Early physics at LHC

Ludwik Dobrzynski

Laboratoire Leprince Ringuet - Ecole polytechnique - IN2P3 - CNRS

Warszawa - November 16th 2007

- Introduction
- Program for the first Days
- Early physics at LHC
- Beyond Standard Model
- Higgs hunting
- Conclusions

Where do we are Today

- **Which is the origine of the mass?**
  - ***Why the Z^0 boson has a mass and not the photon?***
- **Which is the origine of the matter-antimatter asymmetry?**
  - ***Is the CP violation giving the complete response?***
- **Does it exist a new Symmetry? SUSY?**
  - ***Are we taking the right way to the Forces UNIFICATION?***
  - ***Is a unique particle able to explain the Dark Matter?***
- **Does it exist a new form of matter?**
  - ***Quark-gluons Plasma?***
- **Does it exist a sub-structure for presently known particles?**
- **Can Physics be unified : "Theory of Everything"?**

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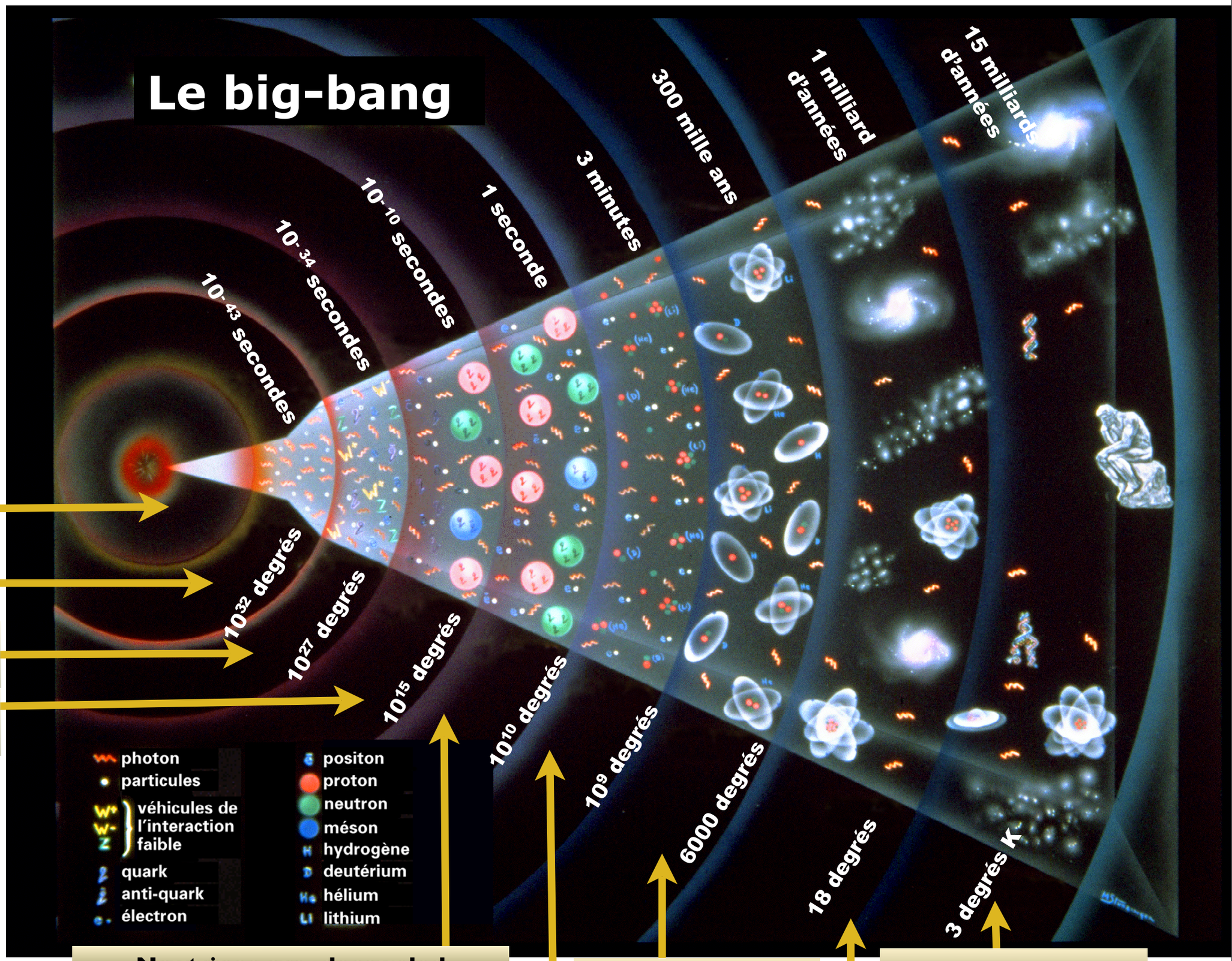
The LHC program has been undertaken to give responses to these questions

Unveiling the Universe



Quantum Gravity Era (10^{19} GeV - 10^{-34} m)

Grand Unified Era (10^{16} GeV - 10^{-32} m)

Electroweek Era (100 GeV - 10^{-18} m)

proton - neutron (1 GeV - 10^{-16} m)

Neutrinos are decoupled

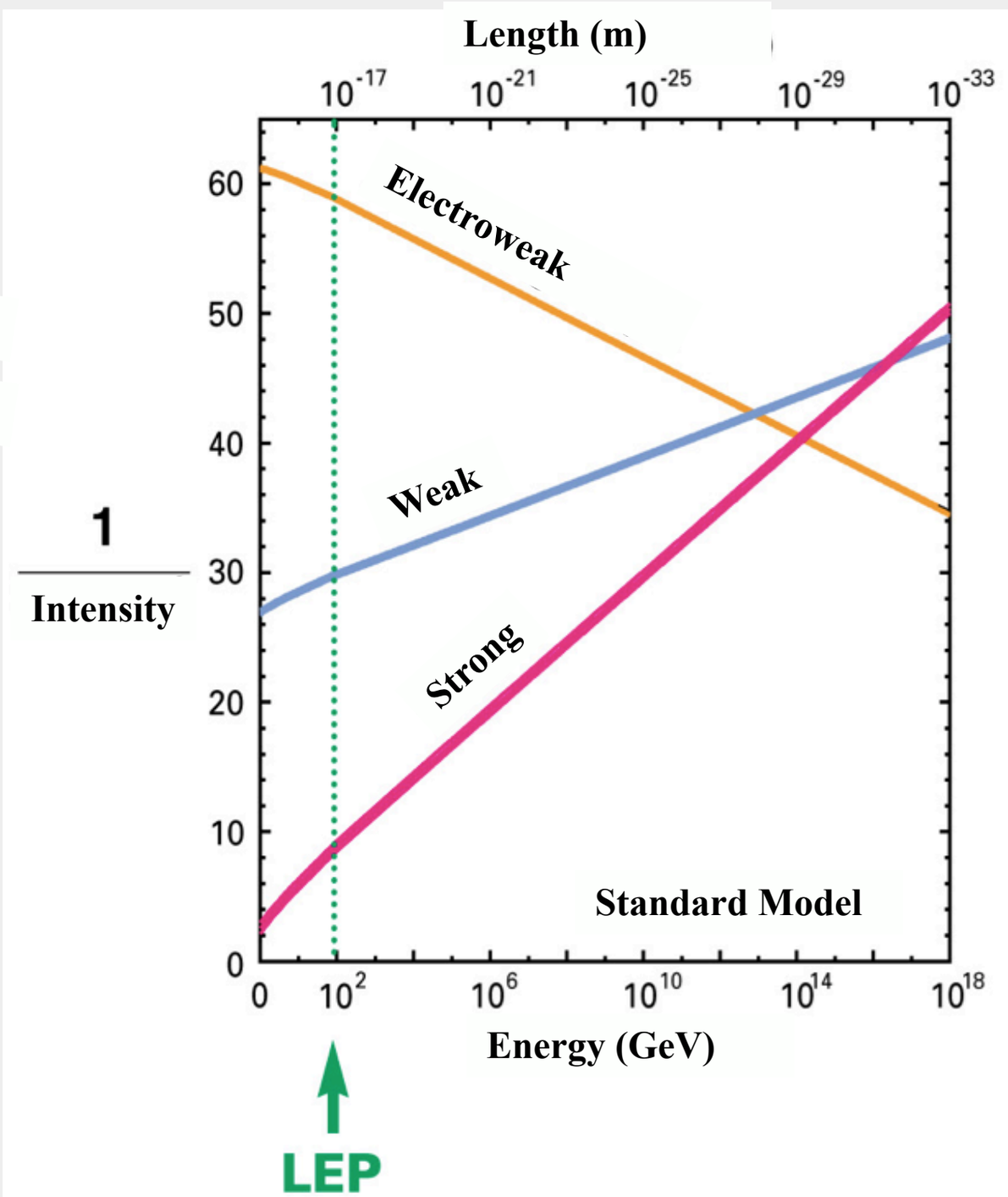
Nuclei

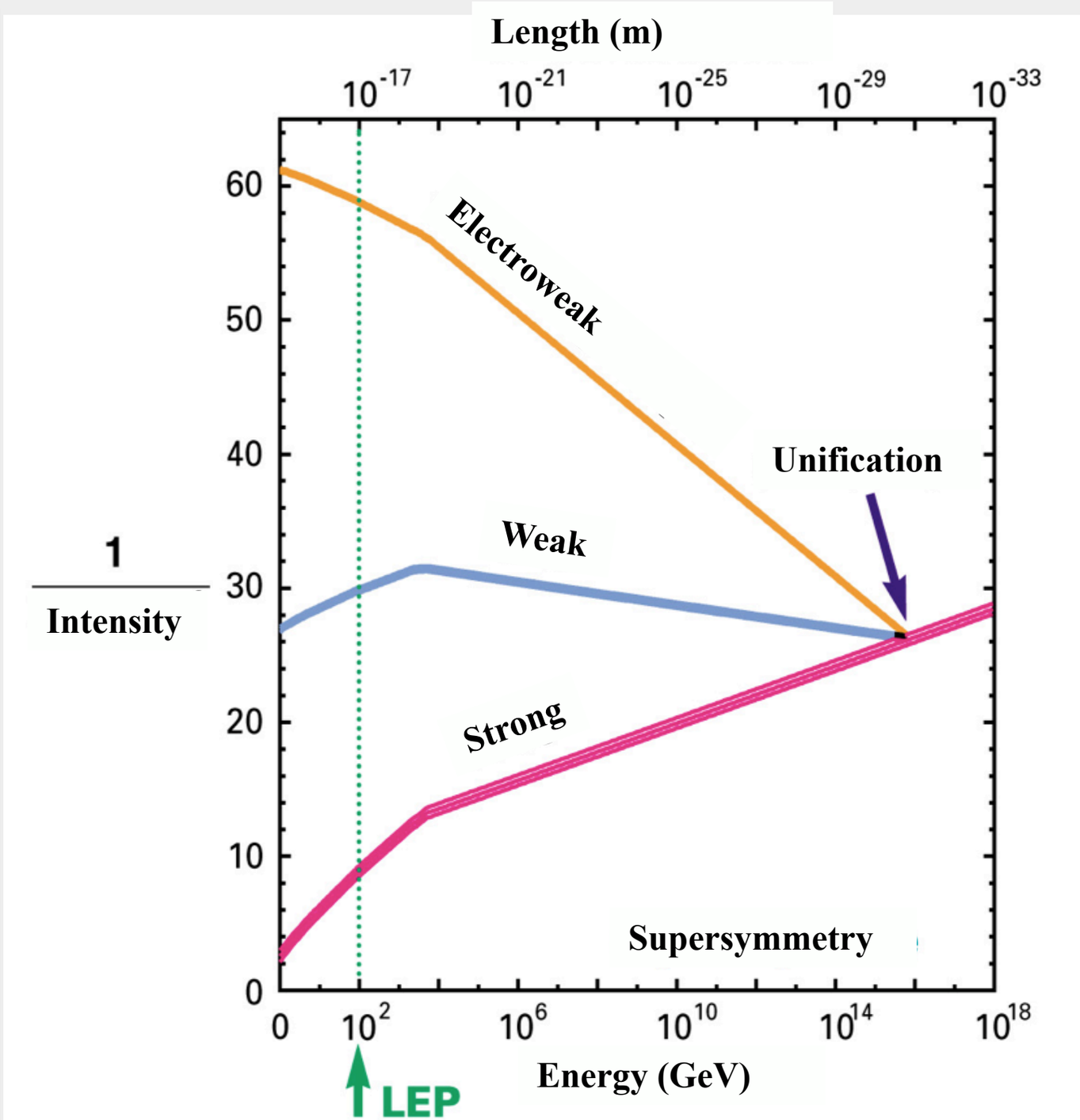
Atoms + Light

Galaxies

Man

Towards unification





Standard Model

Supersymmetry

Open Cosmological Questions

- Why is the Universe so big and old?
  ~ 15,000,000,000 years

LHC

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LHC

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LHC

Need particle physics to answer these questions

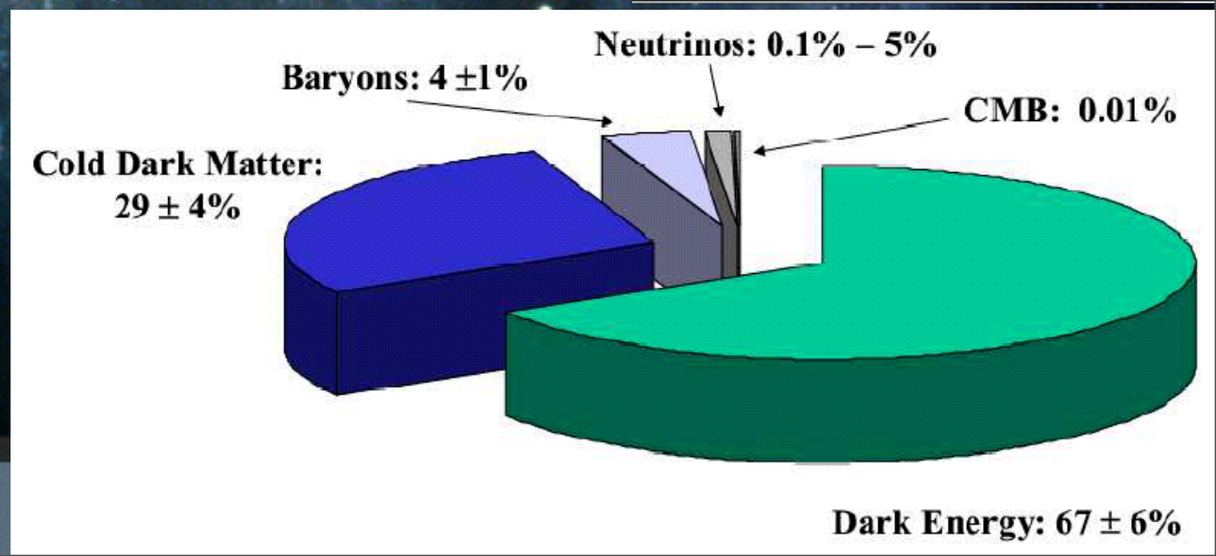
C2

Dark Matter in the Universe

Astronomers say that most of the matter in the Universe is invisible Dark Matter

‘Supersymmetric’ particles ?

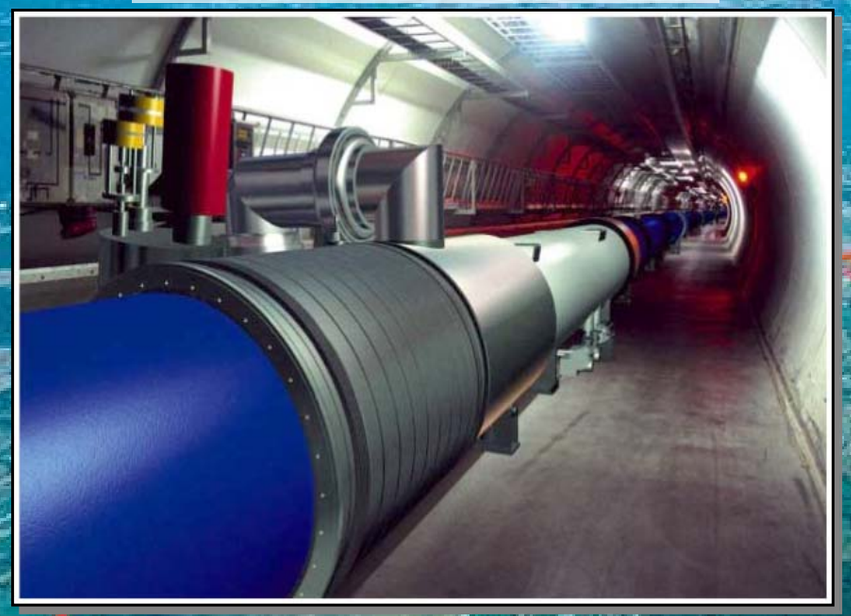
We shall look for them with the LHC

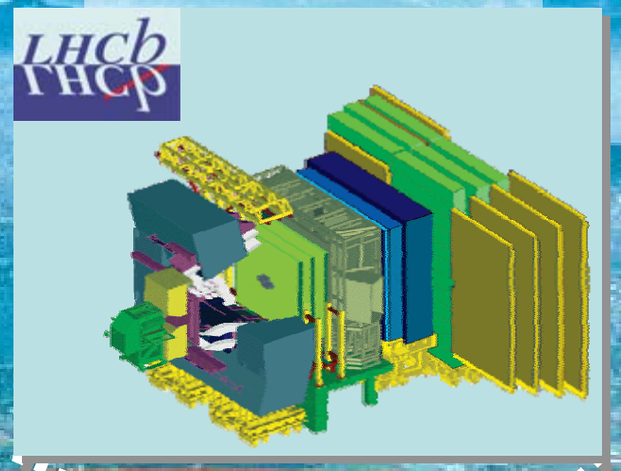


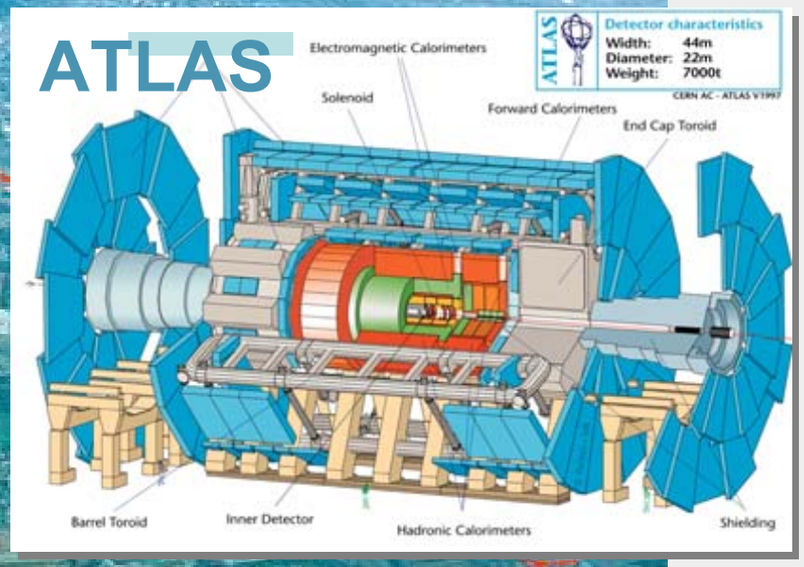
Towards physics at CERN with LHC

pp, B-Physics,
CP Violation

LHC : 27 km long
100m underground

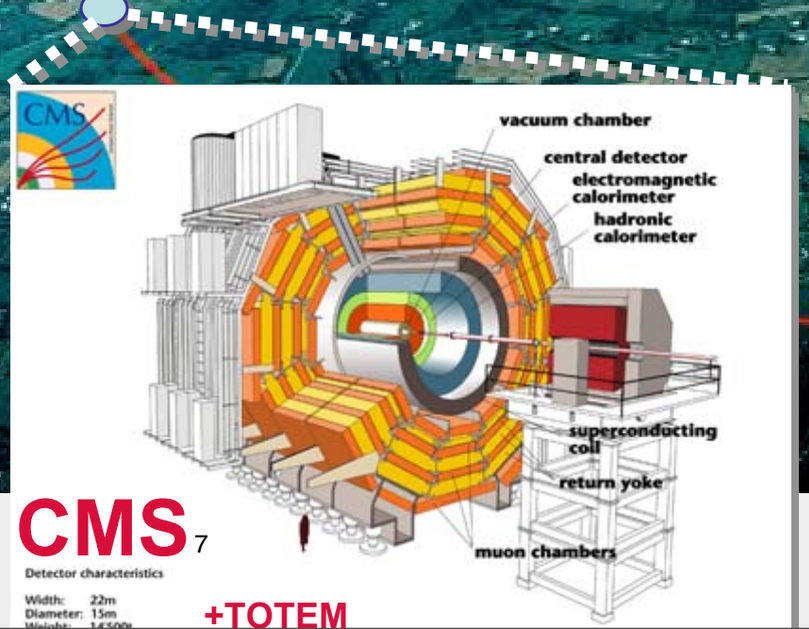






General Purpose,
pp, heavy ions

Heavy ions, pp



First LHC data

“Success-oriented” schedule: Machine closed April 2008, collisions July 2008

LHC Startup Stages

Parameter	Phase A	Phase B	Phase C	Nominal
k / no. bunches	43-156	936	2808	2808
Bunch spacing (ns)	2021-566	75	25	25
N (10^{11} protons)	0.4-0.9	0.4-0.9	0.5	1.15
Crossing angle (μrad)	0	250	280	280
$\sqrt{(\beta^*/\beta^*_{nom})}$	2	$\sqrt{2}$	1	1
σ^* (μm, IR1&5)	32	22	16	16
L ($cm^{-2}s^{-1}$)	6×10^{30}-10^{32}	10^{32}-10^{33}	$(1-2)\times10^{33}$	10^{34}

J. Wenninger

2008 2009 > 2010

Atlas - CMS

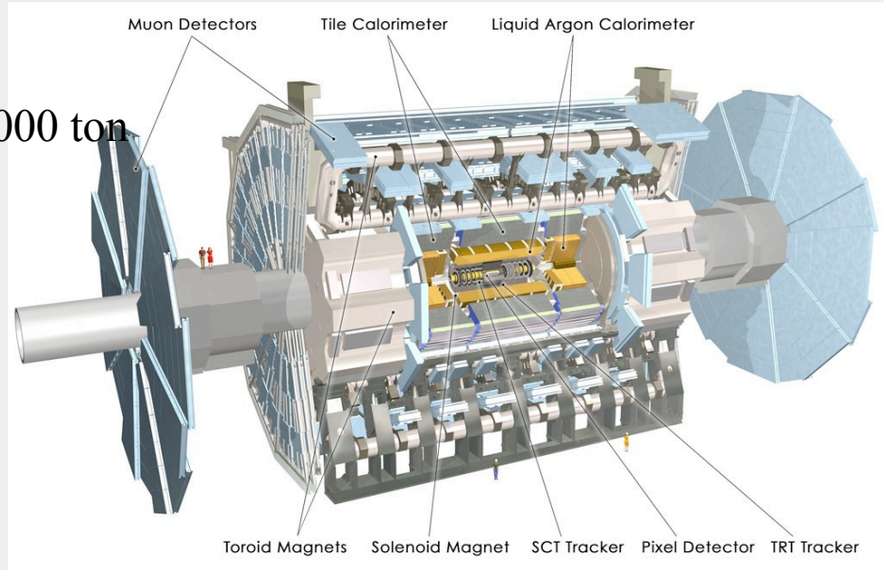
The detector subsystems are designed to **measure** with the best precision: **energy and momenta** of γ, e, μ, jets, missing E_T up to few TeV

