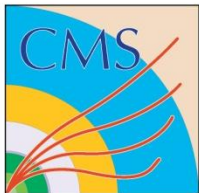


Produkcja i rozpad higgosa



Czułość w poszczególnych kanałach zależy od masy higgosów





Poszukiwanie higgsów

Mechanizmy produkcji i rozpadów higgsów:

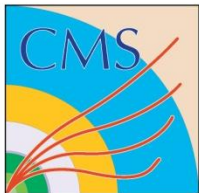
Cząstki Higgsa sprzęgają się najmocniej do najcięższych cząstek, na które mogą się rozpaść.

Np. rozpad $H \rightarrow W^- W^+$

dominuje dla $140 < m_H < 2 m_W$ czyli w obszarze mas higgsów 140-180 GeV/c².

Stąd poszukiwanie higgsów polega na badaniu różnych kanałów rozpadów zależnie od obszaru masy poszukiwanej cząstki.

Ponieważ możliwości detekcji, **tło** i zdolności rozdzielcze różnych kanałów rozpadu są różne, czułość eksperymentów na odkrycie higgsów zależy od masy higgsów.

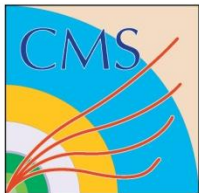


Doświadczenia z CDF i D0

Poszukiwanie higgsów przy **małych masach** (**<140_GeV**) jest bardzo trudne i wymaga szczególnego wysiłku doświadczalnego (np. precyzyjna kalibracja kalorymetrów itp.)

Wymagania dla detektorów:

- Doskonały kalorymetr elektromagnetyczny
- Identyfikacja dżetów b (liczniki wierzchołka)
- Identyfikacja i wyzwalanie na dżety taonowe

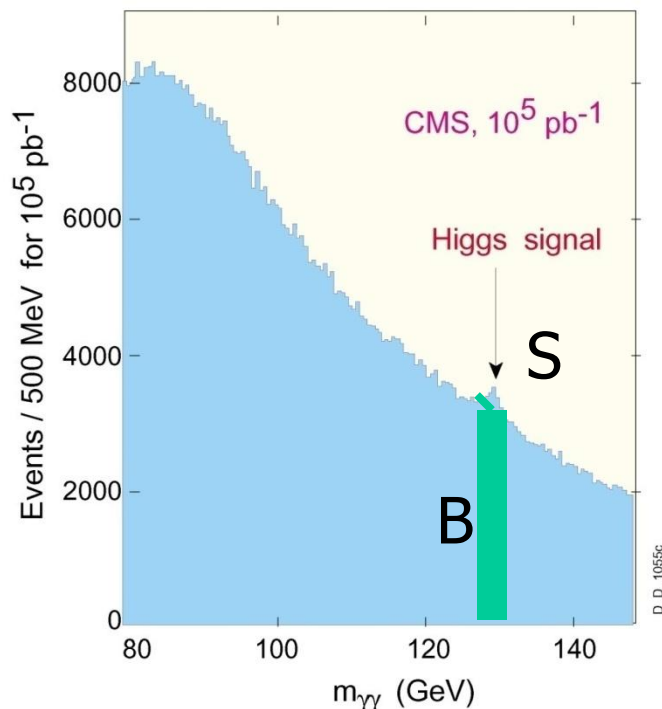


Np. $114.5 < m_H < 140$ rozpady na 2γ

CMS



Simulated 2γ mass plot
for 10^5 pb^{-1} $m_H = 130 \text{ GeV}$
in the lead tungstate calorimeter