ATLAS

Total weight : ~7000 ton

Diameter : ~24m

Length : ~ 45m

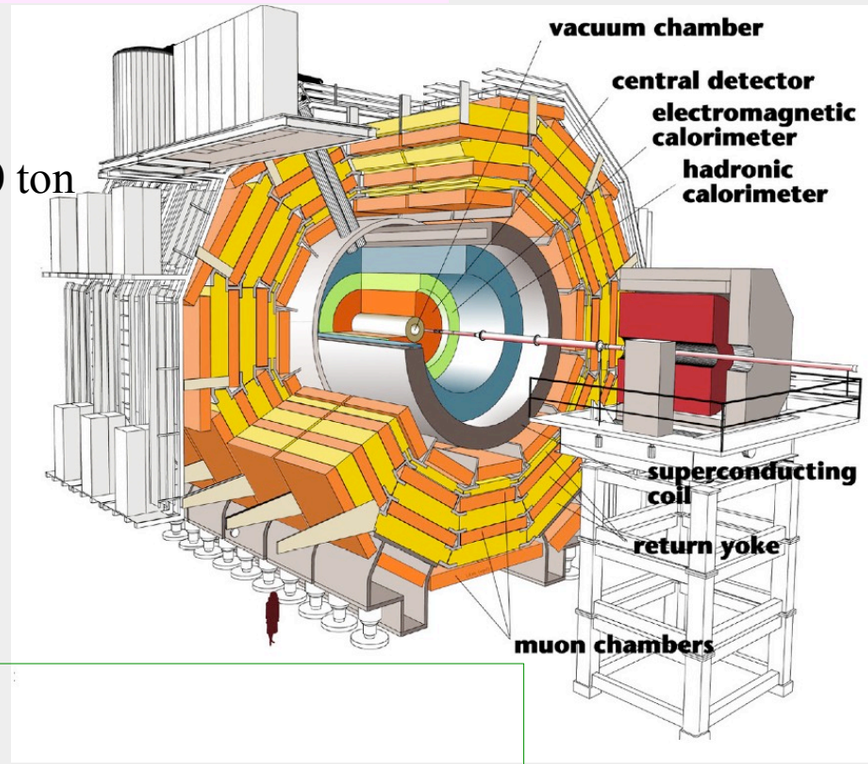


CMS

Total weight : ~12500 ton

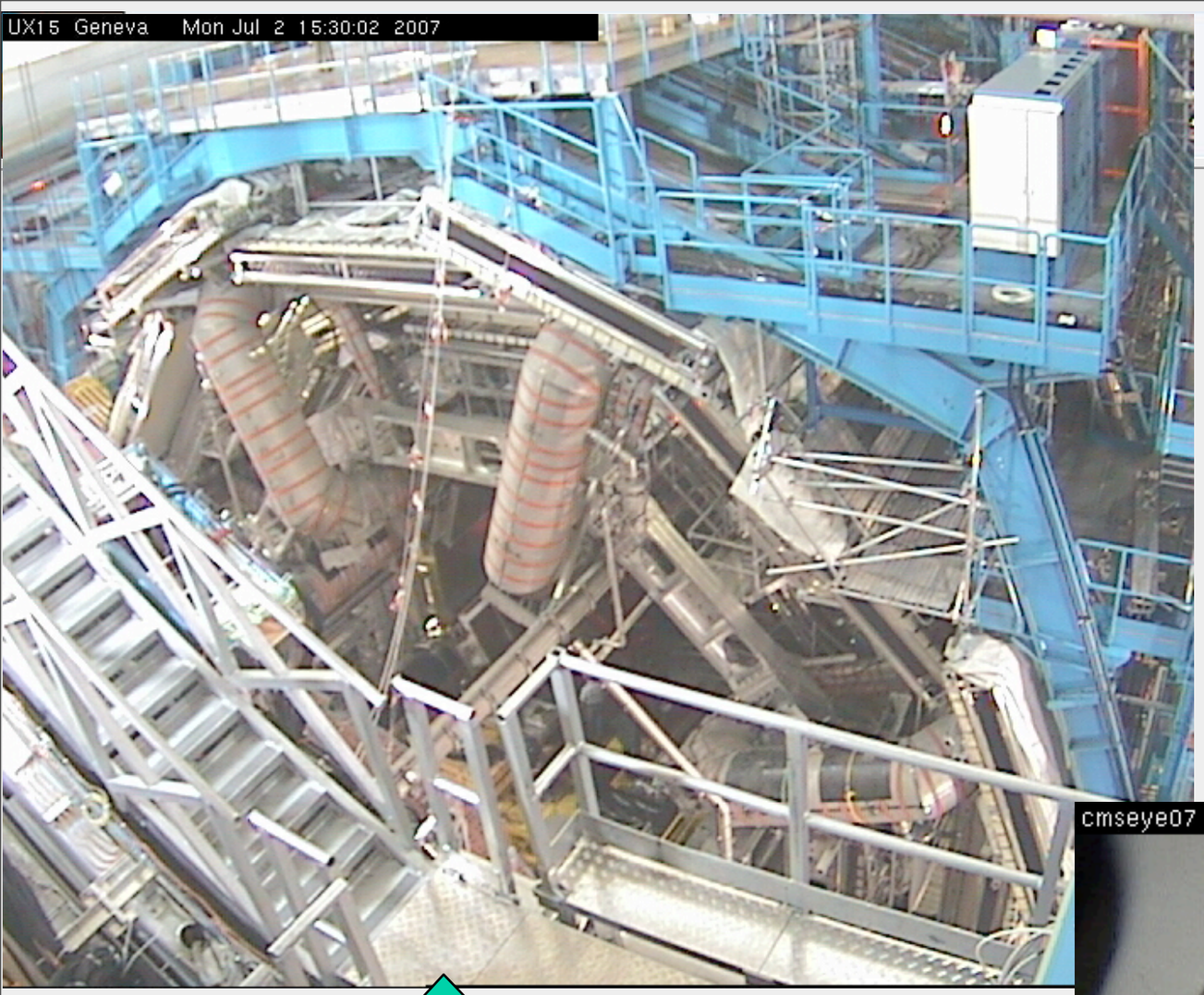
Diameter : ~14 m

Length : ~22 m



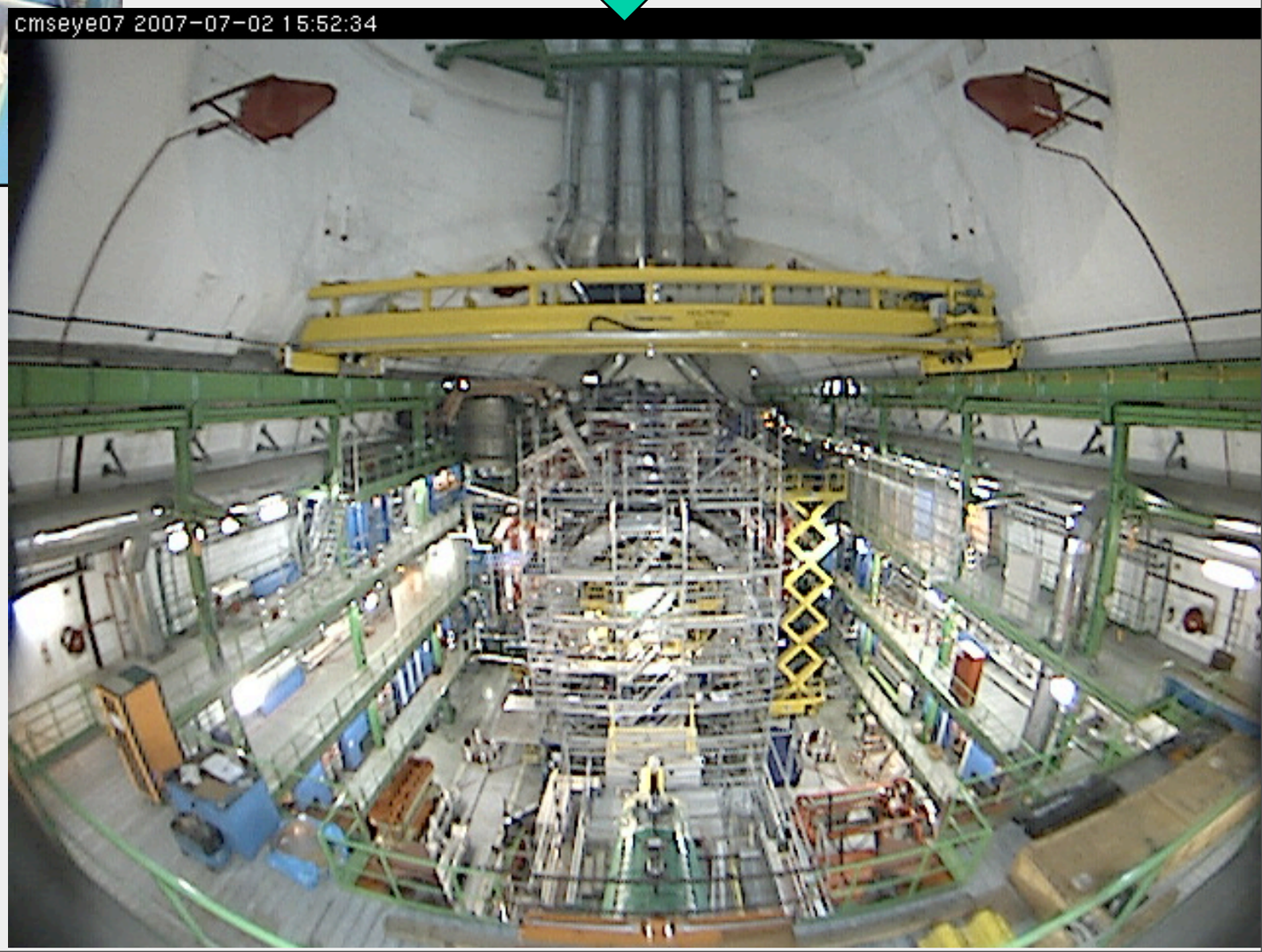
Tracker	B=2 Tesla	B= 4 Tesla
Si pixels + Si strips	$\frac{\sigma}{p_T} \sim 5\times10^{-4}\, p_T \oplus 0.01$	$\frac{\sigma}{p_T} \sim 1.5\times10^{-4}\, p_T \oplus 0.005$
EM calorimeter	Pb-liquid Argon $\frac{\sigma}{E} \sim \frac{10\%}{\sqrt{E}}$ uniform	$PbWO_4$ crystals $\frac{\sigma}{E} \sim \frac{2.7\%}{\sqrt{E}} \oplus \frac{200\text{MeV}}{E} \oplus 0.5\%$
Hadron calorimeter	Fe-scintilator + Cu-liquid argon $\sigma/E \sim 50\%/\sqrt{E} \oplus 3\%$	Cu-scintilator $\sigma/E \sim 120\%/\sqrt{E} \oplus 5\%$
Muon spectrometer	air $\sigma/p_T \sim 7\%$ at 1 TeV standalone	Fe : $\sigma/p_T \sim 5\%$ at 1 TeV, $\sigma/p_T \sim 8-15\%$ at 10 GeV combination with tracker : $\sigma/p_T \sim 0.8-1.5\%$ at 10 GeV
Magnet	4 magnet : air-core toriods + solenoid in inner cavity calorimeters in B-field free region	1 magnet : solenoid calorimeters in B-field

The LHC Detectors

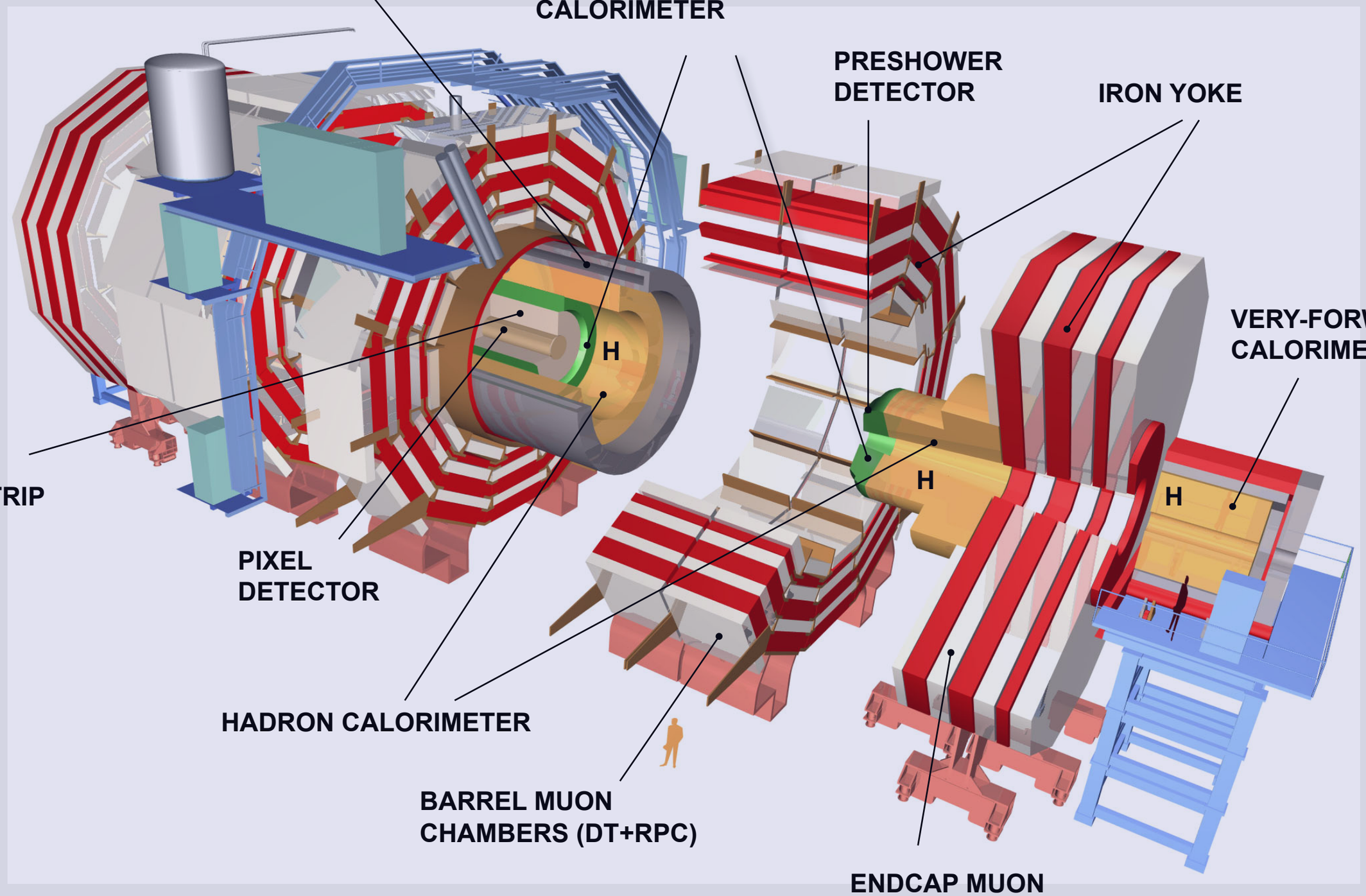


CMS
all components are now in the cavern

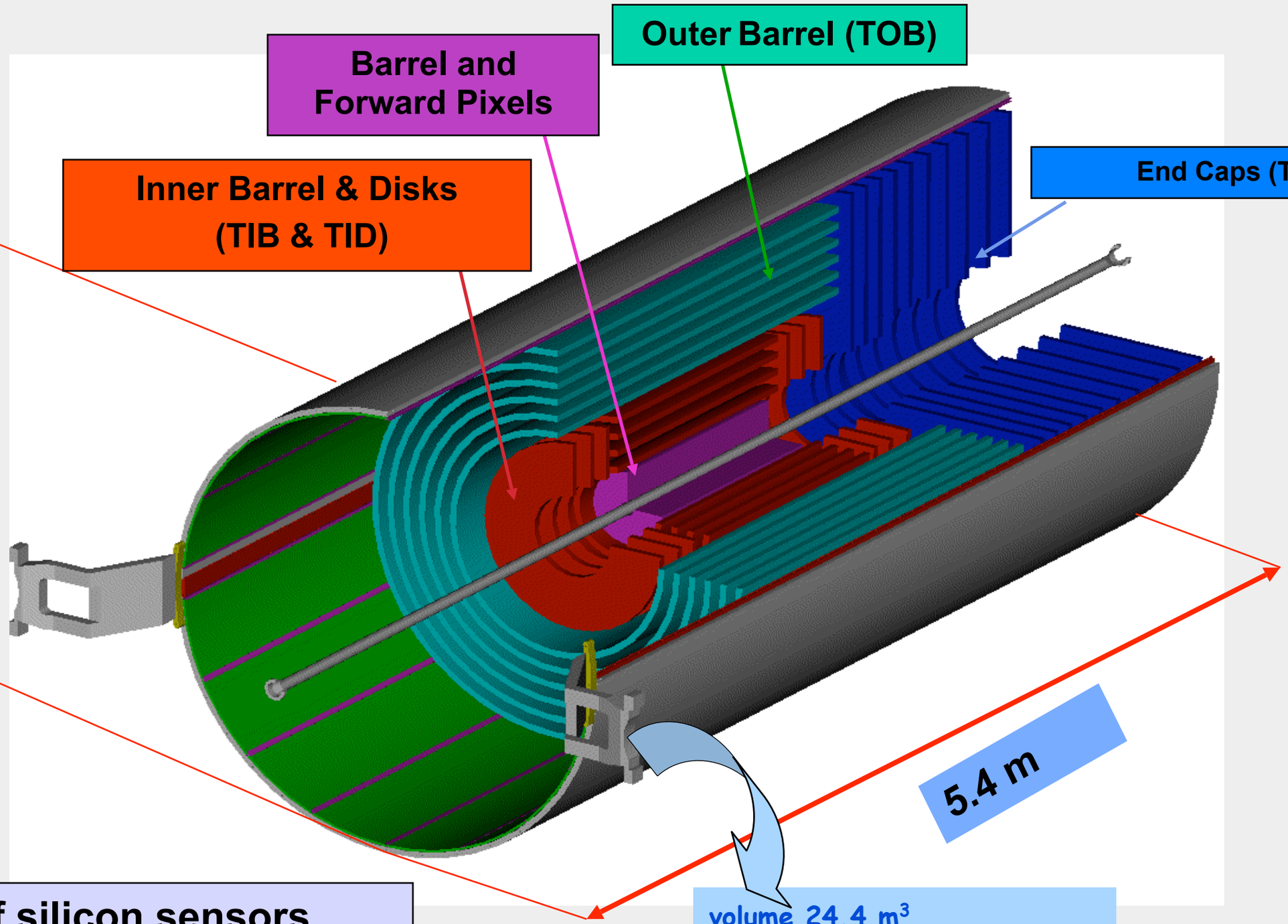
Atlas
about ready



Layout of CMS



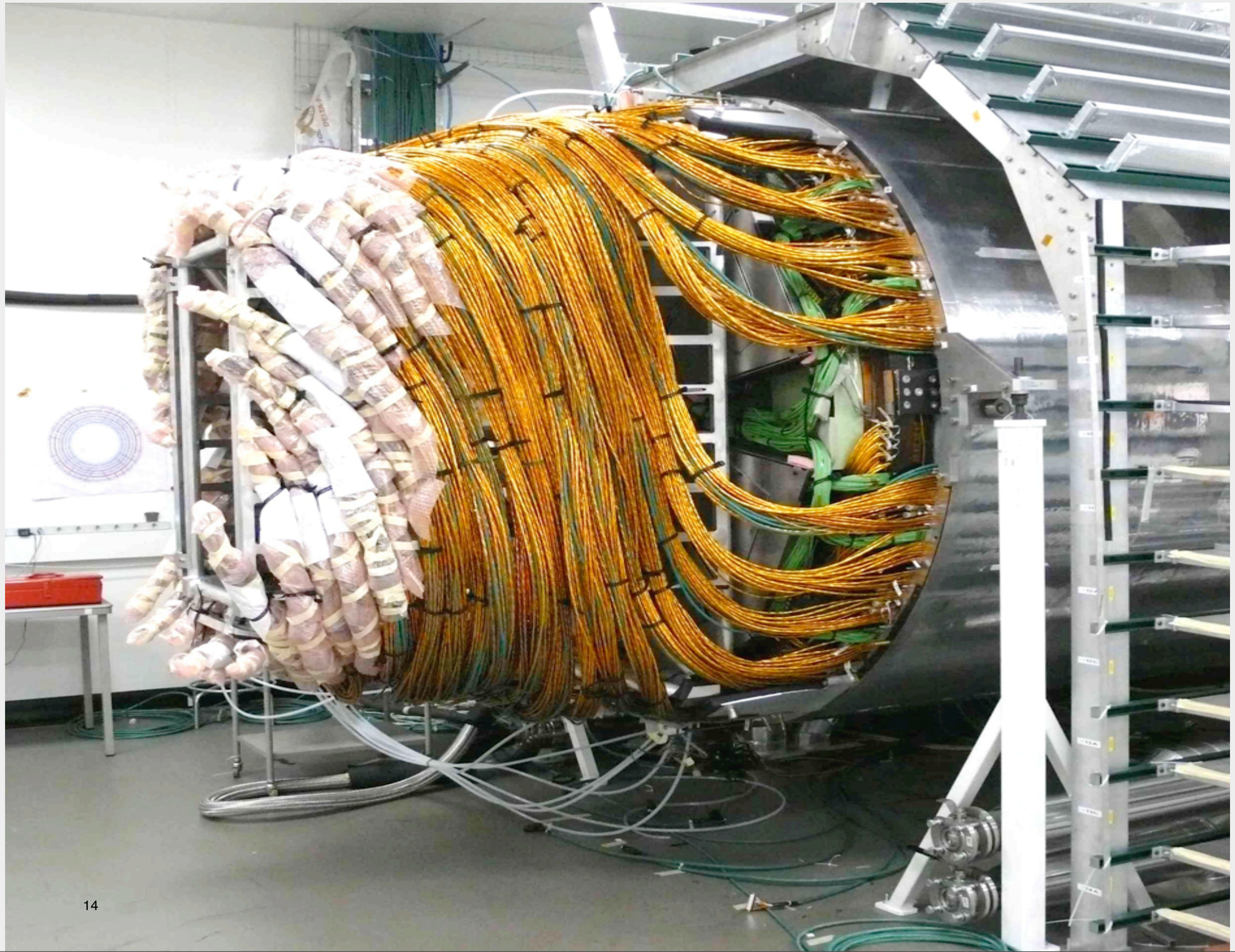
All Silicon Tracker



volume 24.4 m^3
running temperature - 20 ^0C

207m^2 of silicon sensors
10.6 million silicon strips
65.9 million pixels ~ 1.1 m^2

Tracker Ready for instalation



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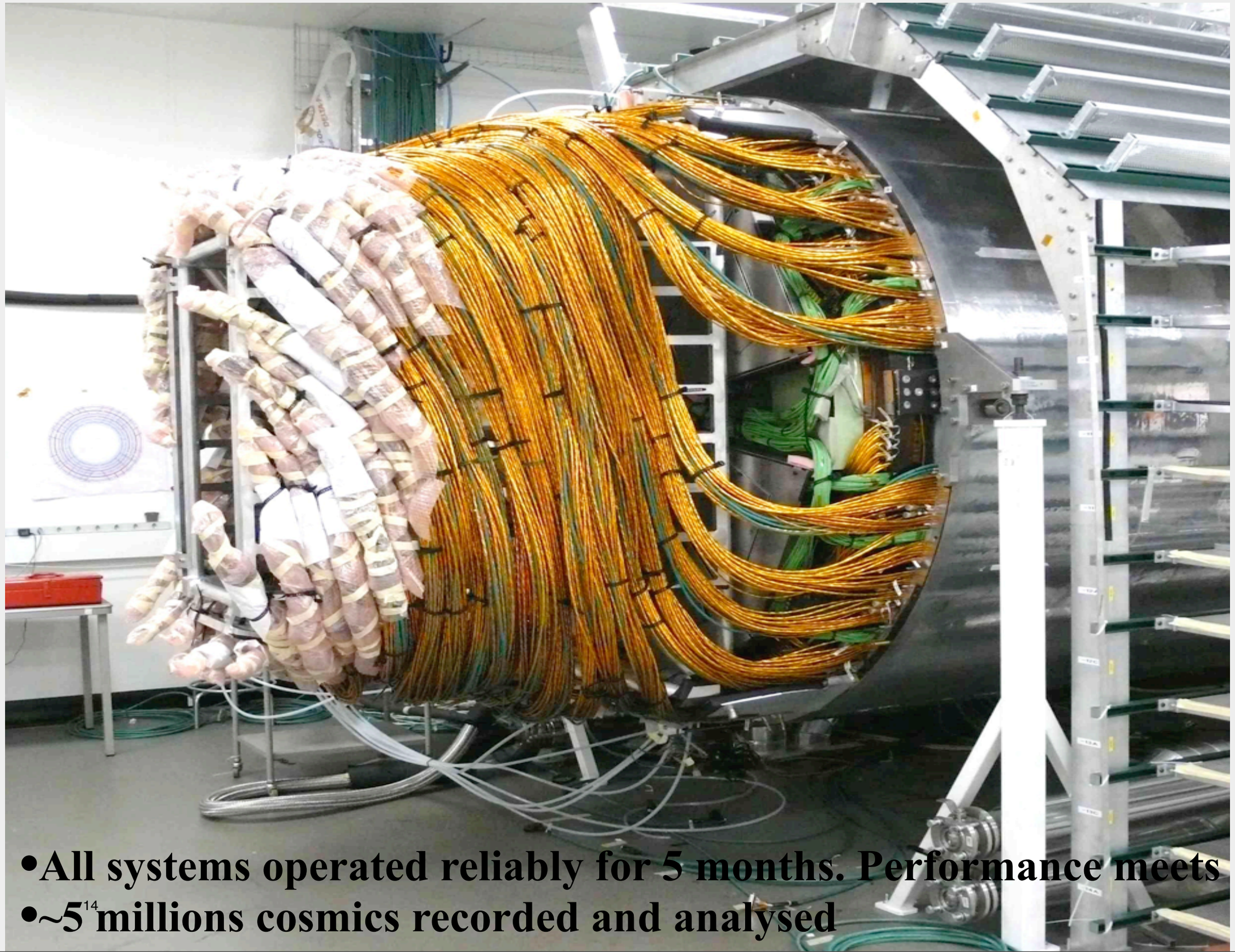
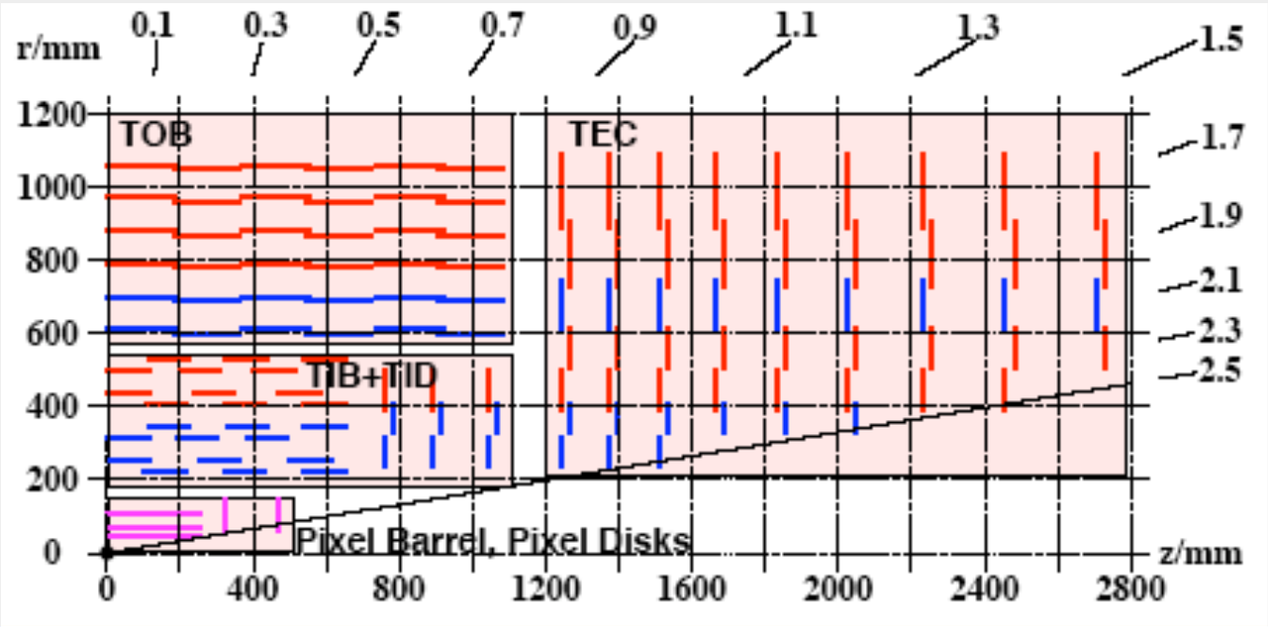
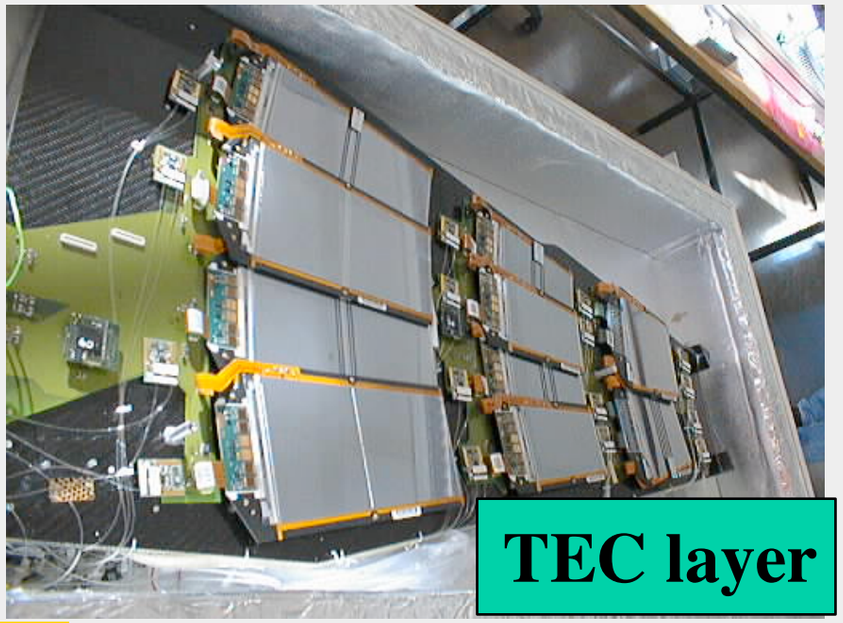


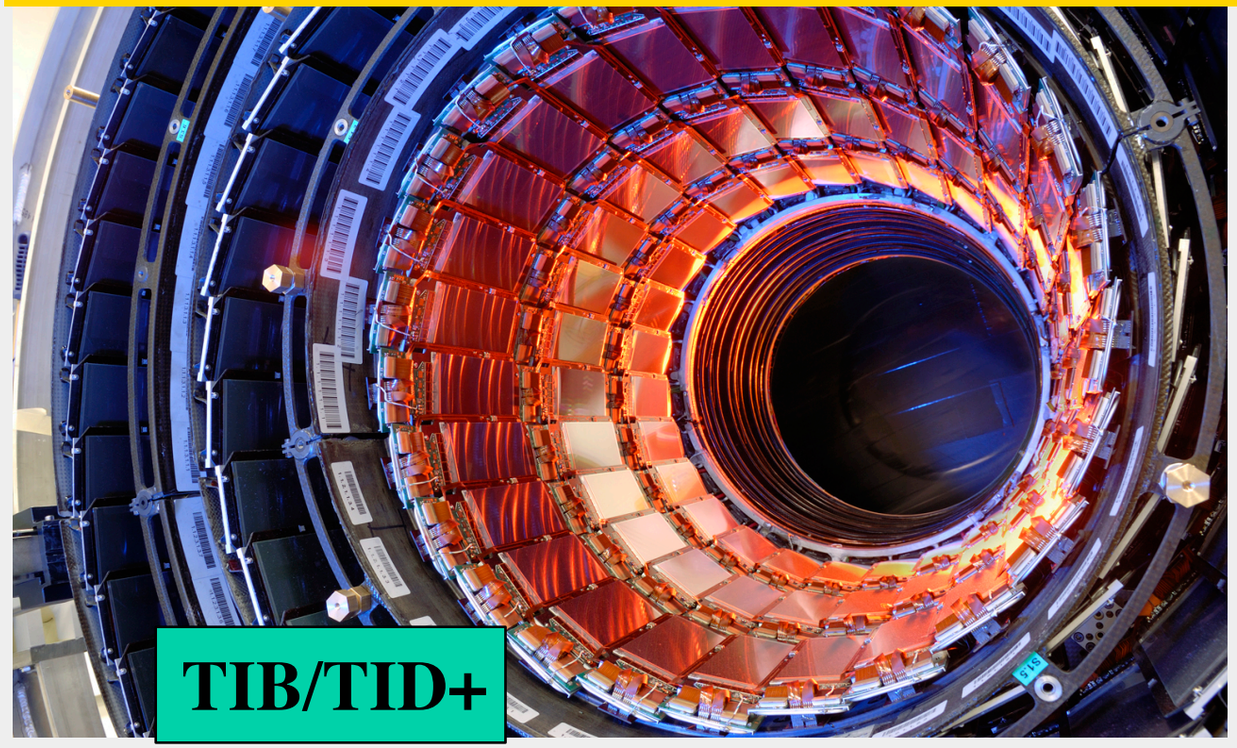
- All systems operated reliably for 5 months. Performance meets
- ~5 millions cosmics recorded and analysed

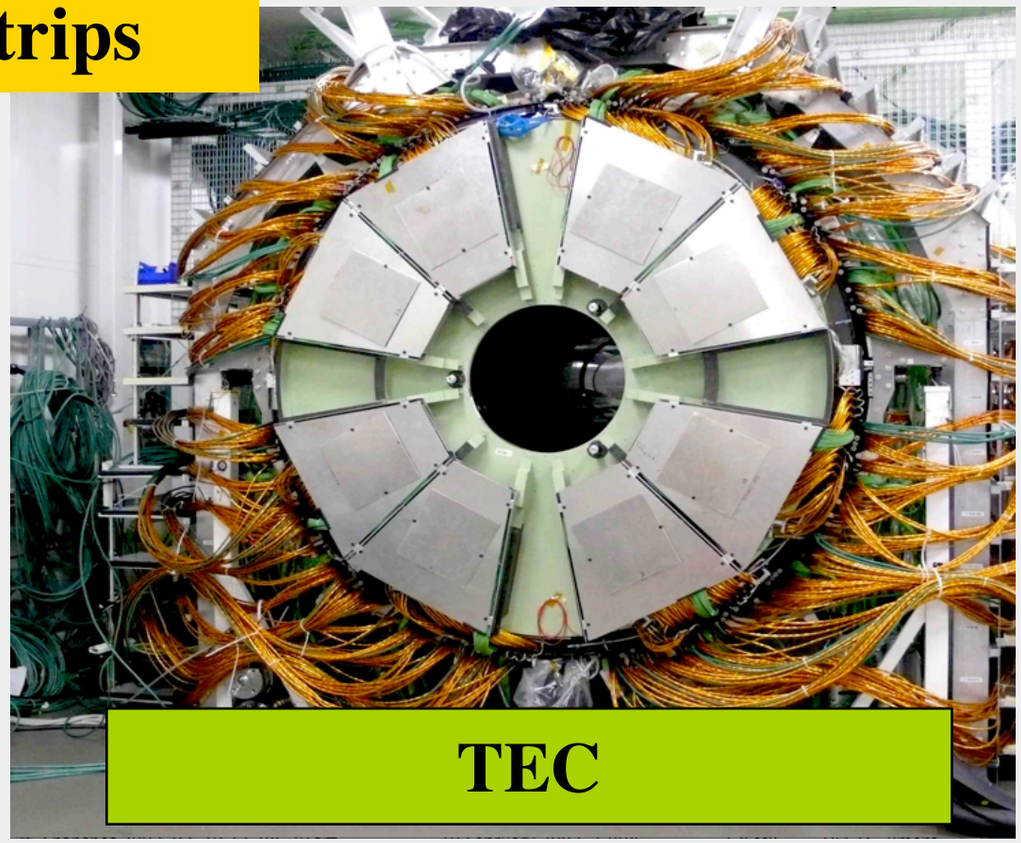
Silicon Strip Tracker



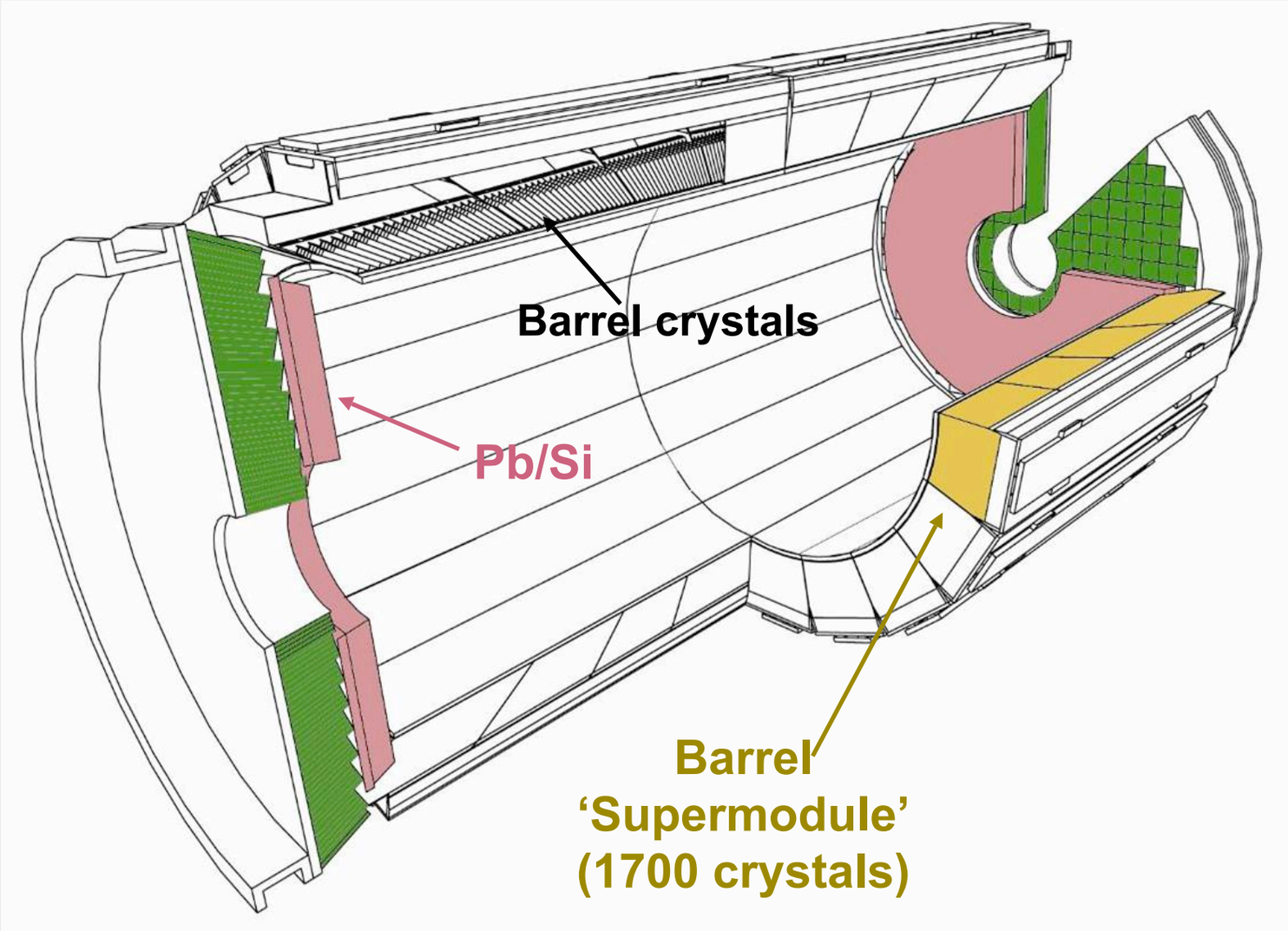


220 m² of Si sensors, 10.6 million Si strips





ECAL layout



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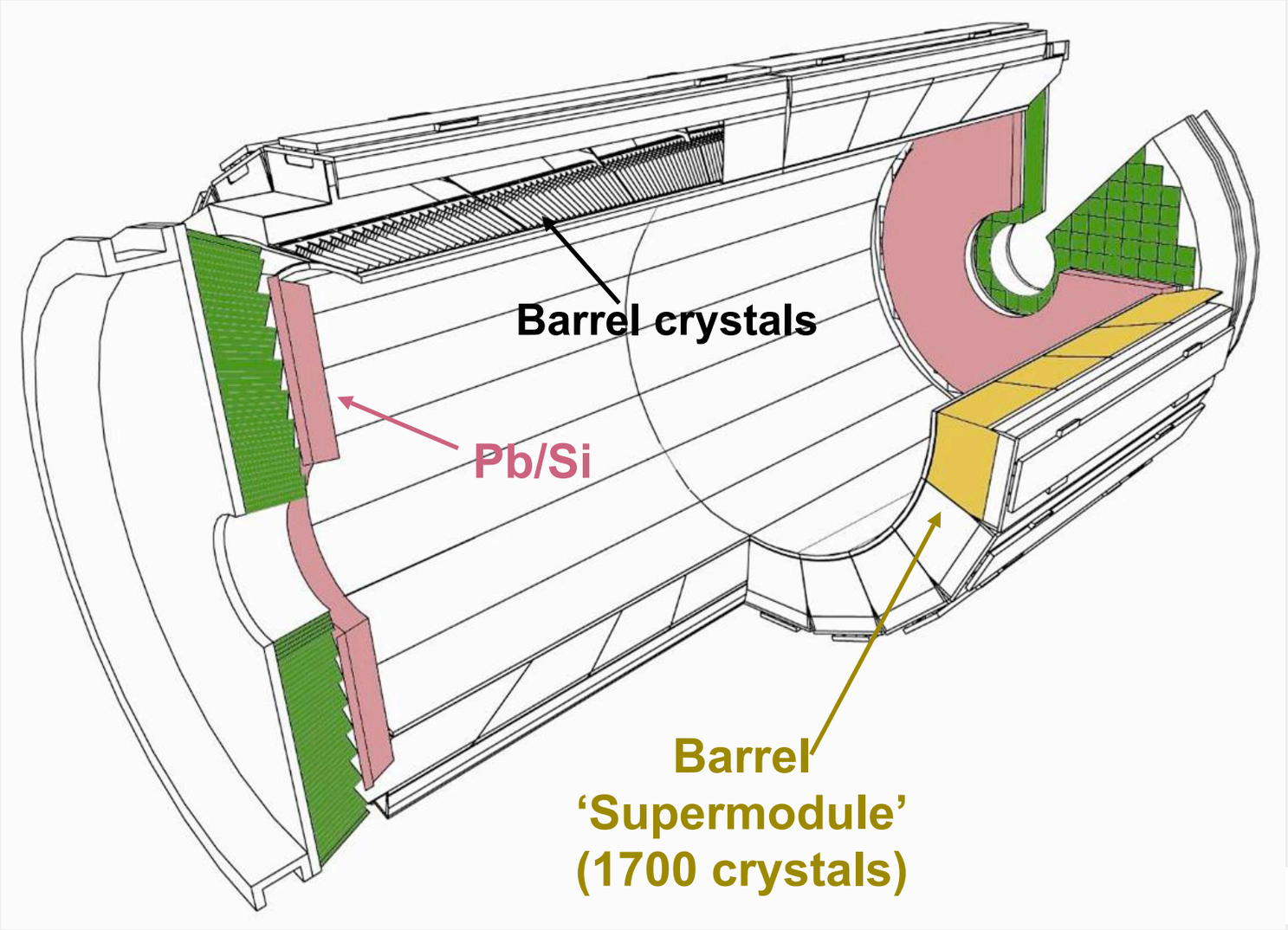
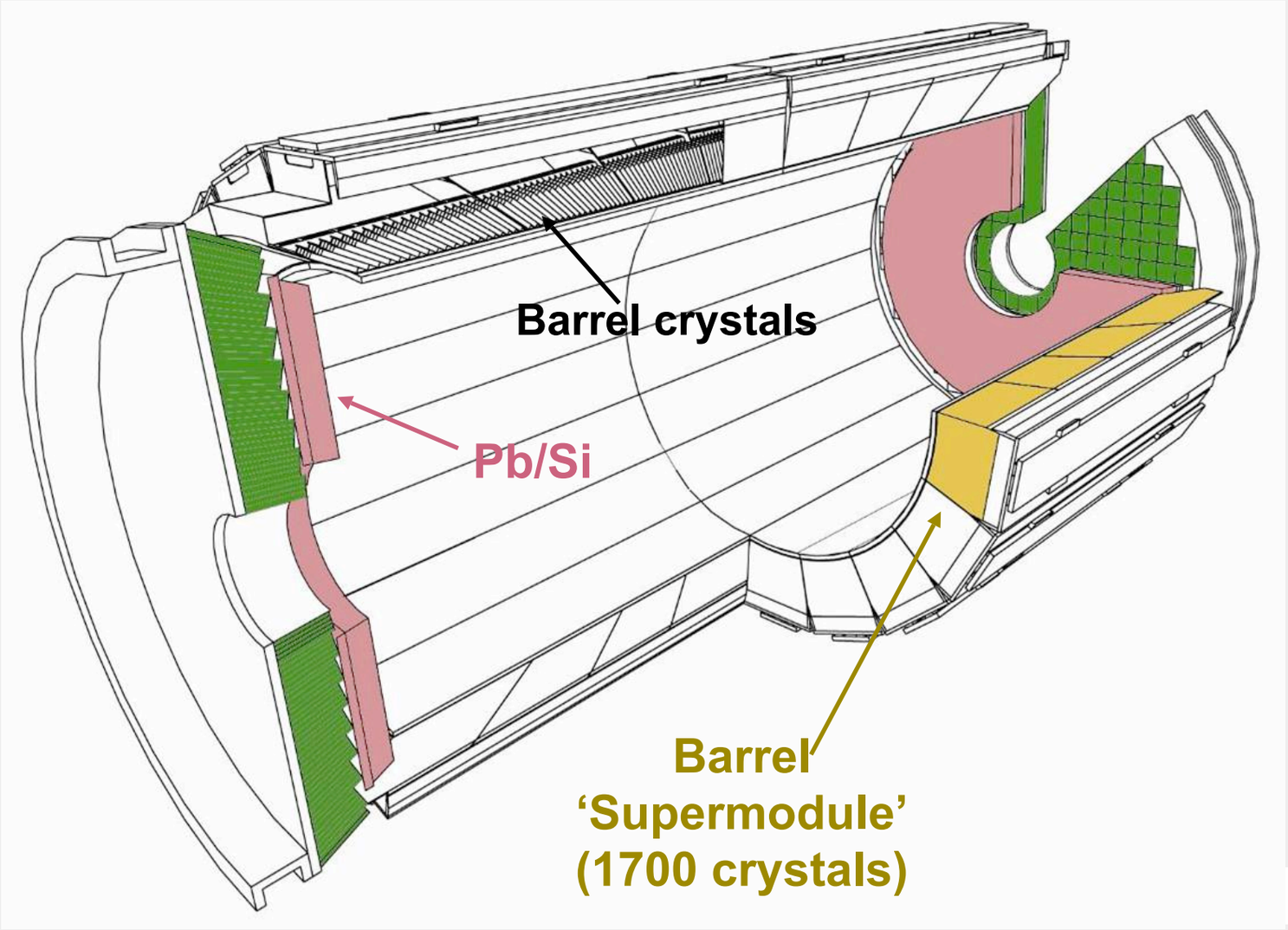


Lead tungstate
($PbWO^4$)
~ 10 m^3, 90 t

ECAL layout



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Barrel: $|\eta| < 1.48$
36 Super Modules
61200 crystals ($2x2x23cm^3$)