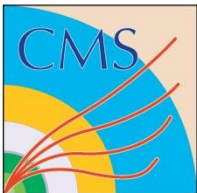
Znaczoność sygnału:

$$Z = \frac{S}{\sqrt{B}}$$

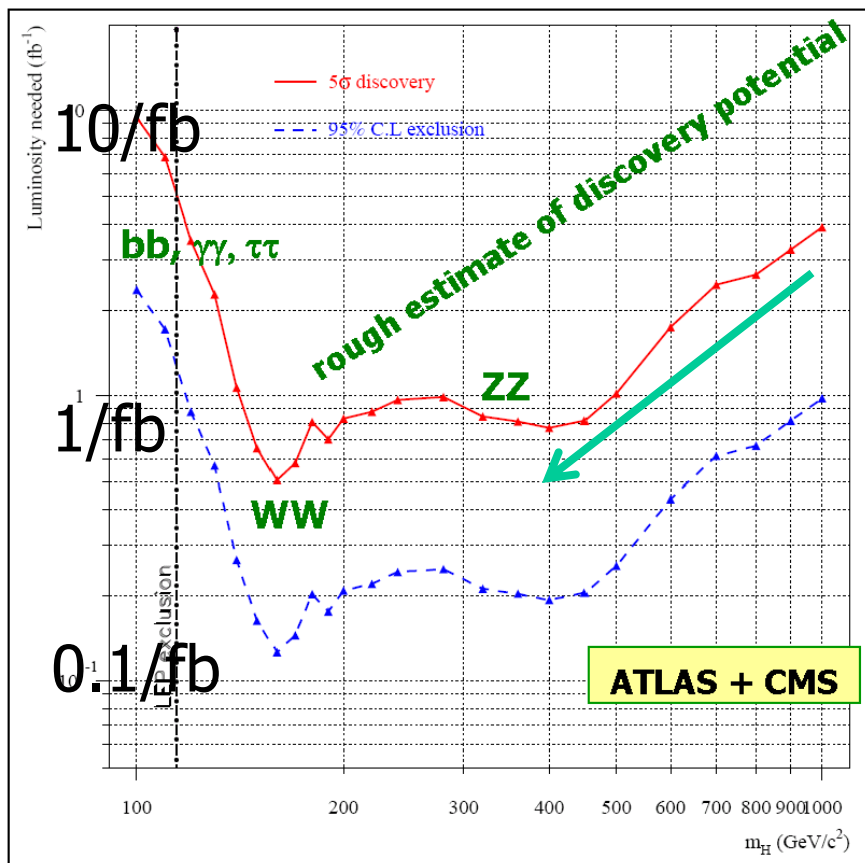
Liczba przypadków tła B jest tym większa im gorsza jest rozdzielczość masy niezmienniczej 2γ .

Rozdzielczość masy zależy od:

- rozdzielczości energii kwantów w kalorymetrze e-m,
- rozdzielczości kąta między pędami dwóch kwantów.



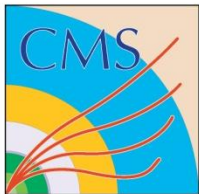
ODKRYCIE HIGGSA $z > 5$



$$z = \frac{S}{\sqrt{B}} \propto \sqrt{\int L dt}$$

Znaczoność sygnału
wzrasta ze scałkowaną
światłością L .

L (2009-2010) $\sim 200-250$
/pb=
 $= 0.20-0.25$ /fb



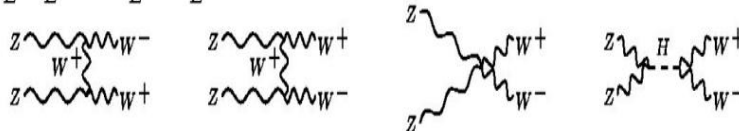
Rozpraszanie WW oknem na SSP dla dużych mas