ECAL layout

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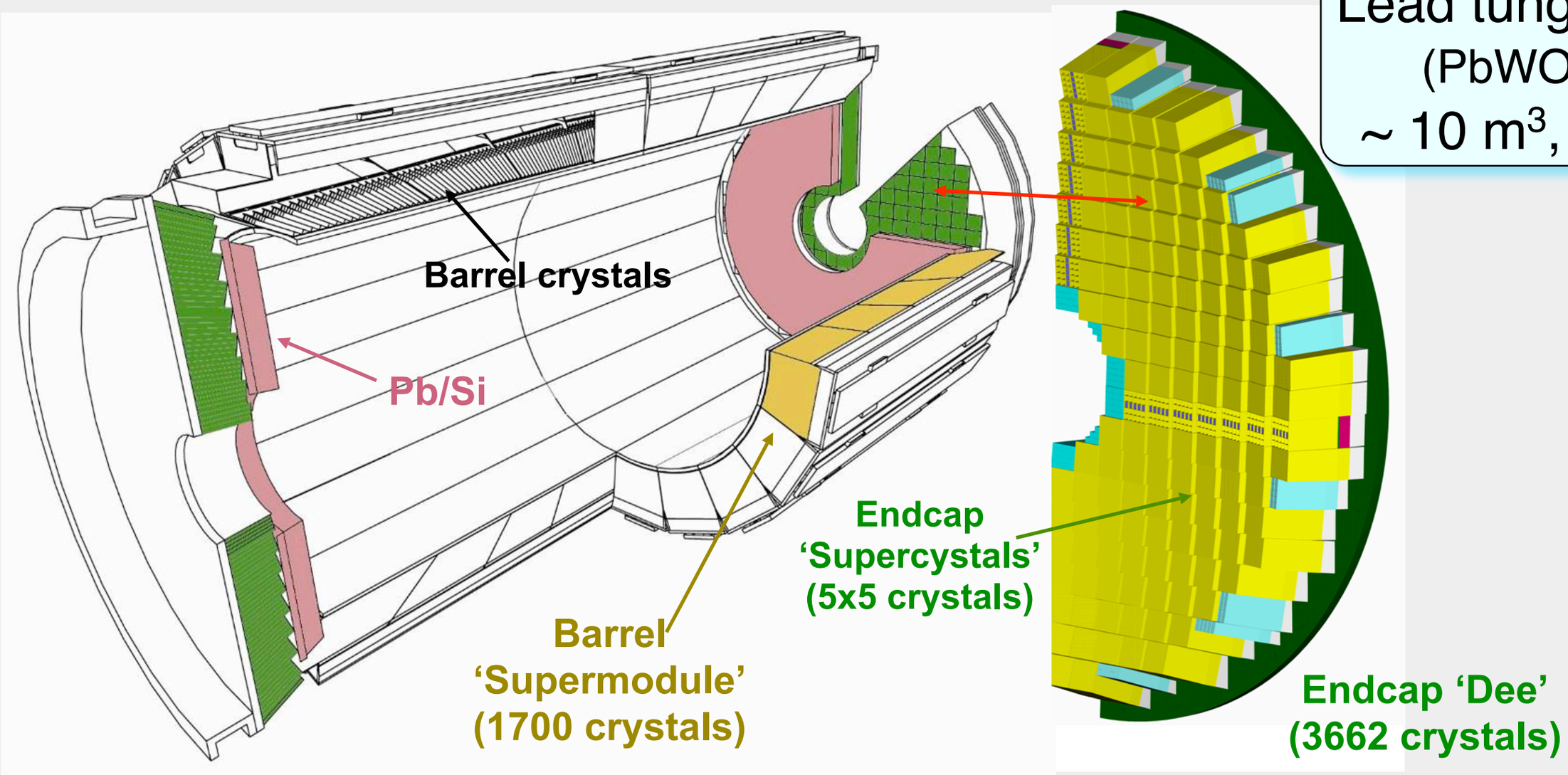
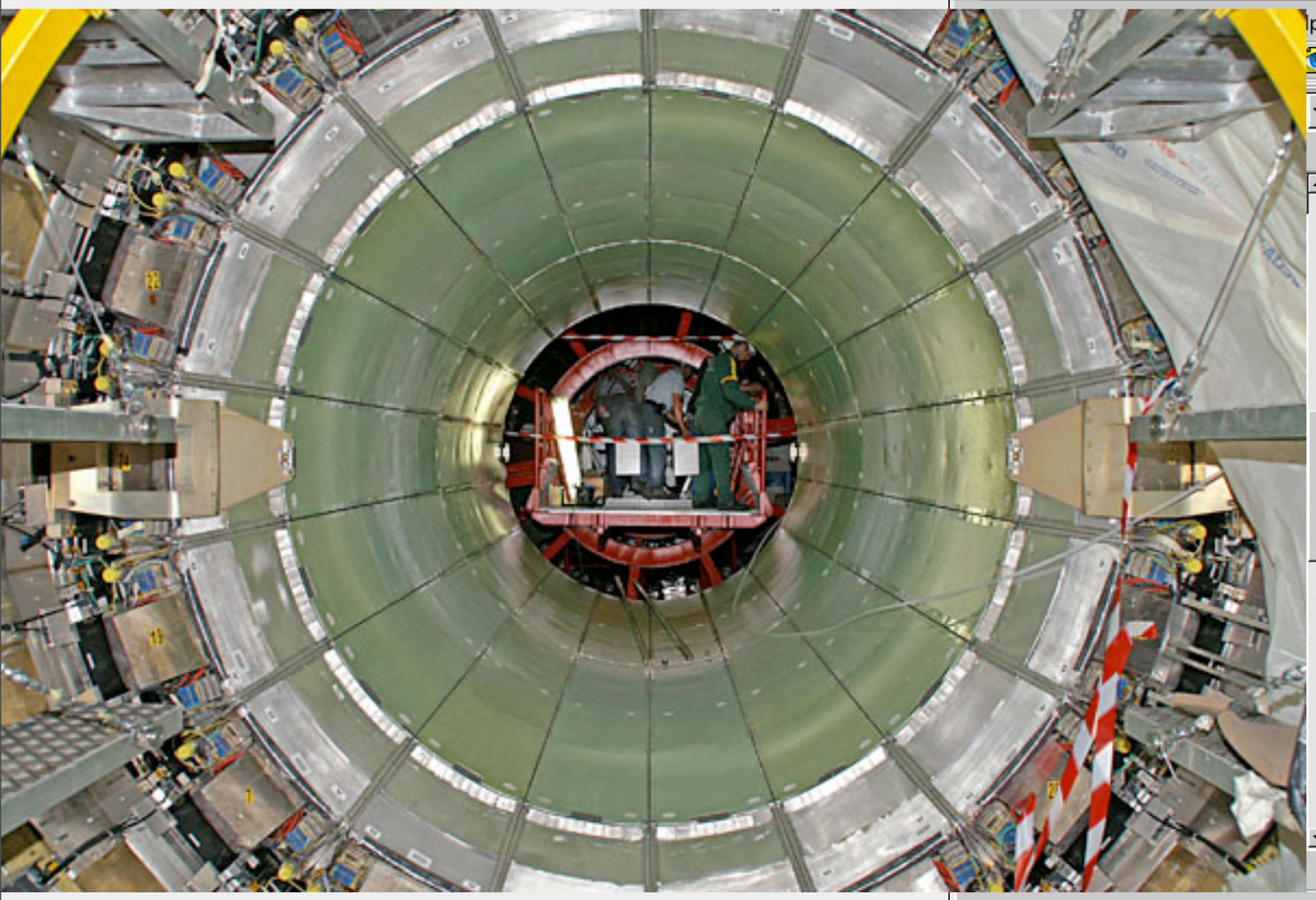
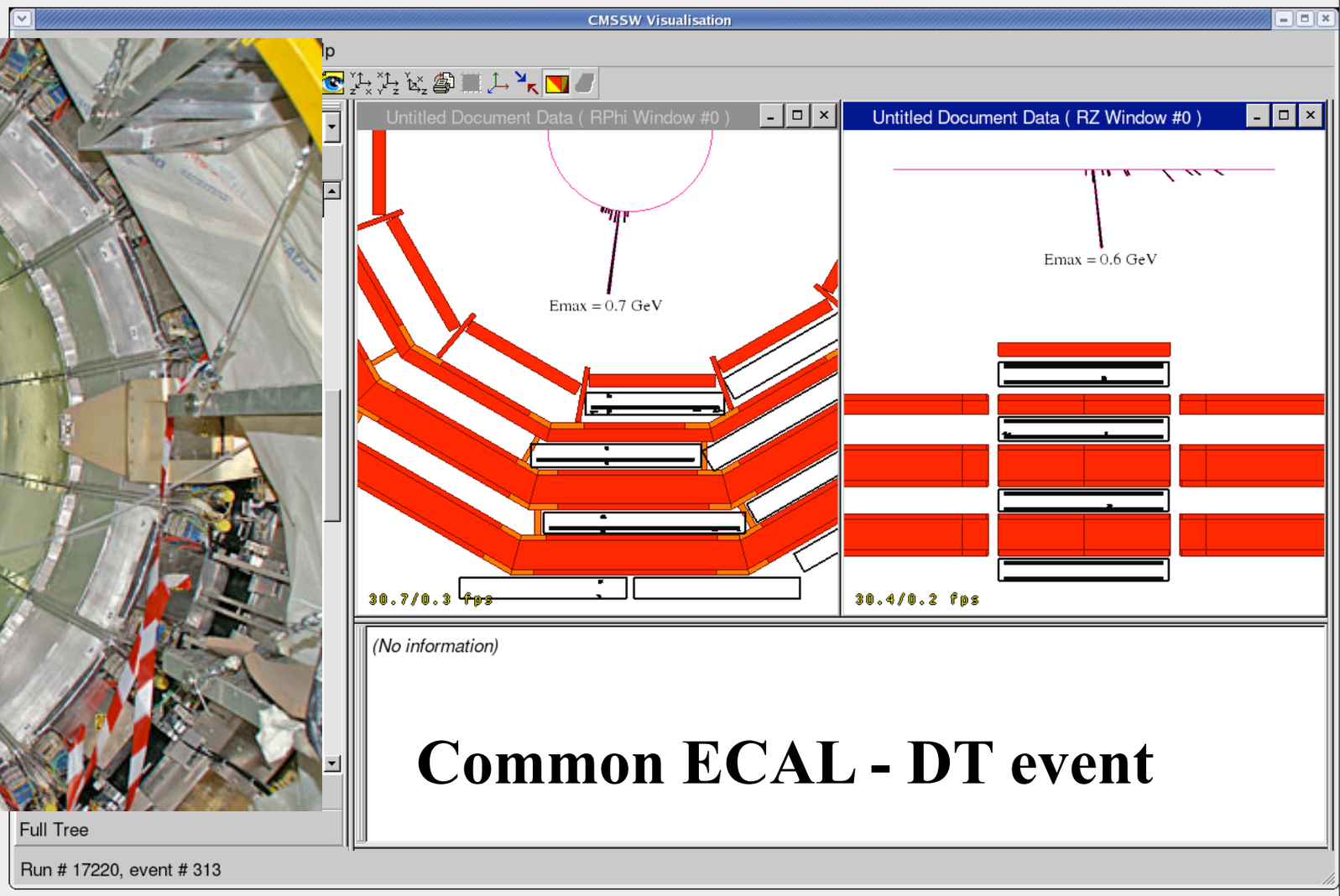


Barrel: $|\eta| < 1.48$
36 Super Modules
61200 crystals ($2x2x23cm^3$)

Endcaps: $1.48 < |\eta| < 3.0$
4 Dees
14648 crystals ($3x3x22cm^3$)

ECAL Barrel completed



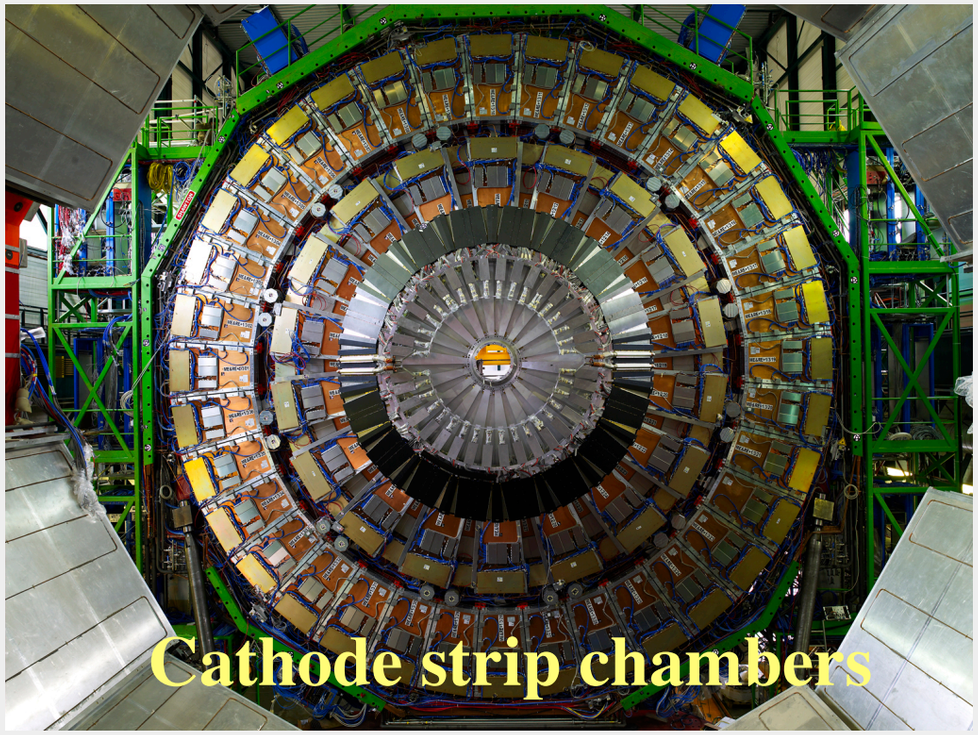


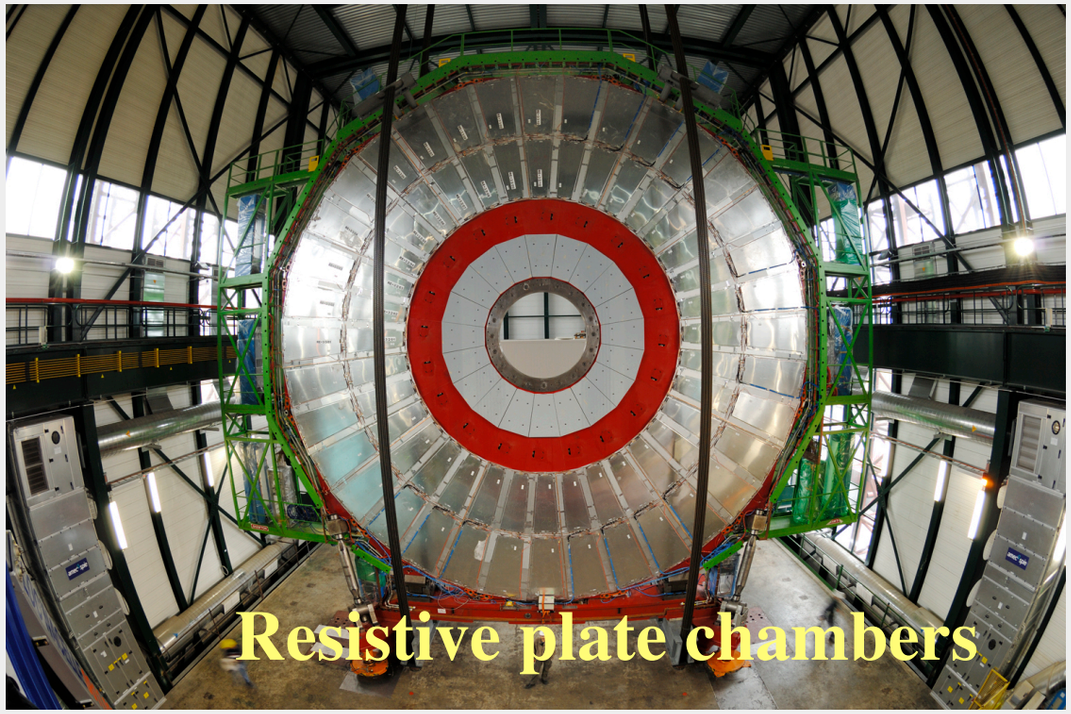
Common ECAL - DT event

Muon System

For redundancy and robustness, 3 types of muon detectors, are used both for precision tracking and triggering:

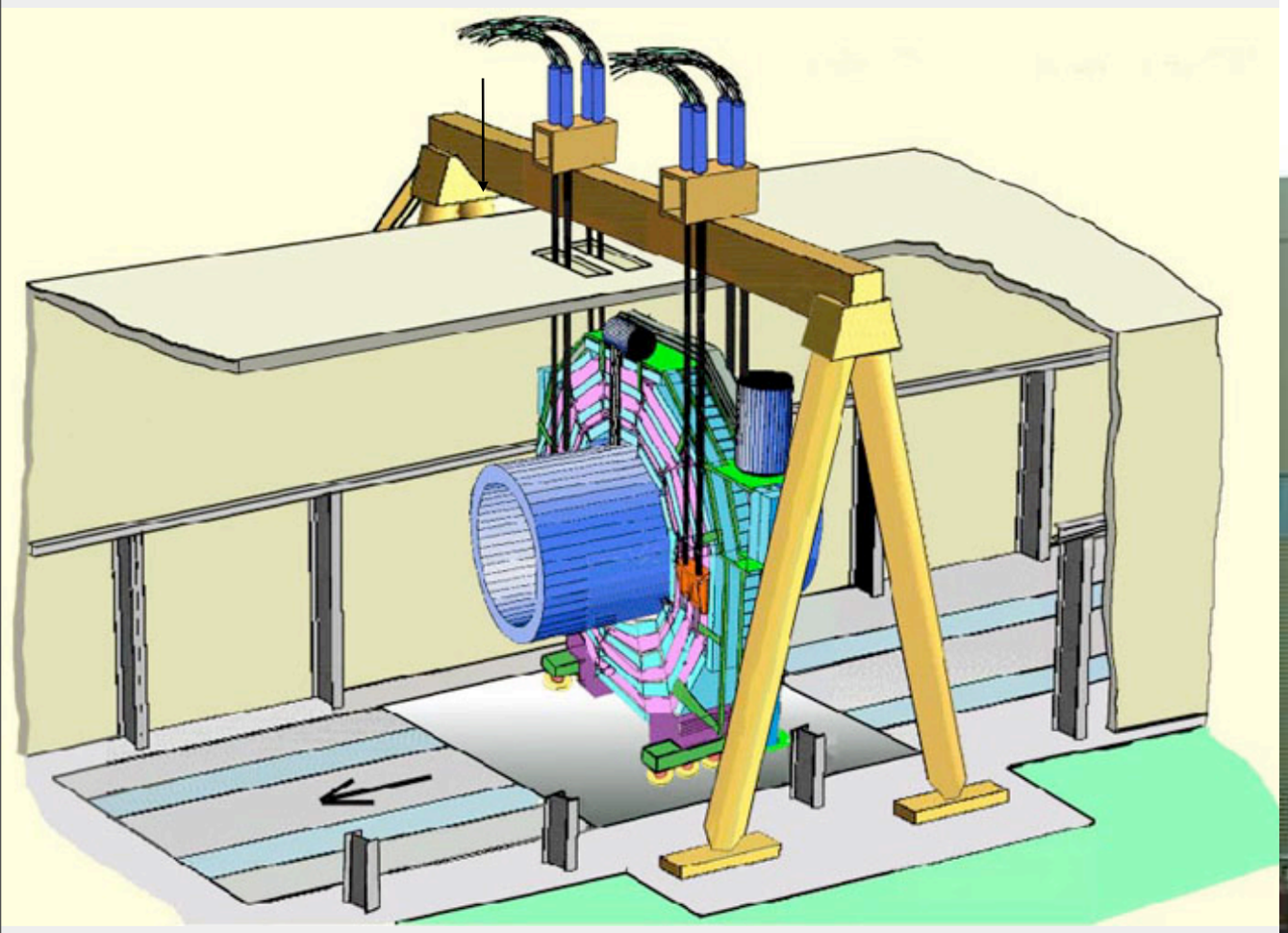
- drift tubes (barrel),
- cathode strip chambers (endcaps),
- resistive plate chambers (barrel, endcaps).





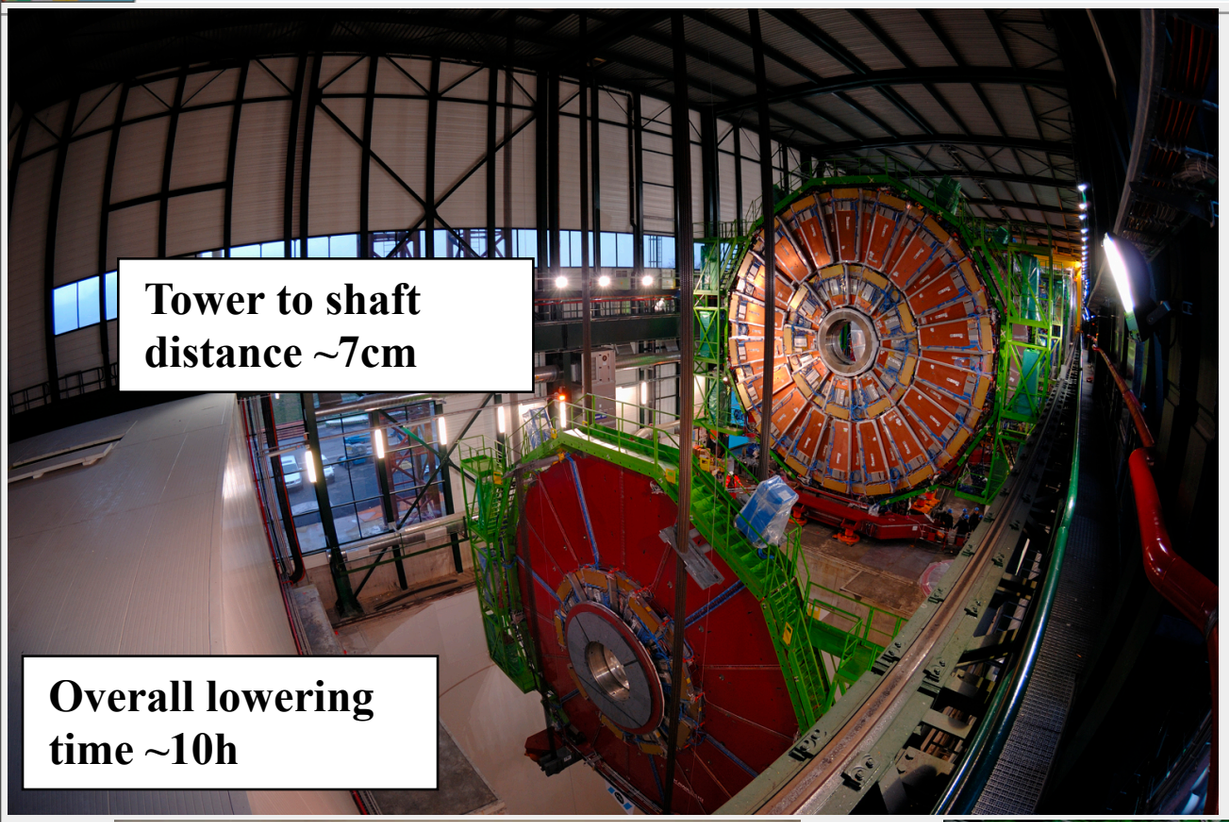
Transfer CMS Underground

Gantry installed over PX56. load test in June and start HF lowering.

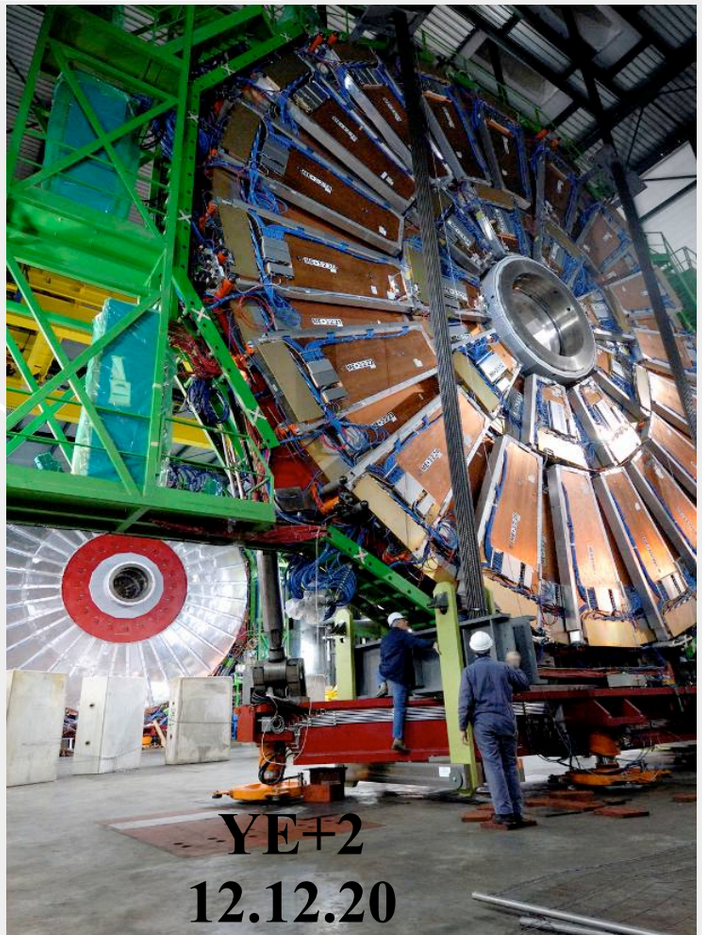


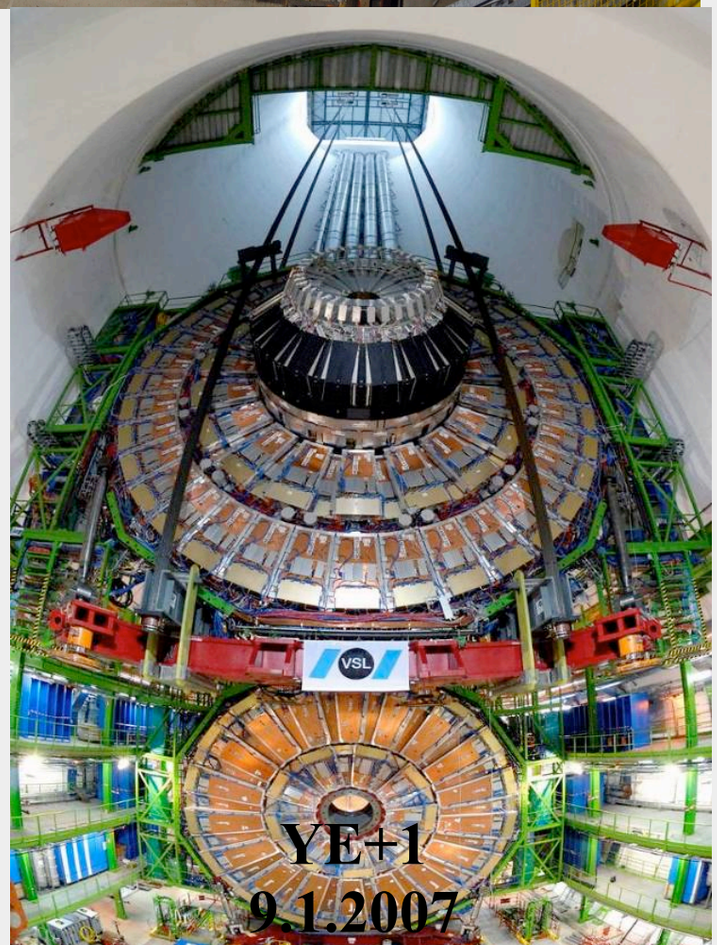
Start YB0 lowering (2000t): March 07

YE lowering

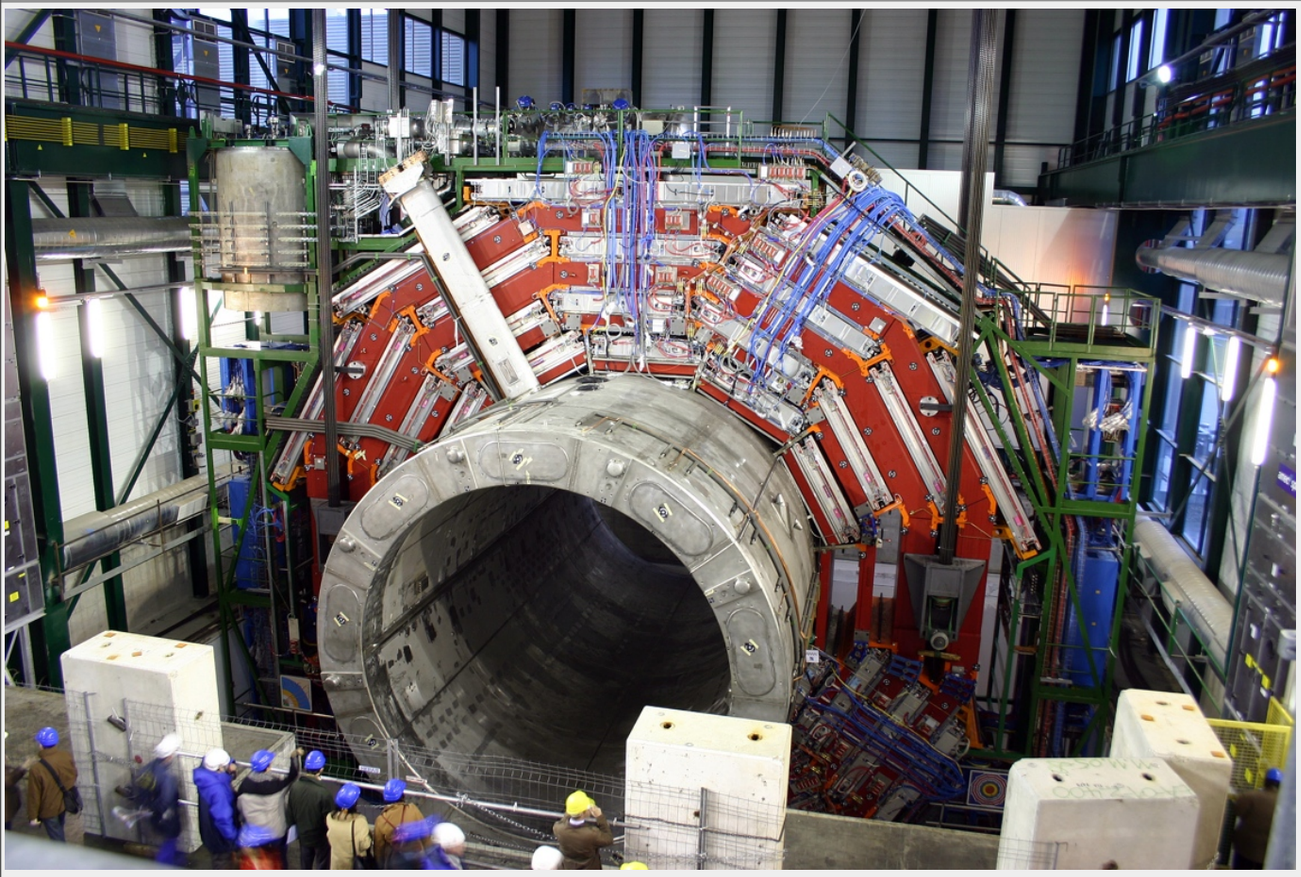

Tower to shaft distance ~7cm
Overall lowering time ~10h

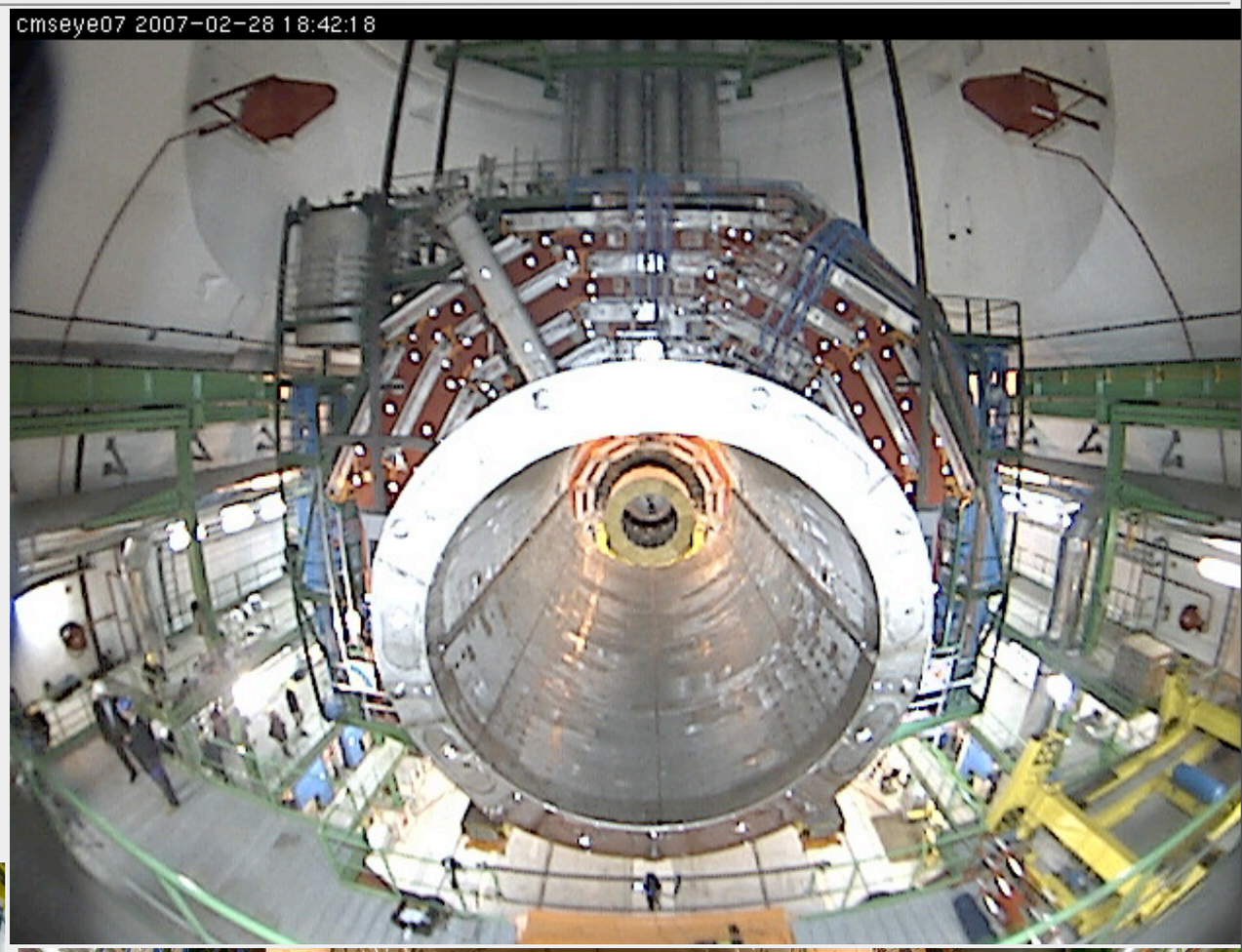
YE+3
30.11.2006

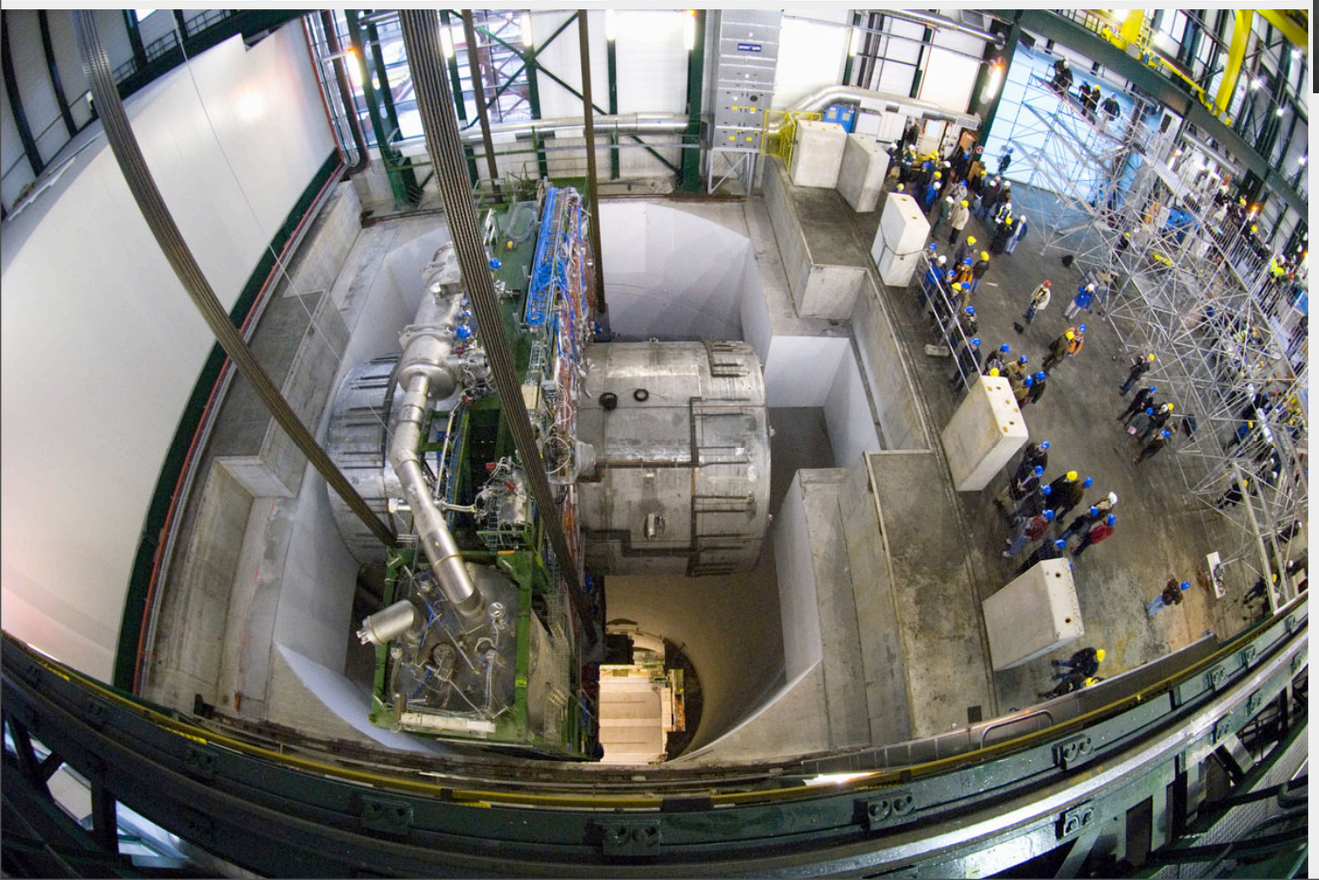

YE+2
12.12.20

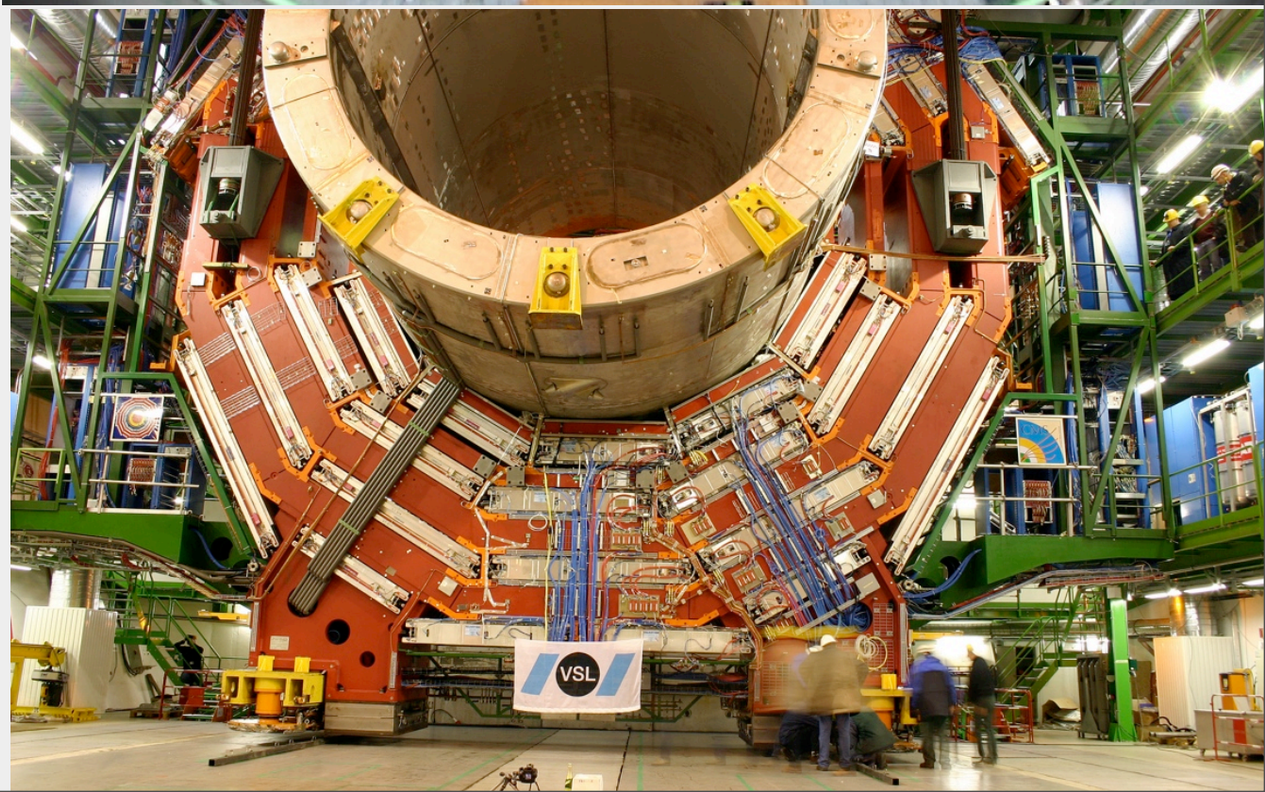

YE+1
9.1.2007

YB0 going to the experimental hall







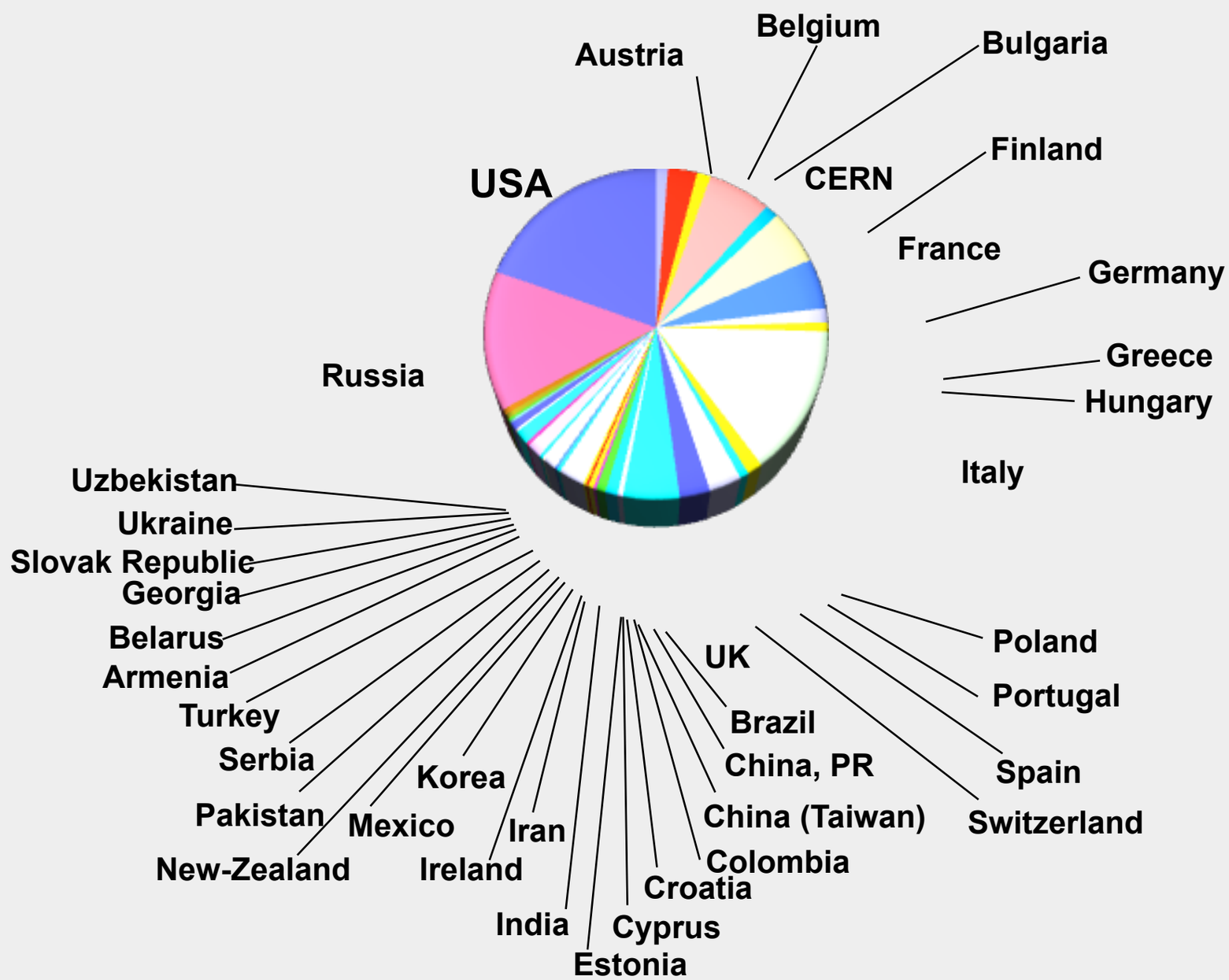


The CMS Collaboration

	Institutions
Member States	61
Non-Mem. States	64
USA	49
Total	174

	Scientists
Member States	1055
Non-Mem. States	428
USA	547
Total	2030

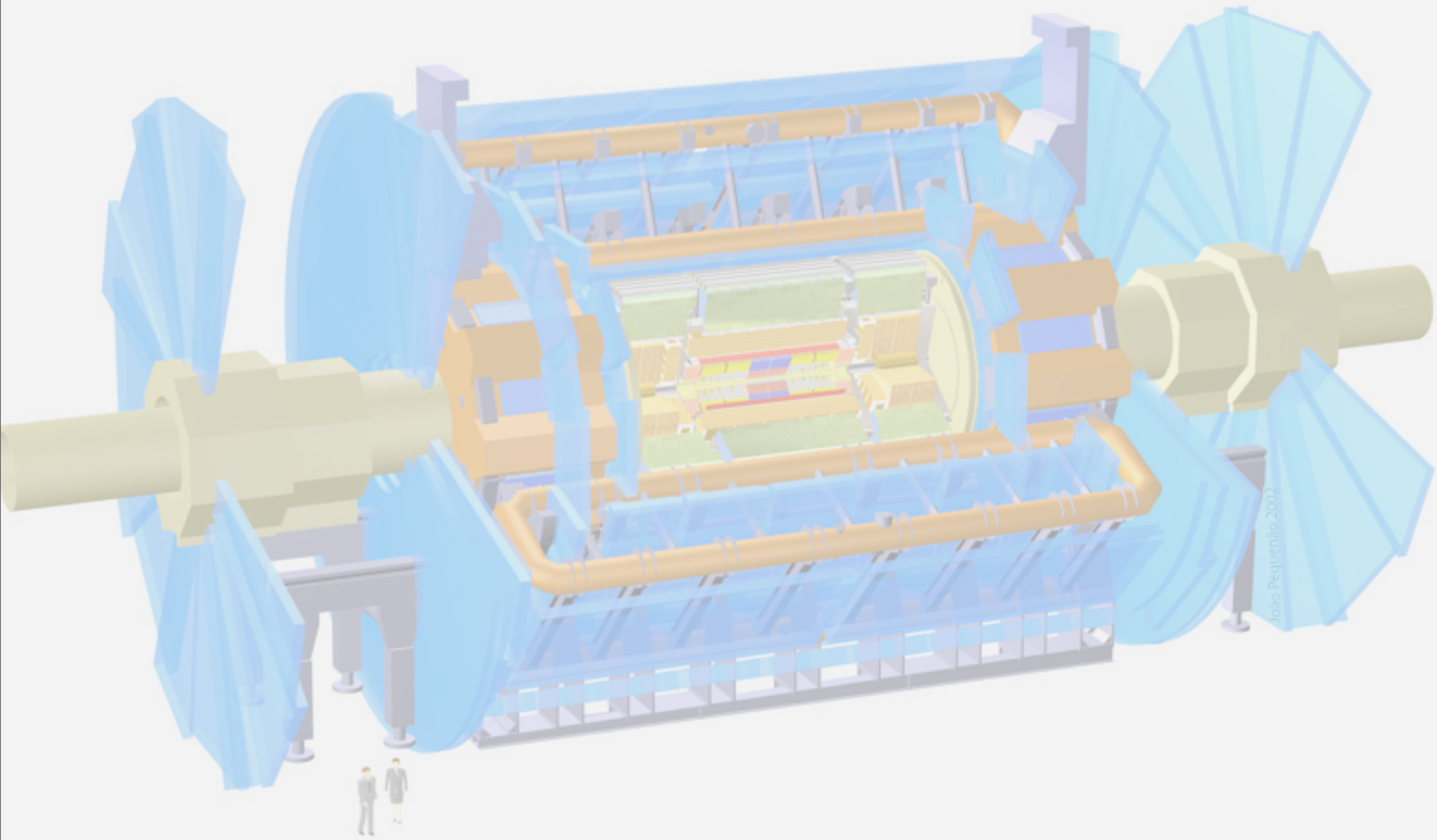
Associated Institutes	
Number of Scientists	46
Number of Laboratories	8