Będzie wymagało co najmniej 30/fb **CMS**

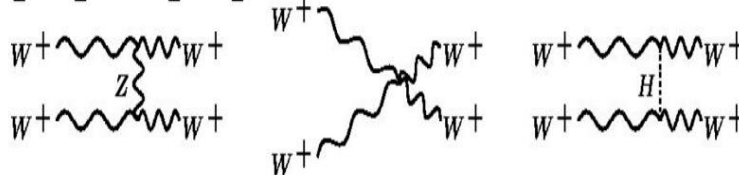
$$W_L^+ W_L^- \rightarrow W_L^+ W_L^-$$



$$Z_L Z_L \rightarrow W_L^+ W_L^-$$



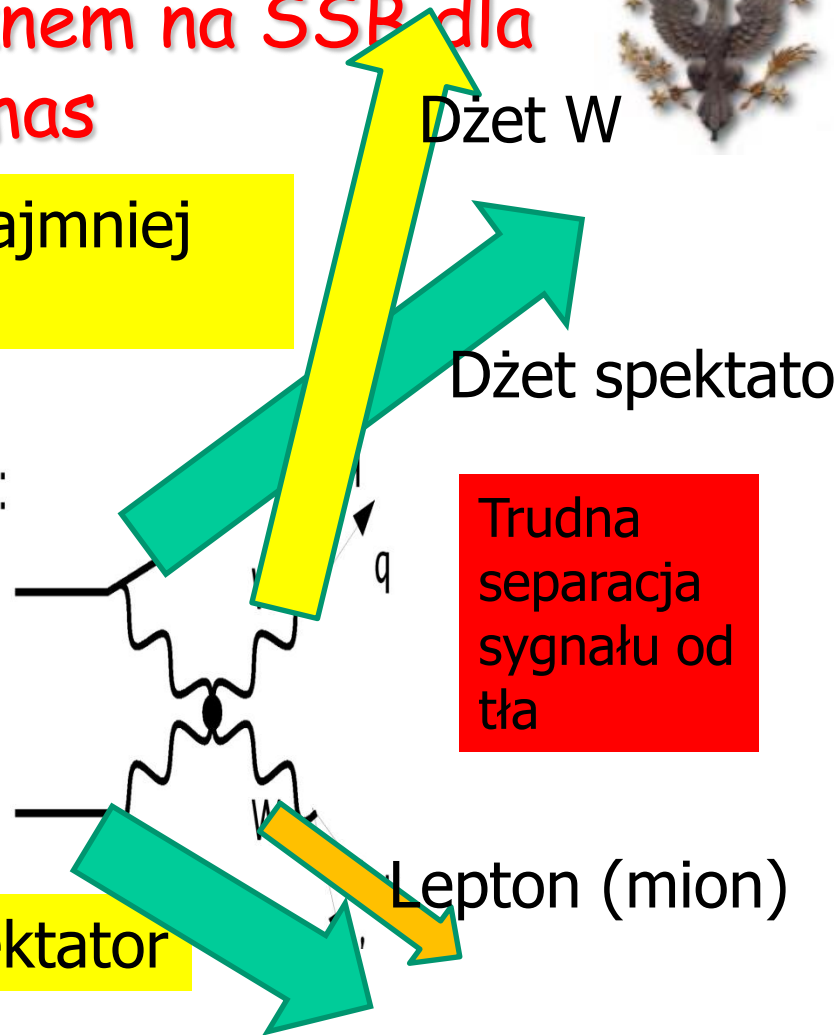
$$W_L^+ W_L^+ \rightarrow W_L^+ W_L^+$$



• wybrany kanał :

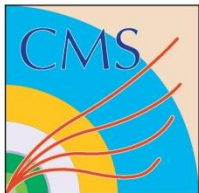
- $VV \rightarrow WW$
- $WW \rightarrow qq\mu\nu$

• **Dżet spektator**



Trudna separacja sygnału od tła

Skomplikowany stan końcowy: mion+ dżet W+ 2 dżety spektatorzy



Wnioski

- LHC bliskie 1-szych zderzeń przy energii 7 TeV
- W 2010- fizyka Modelu Standardowego ew. z elementami niektórych odkryć (np. SUSY)
- Kiedy podwyższenie energii? **Czas pokaże**
- Fizyka SSB i poza Modelem Standardowym **2012-2013**