2030 Scientific Authors, 38 Countries, 174 Institutions

May, 04 2006/gm
http://cmsdoc.cern.ch/pictures/cmsorg/overview.html

First physics at 14 TeV



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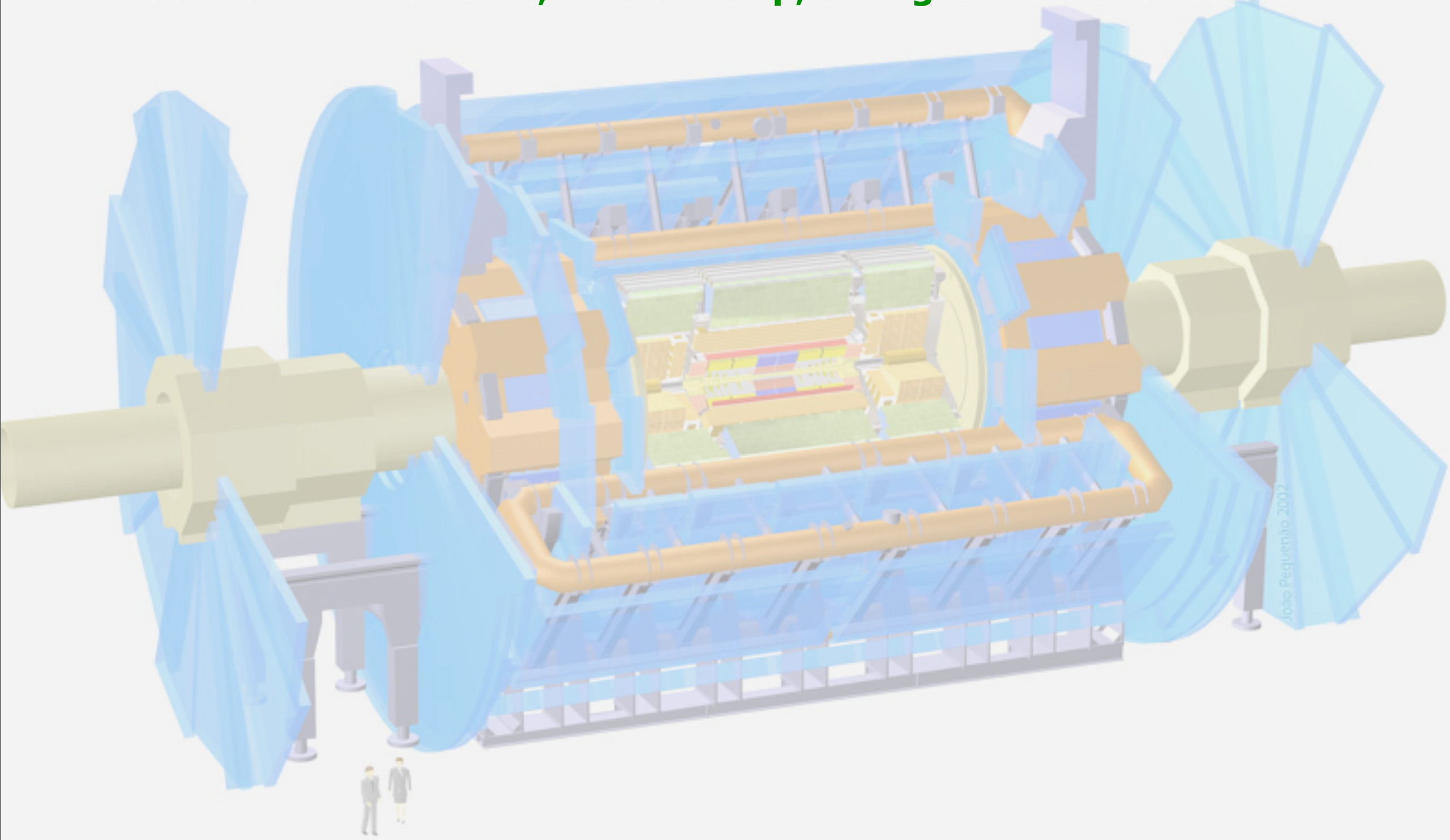

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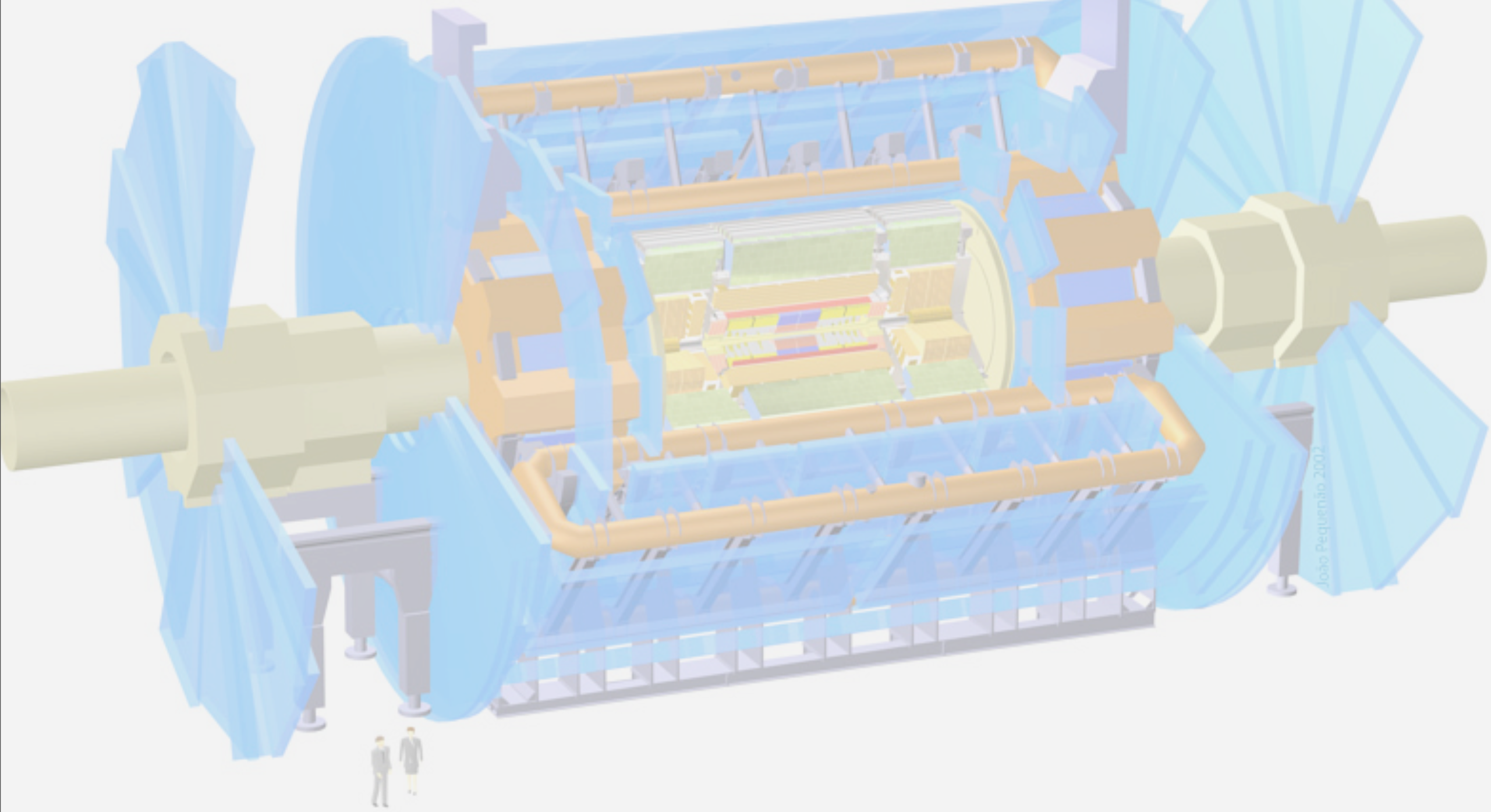

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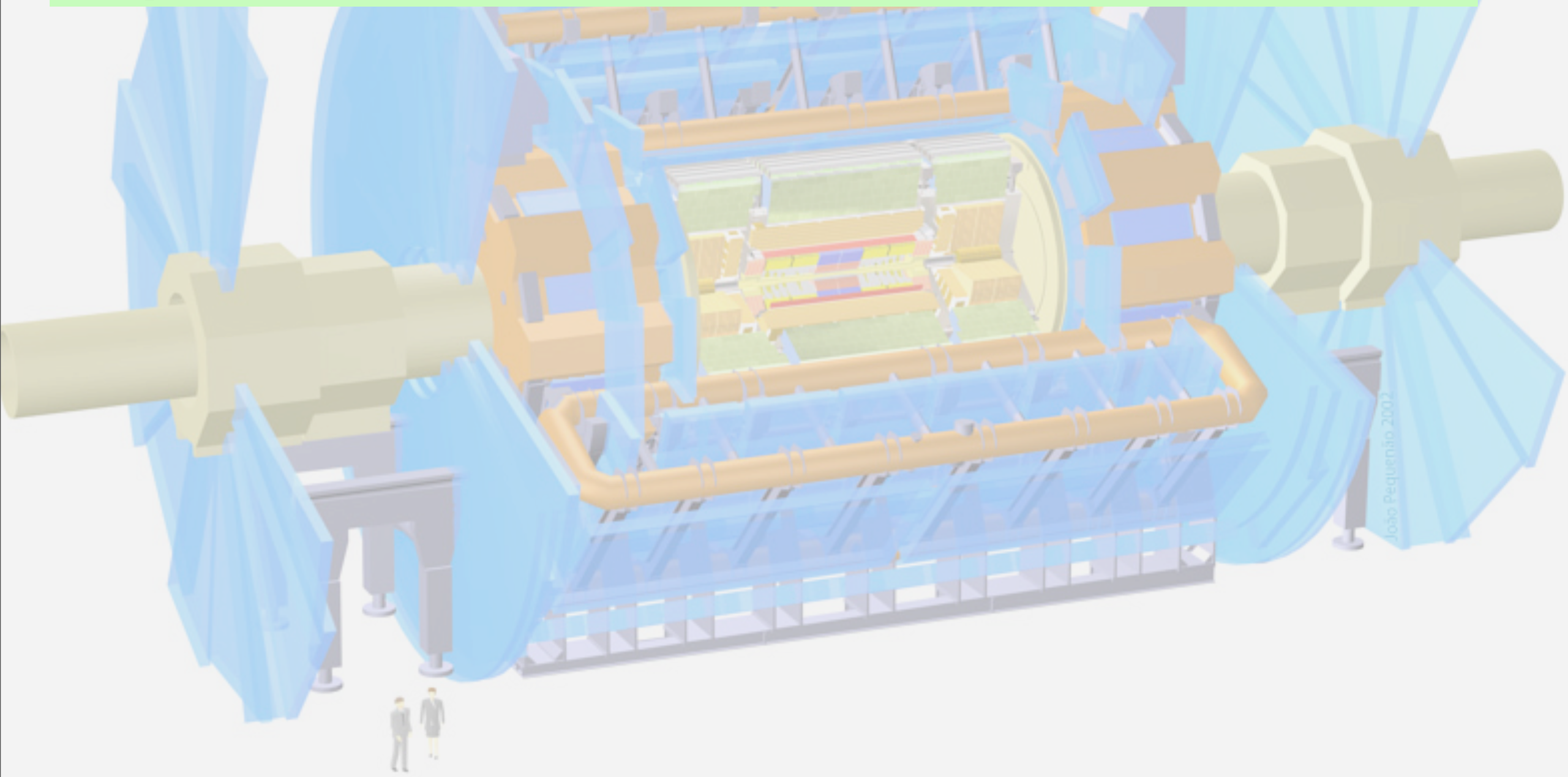

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- **Measure W, Z cross-sections to 10% with 100 pb^{-1}?**
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- **Measure tt cross-section to 20% and m(top) to 7-10 GeV with 100 pb^{-1} ?**
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And, more ambitiously:

- Discover SUSY up to gluino masses of ~ 1.3 TeV ? <=== End 2008 with 1fb^{-1}
- Discover a Z' up to masses of ~ 1.3 TeV ?
- Surprises ?

Detector commissioning

The commissioning of LHC machine and detectors of unprecedented complexity, technology and performance will be one of the biggest challenges in the next year!

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➡ ***But must not compromise quality!***

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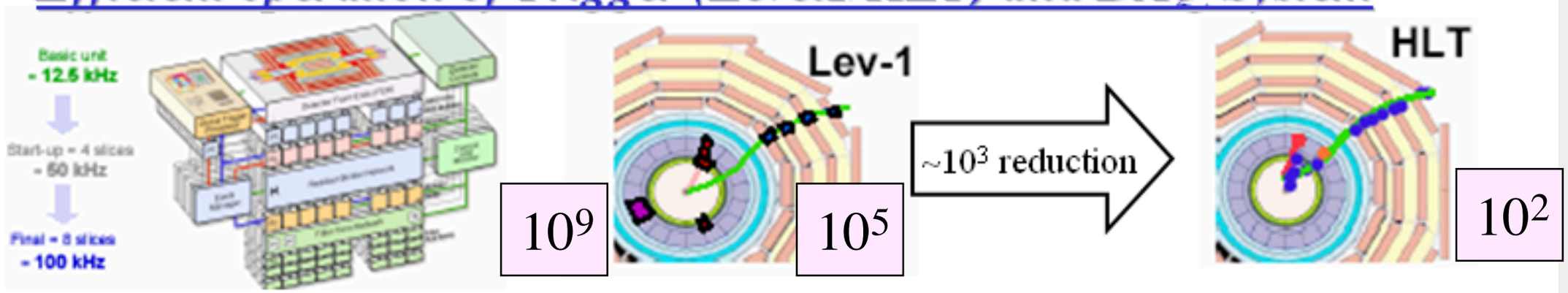
But must not compromise quality!

Blind analyses: desirable, but practical?

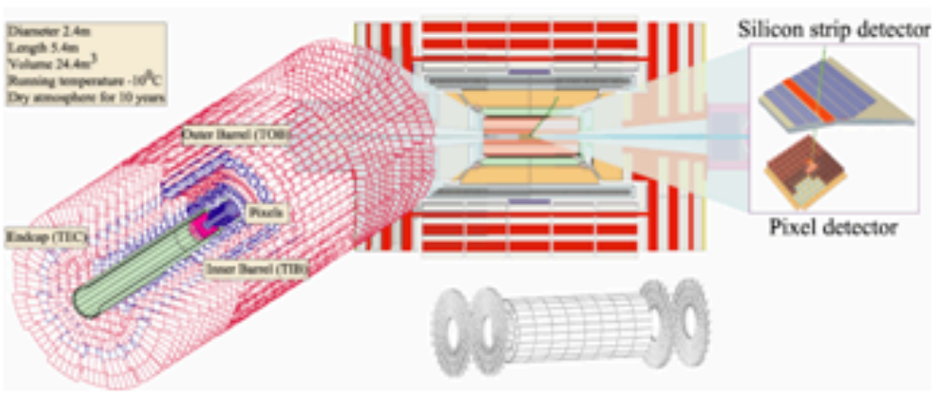
Look at 10^7 bins, see three 5σ peaks even if no new physics!

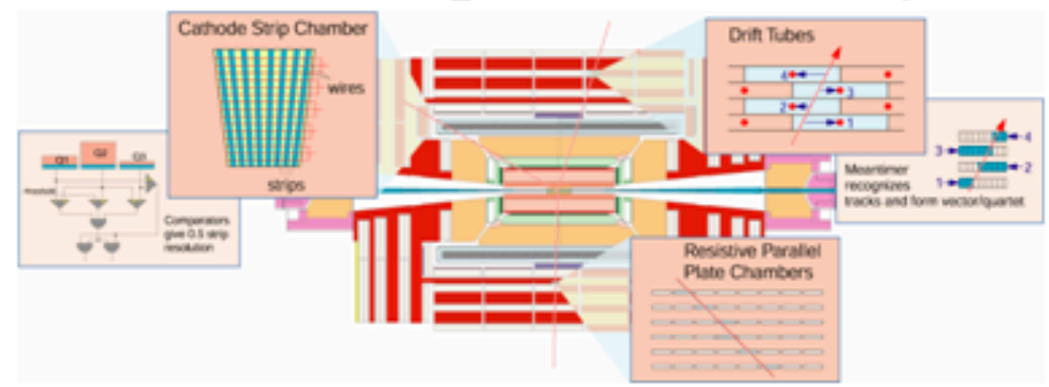
Major Commissioning Challenges

Efficient operation of Trigger (Level1/HLT) and DAQ System

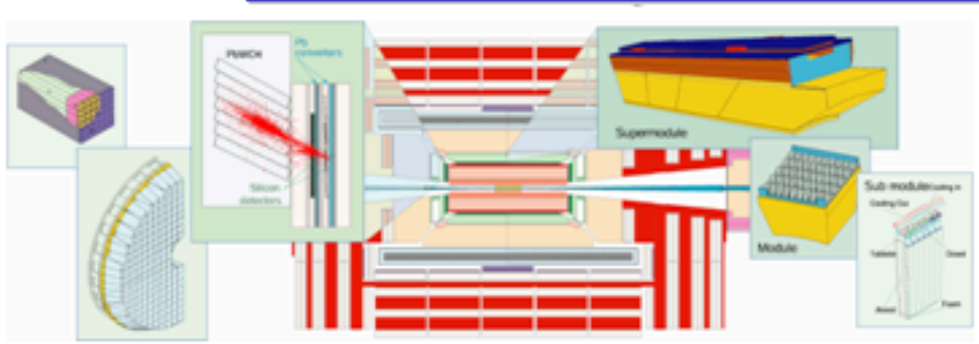


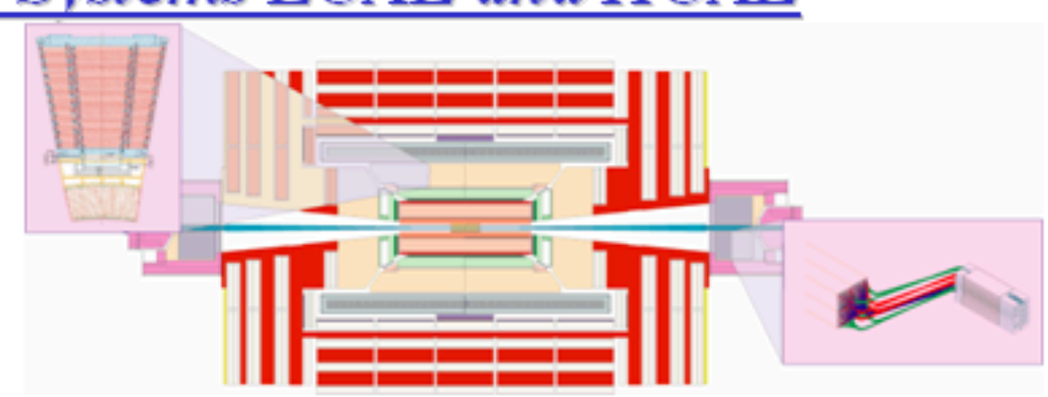
Alignment of the tracking devices Tracker(PIXEL,Strip) and Muon System





Calibration of the Calorimeter Systems ECAL and HCAL





→form the base for the "commissioning of physics tools" like b and τ tagging, jets, missing E_T …

Starting conditions

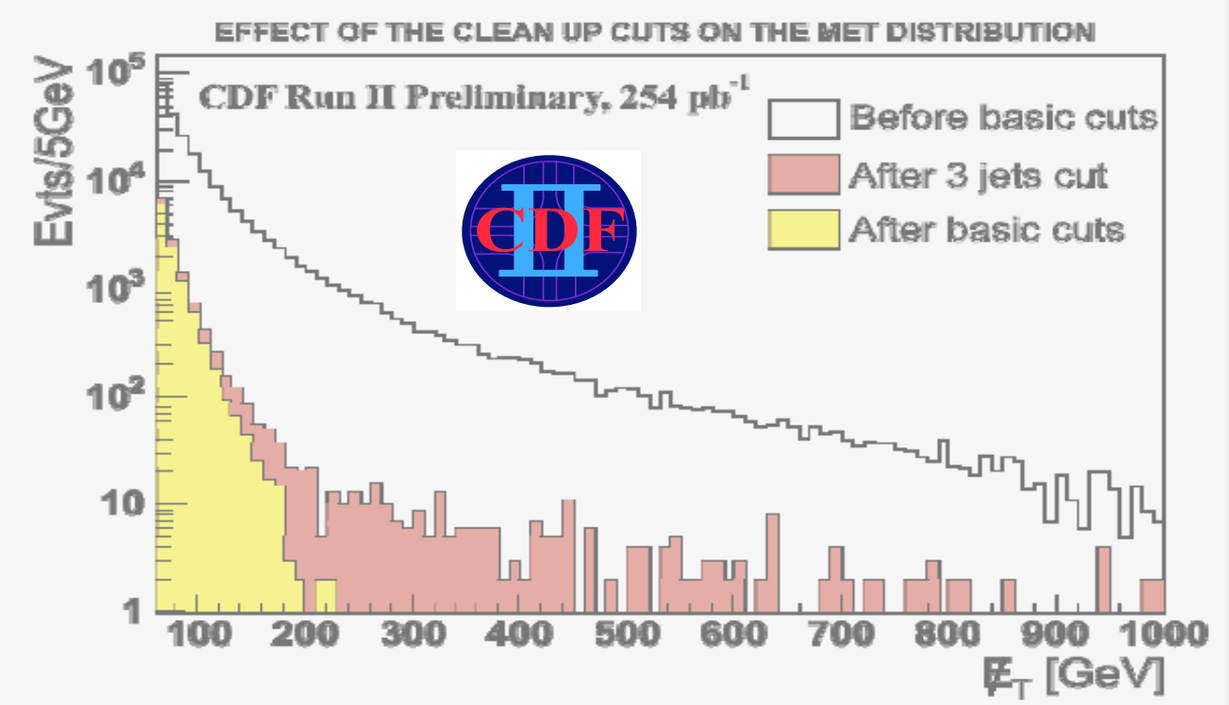
	Expected performance day 1 CMS	ATLAS	Goals for Physics	Physics samples to improve (examples)
ECAL Uniformity	~2%	~1%	<1%	MinimumBias; Z→ee
e/gamma	1-2%		0.1%	Z→ee
HCAL Uniformity	2-5%		<1%	Single Pions; QCD Jets
Jet Scale	~10%	~15%	1%	Z→jj; γJet; W→jj; tt
Tracking Alignment	50-200 μm		~10μm	MinimumBias; Z→μμ

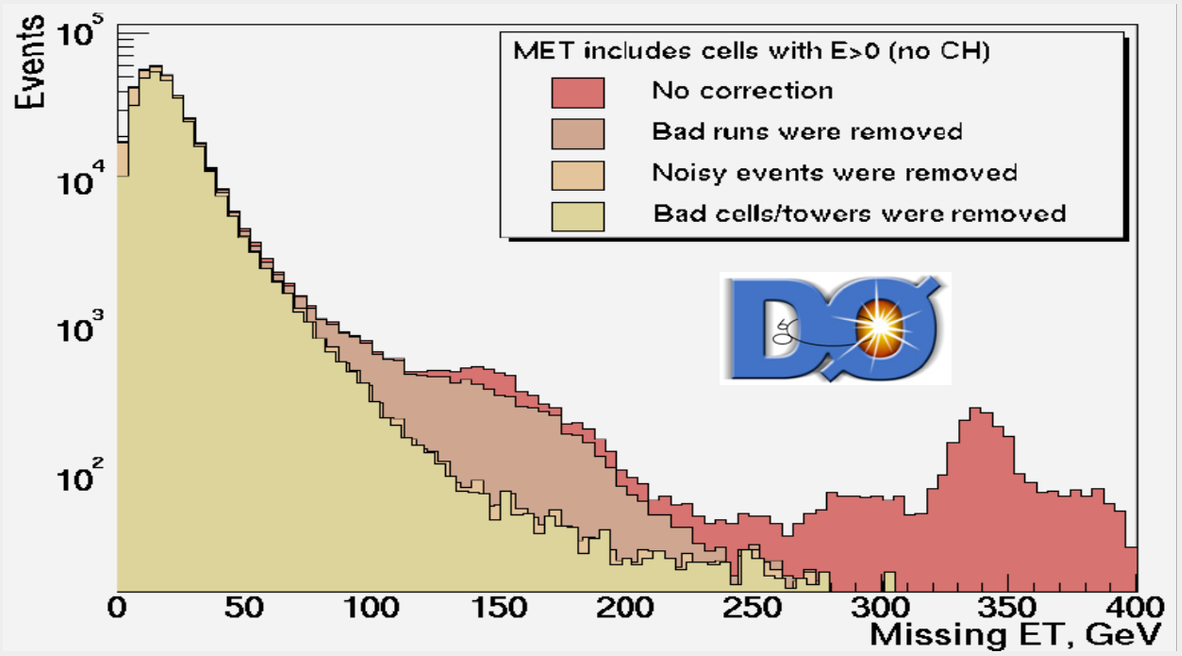
- Understand and calibrate detector and trigger in situ using well-known physics samples
  - Are trigger tables OK?
  - MB-UE → PiluUp is what we were expecting?
  - … and QCD?
  - PDF and MonteCarlo Generators used in the past (today!) studies were reasonable?
- Most of the processes mentioned will have a negligible statistical errors after few days/weeks…

Systematics Errors will be our main concern

Why MET in the Trigger is Tough?

- Jets tend to fluctuate wildly:
  - Large shower fluctuation
  - Non-linear calorimeter response
  - Non-compensation (i.e., e/h ≠ 1)
  - Fluctuations in the e/h energy ratio
- Instrumental effects:
  - Dead or “hot” calorimeter cells
  - Cosmic rays
  - Poorly instrumented area of the detector
  - Muons that can’t be accounted for at the Level 1





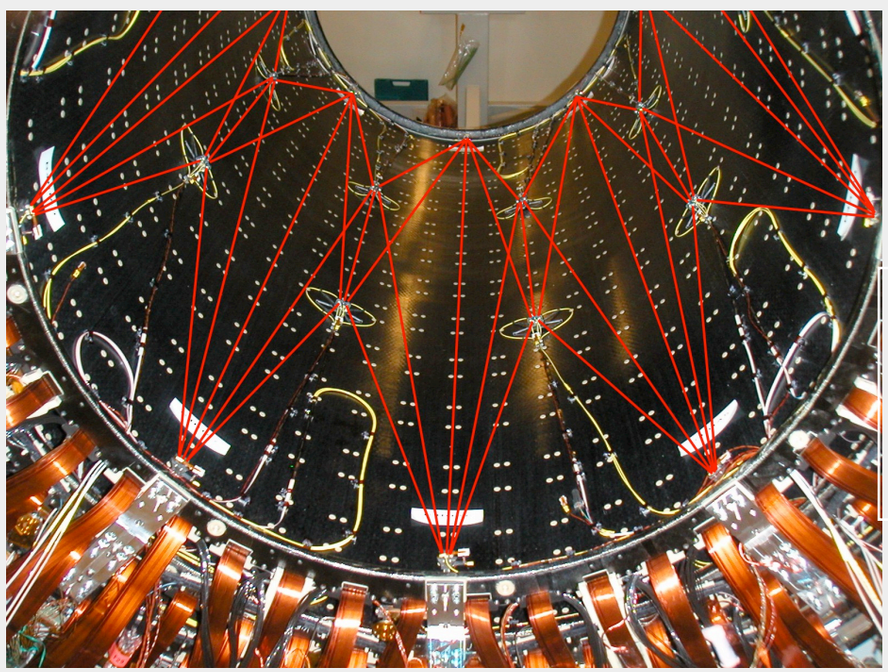
Raw ME_T spectrum at the Tevatron and that after a thorough clean-up

Challenge: tracker alignment

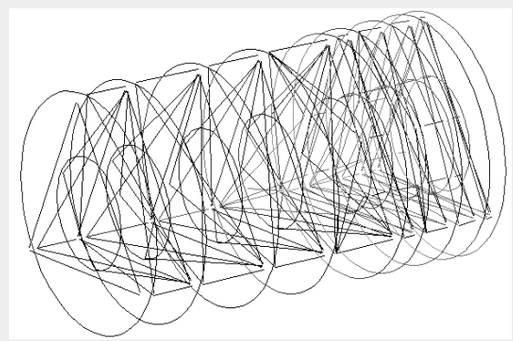
At start-up: hardware based-alignment, plus cosmics

→ 20-200 μm accuracy at startup

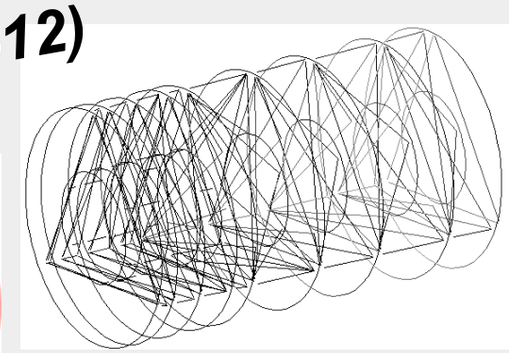
e.g. ATLAS: frequency scanning interferometry in silicon strip detector



End-cap SCT grid (165)



Barrel SCT grid (512)



End-cap SCT grid (165)

842 grid line lengths measured precisely
→ measures structure shapes, not sensors
→ monitor movements over ~hours

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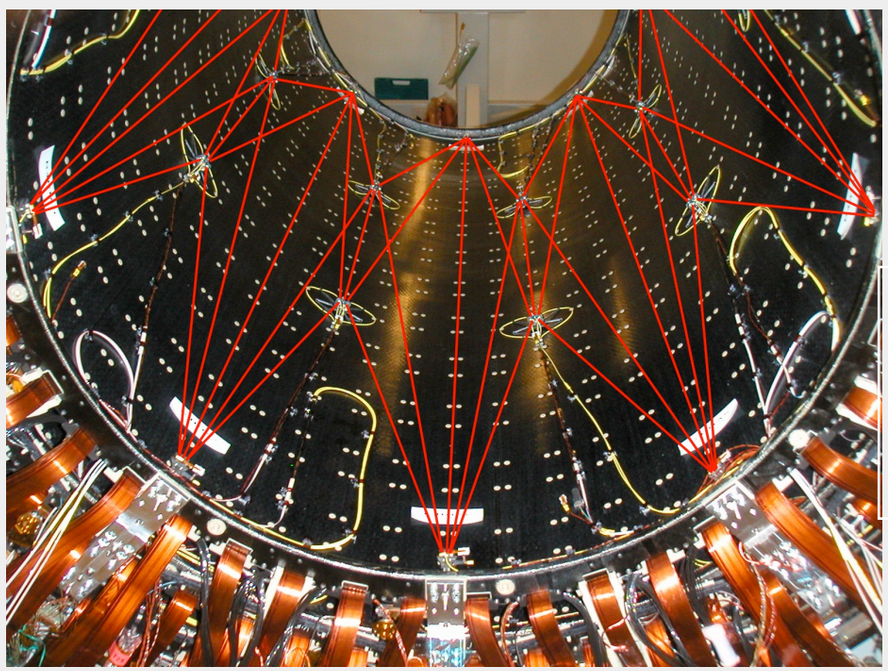

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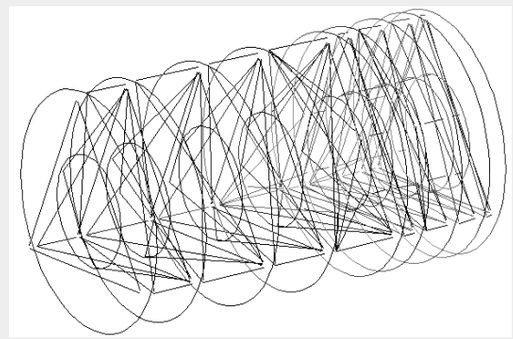

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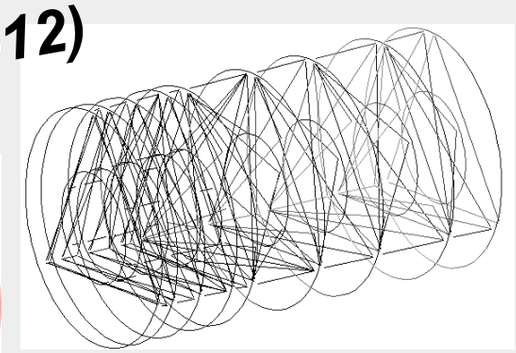

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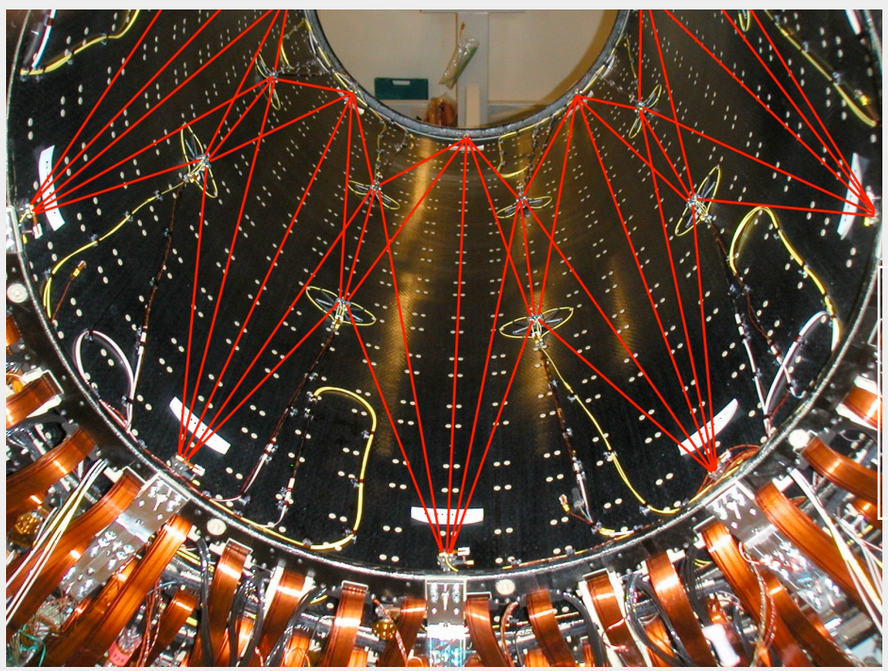

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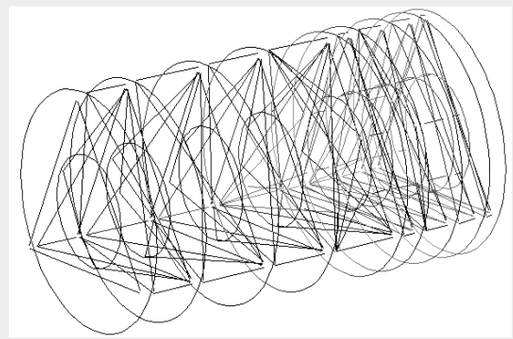

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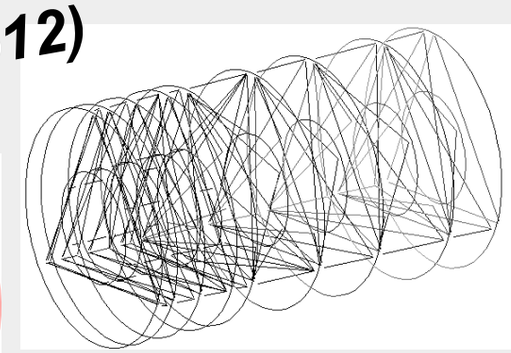

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CMS: laser alignment

"robust" local vs big matrix inversion

Track-based alignment using minimum bias, Z→ee, μμ

Few days of data taking: sufficient statistics.

Challenge: <10 μm precision, 120 000 parameters (CMS)
36 000 parameters (ATLAS)

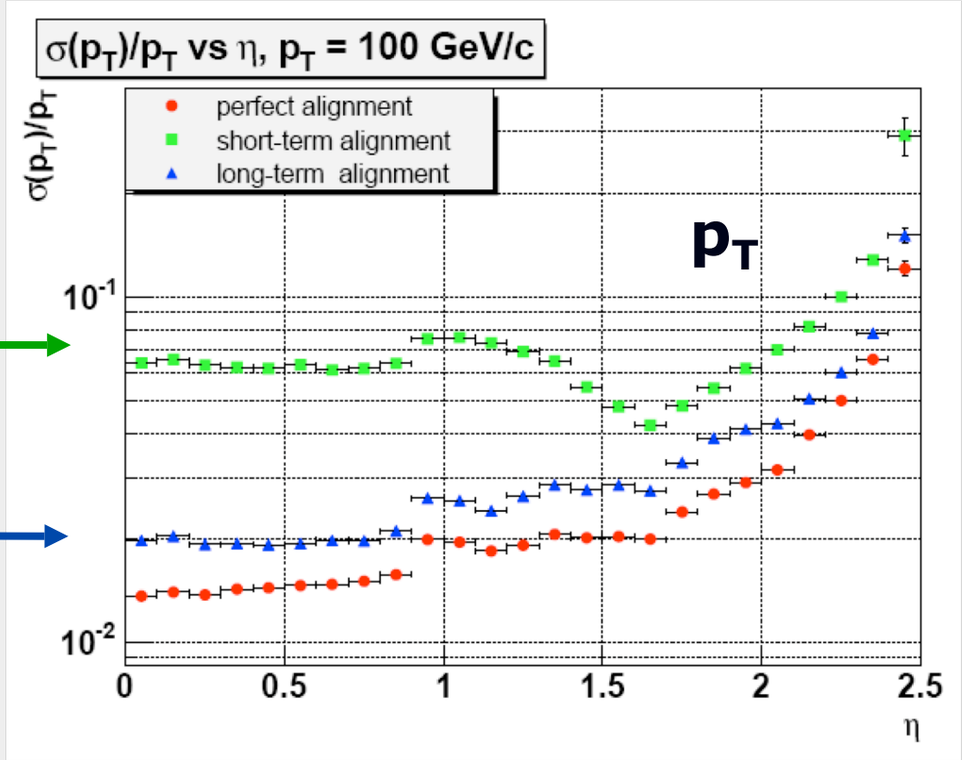
Challenge: tracker alignment

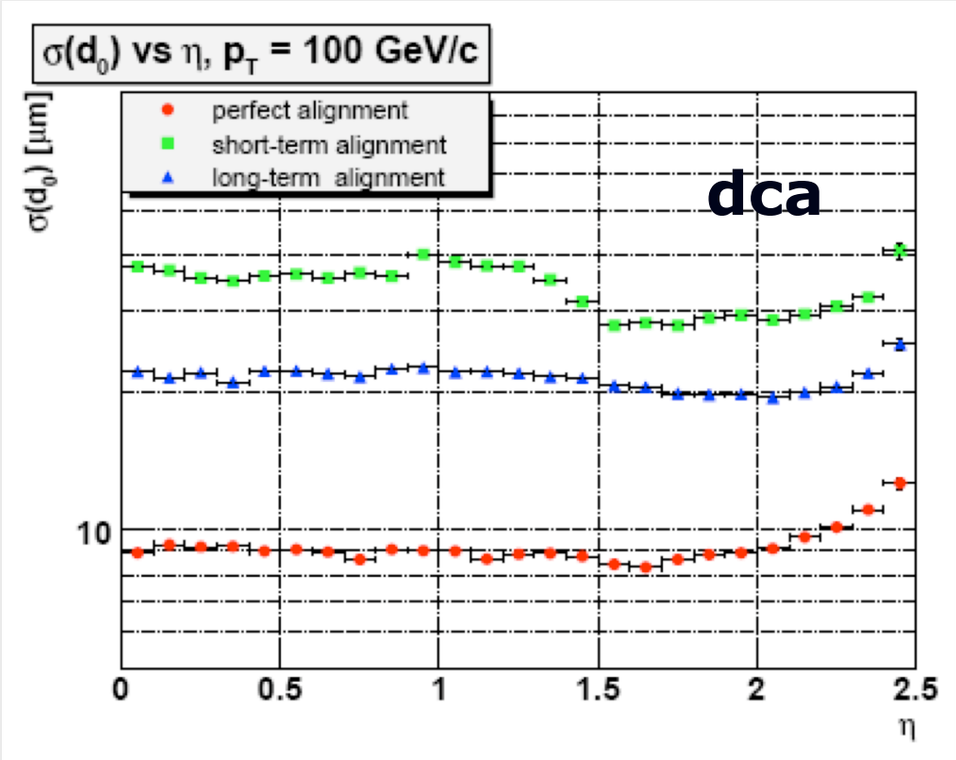
CMS plots:

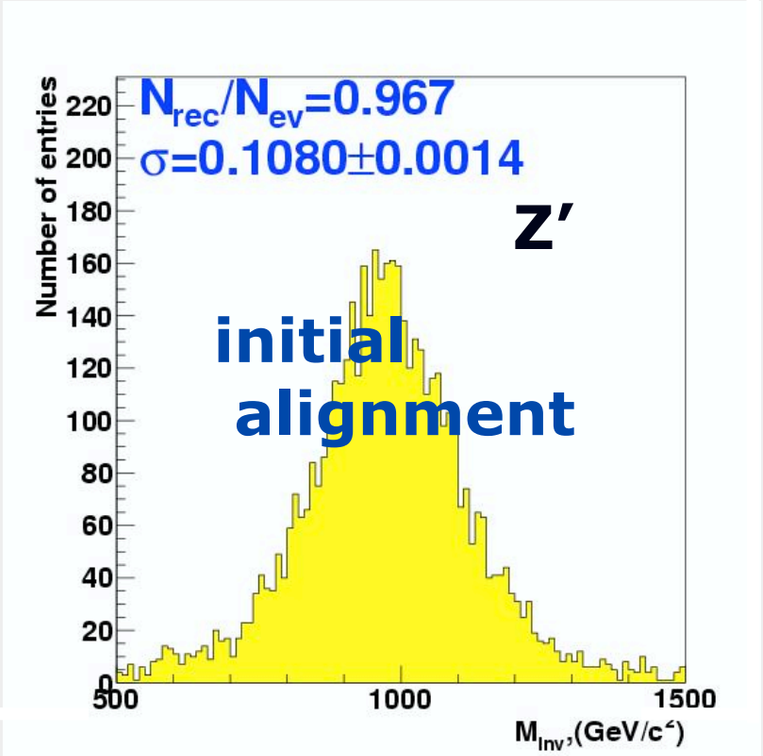
Track-based alignment using minimum bias, Z→ee, μμ

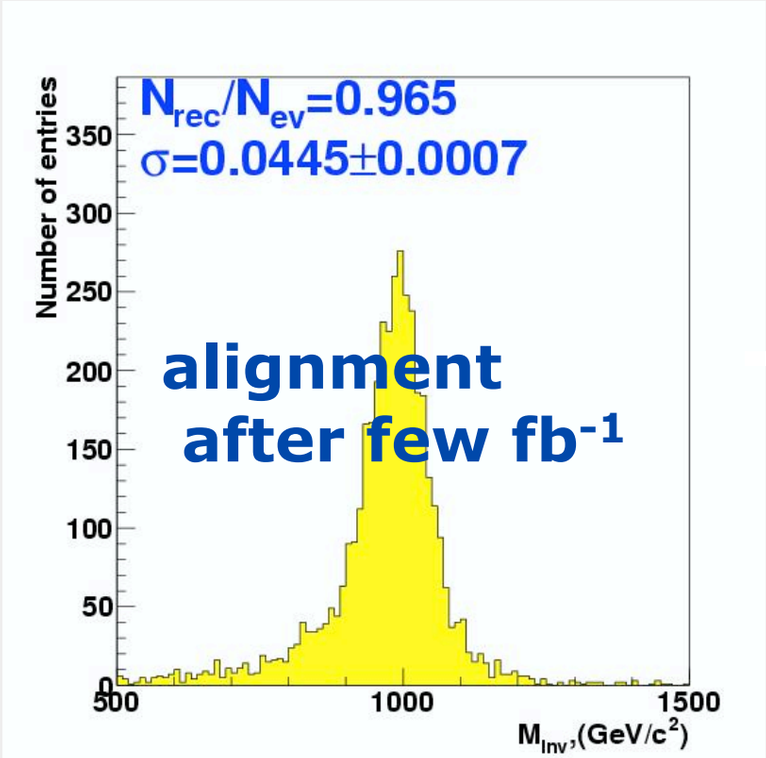
initial:

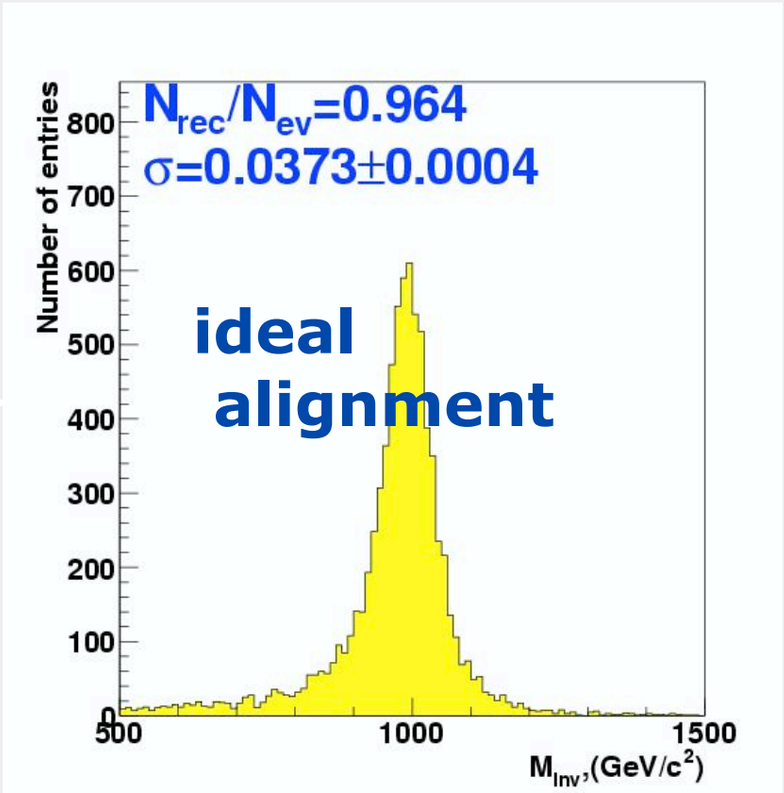
after few fb^{-1}



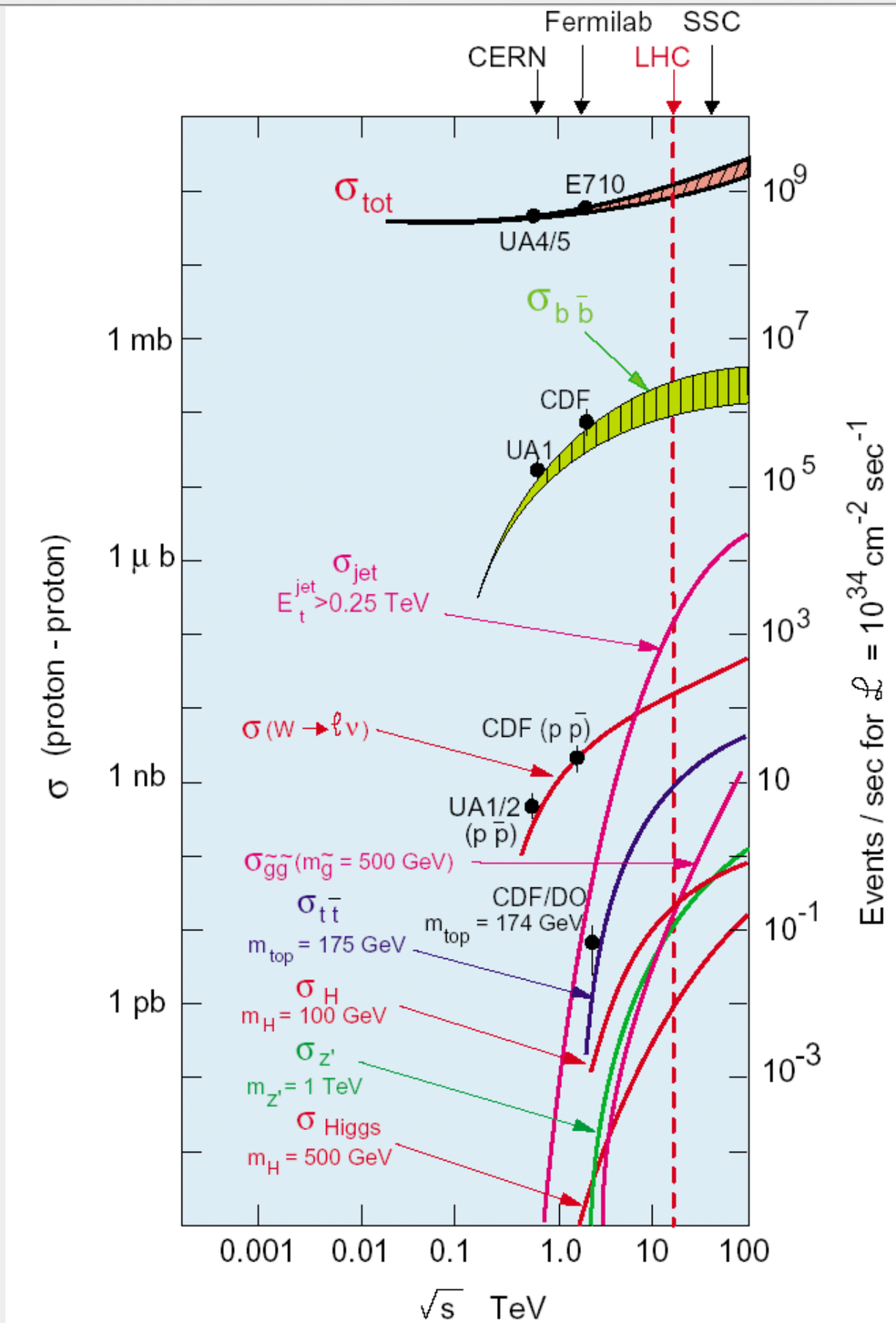








Cross section and Events rate (√s=14 TeV)



Process	σ(nb)	$\mathcal{L}$=10pb^{-1}	$\mathcal{L}$=1 fb^{-1}
Minimum bias	10^8	10^{12}	~10^{14}
Inclusive jets – p_T>200GeV	100	10^6	~10^8
W → eν	15	10^5	~10^7
Z → e⁺e⁻	1.5	10^4	~10^6
Dibosons	0.2	10	10^5
tt →μ+X		10^3	10^5

~ few hour ~ 1 Day ~ end 2008

pp Total Cross-Section

Current models predict for

14 TeV: 90 – 130 mb

Aim of TOTEM: **~ 1%**

First year : **~5%**

Luminosity independent method:

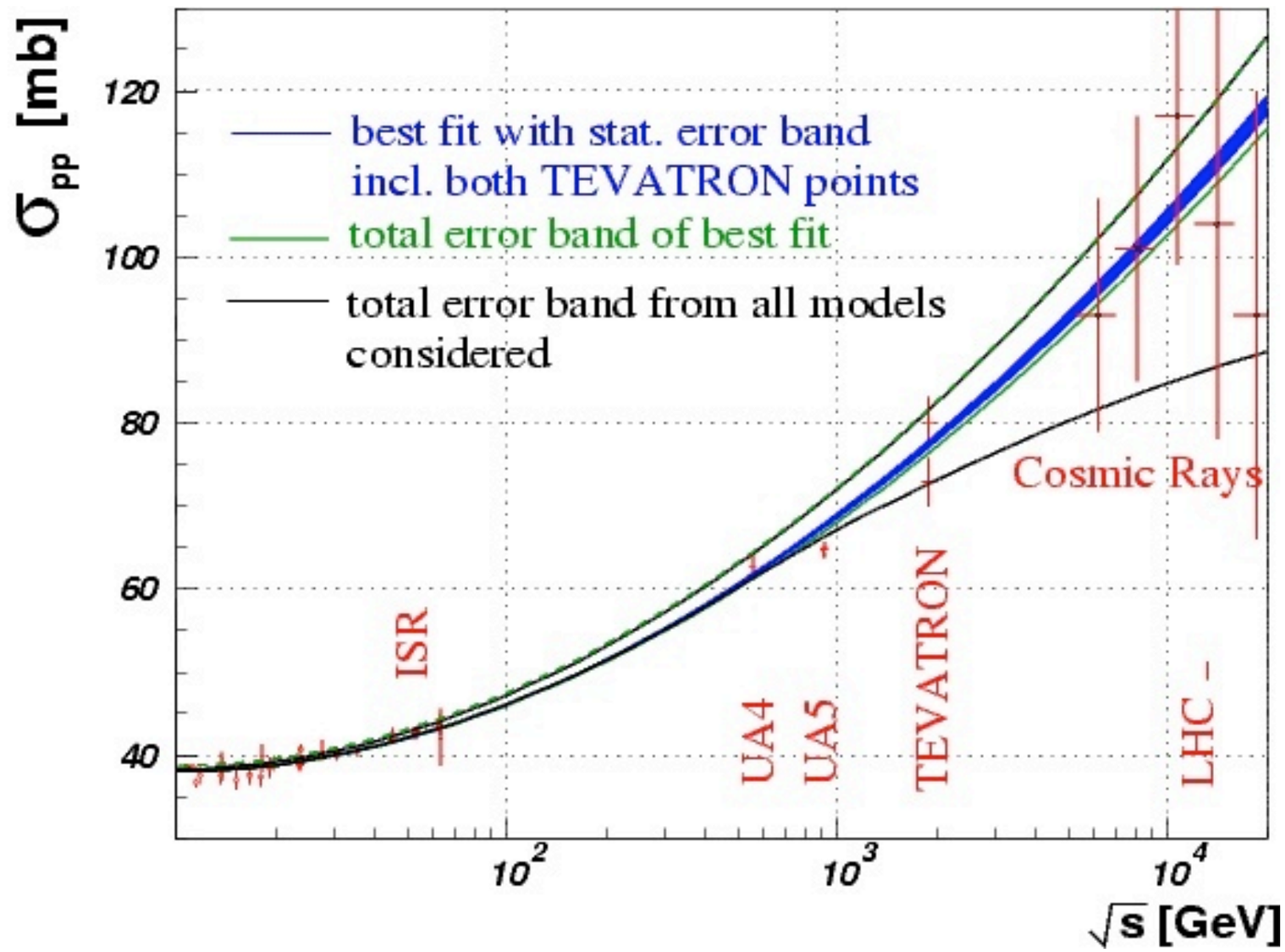
Optical Theorem $L\sigma_{tot}^2 = \frac{16\pi}{1+\rho^2} \times \left.\frac{dN}{dt}\right|_{t=0}$

$$L\sigma_{tot} = N_{elastic} + N_{inelastic}$$

$$\Downarrow$$

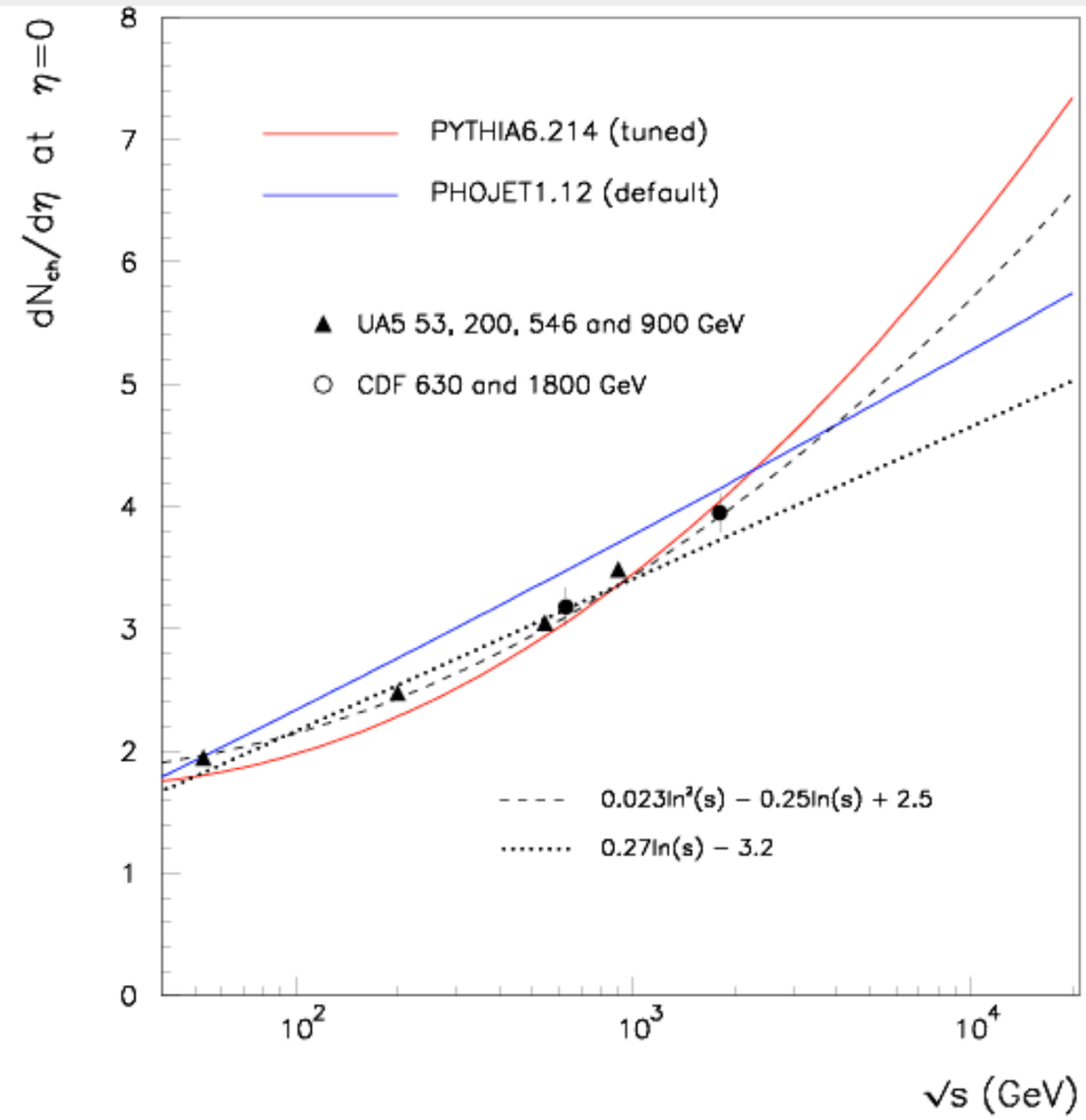
$$\sigma_{tot} = \frac{16\pi}{1+\rho^2} \times \frac{(dN/dt)|_{t=0}}{N_{el} + N_{inel}}$$

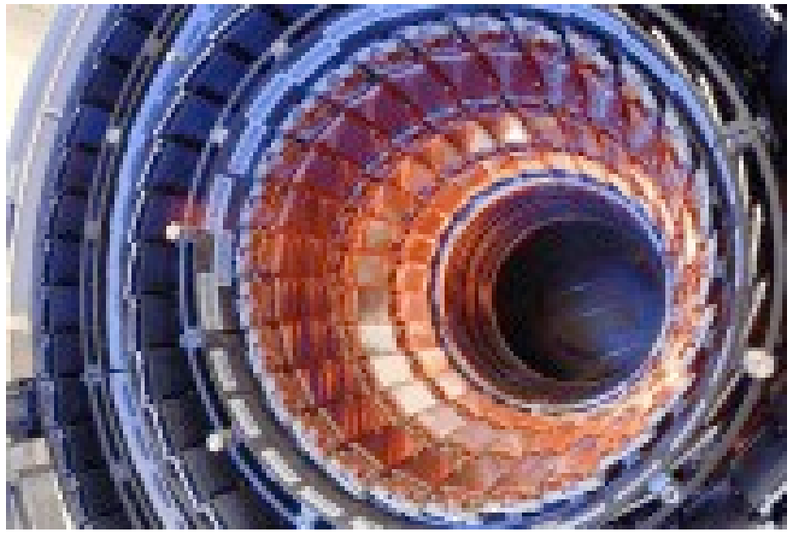
COMPETE Collaboration:



Measure $dN_{ch}/d\eta$, dN_{ch}/dp_T

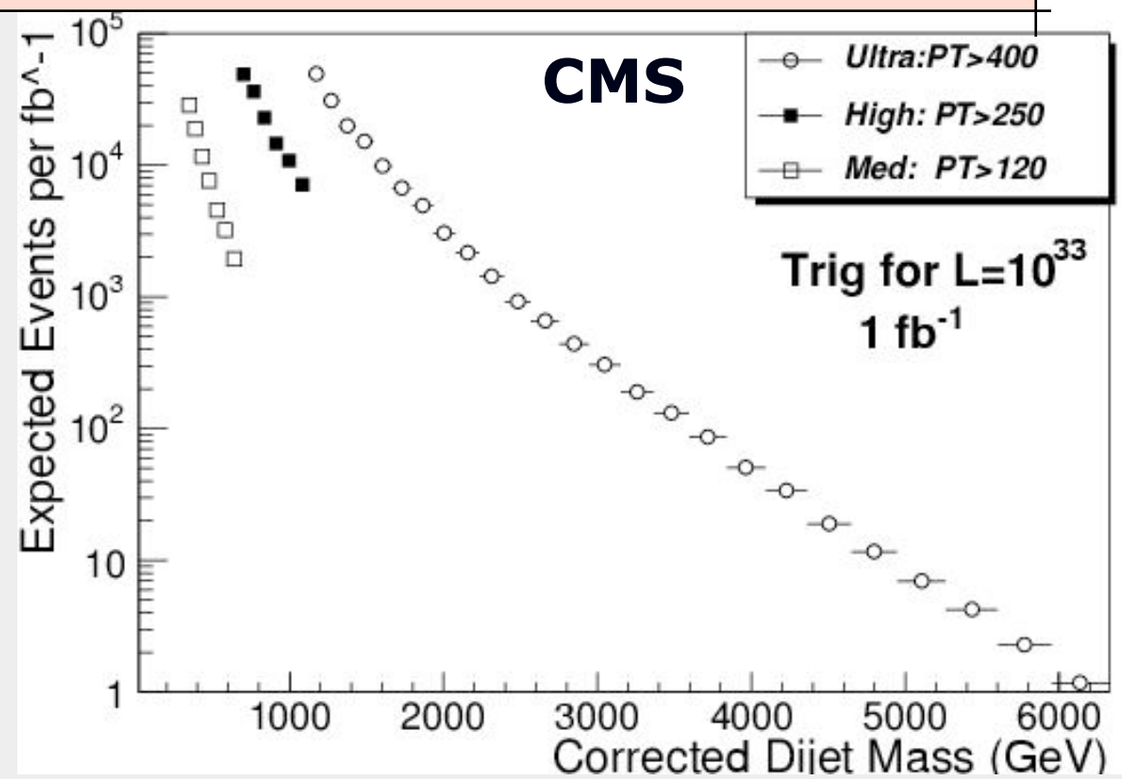
- In theory, we know:
  - W, Z cross sections at ~3%,
  - ttbar cross section at ~10%,
  - but minimum bias charge multiplicity only at ~50%
- Candidate for very early measurement
  - few 10^4 events enough to get $dN_{ch}/d\eta$, dN_{ch}/dp_T
    - ~15 minutes of good data !
  - Caveat: need to understand
    - Beam backgrounds,
    - Pile-up
    - Tracking efficiency !!!
- Initial tracker alignment is good enough as long as it is accounted for in the tracking algorithm.





Possible early discovery: anomalies in high E_T QCD jets, di-jet masses

- **1 fb^{-1} : jets up to 3-3.5 TeV, di-jet masses up to 6 TeV: <u>new territory!</u>**
- **Sensitive to substructure, contact interactions, high mass resonances**



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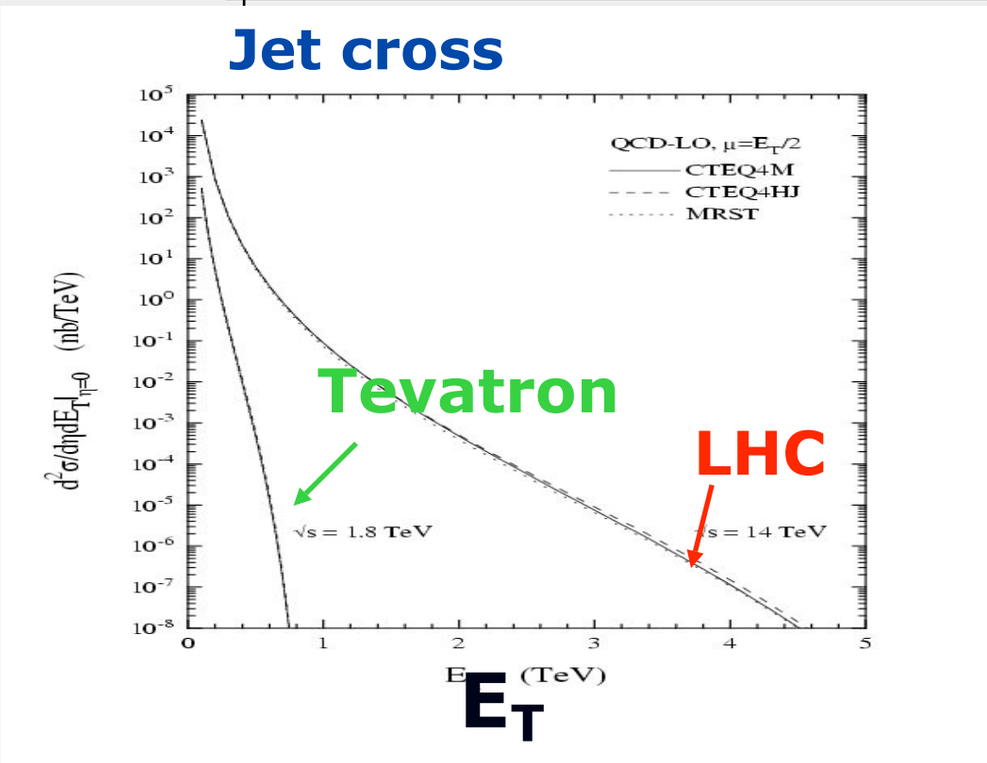

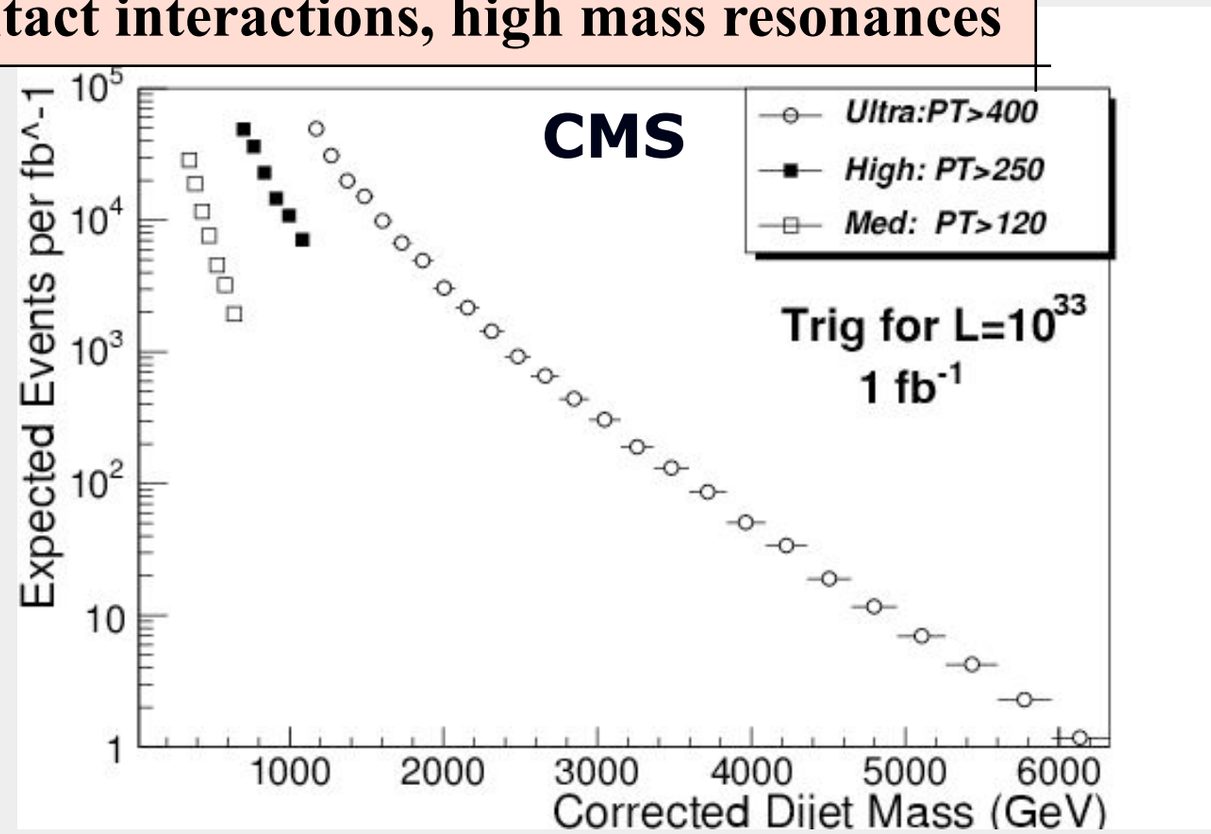

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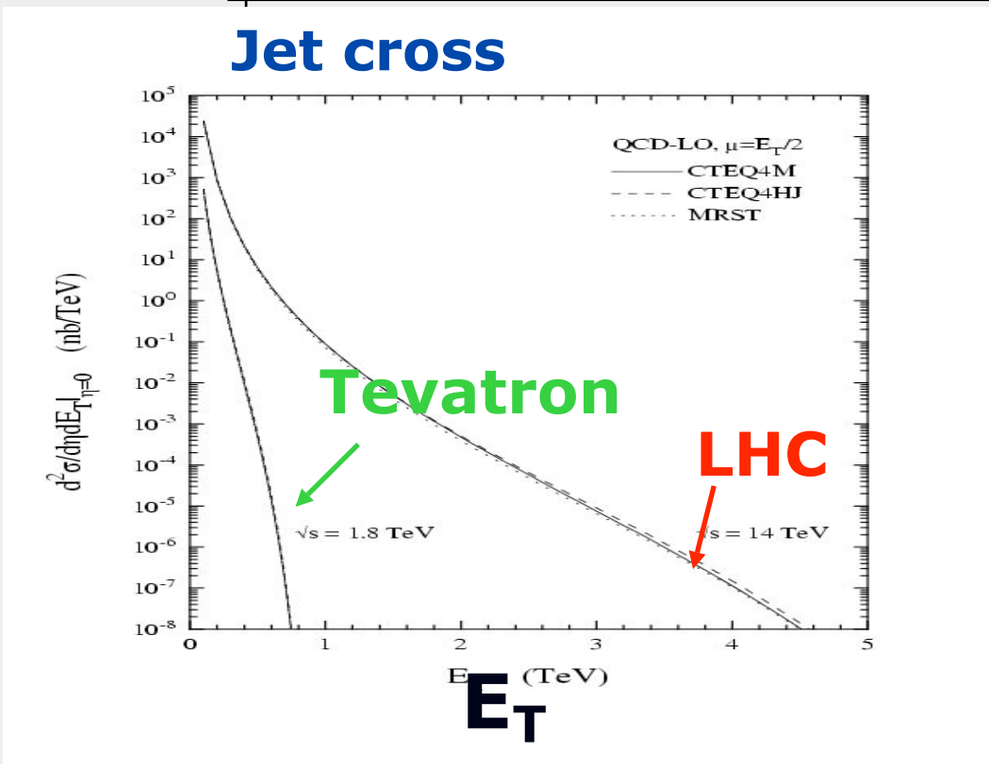

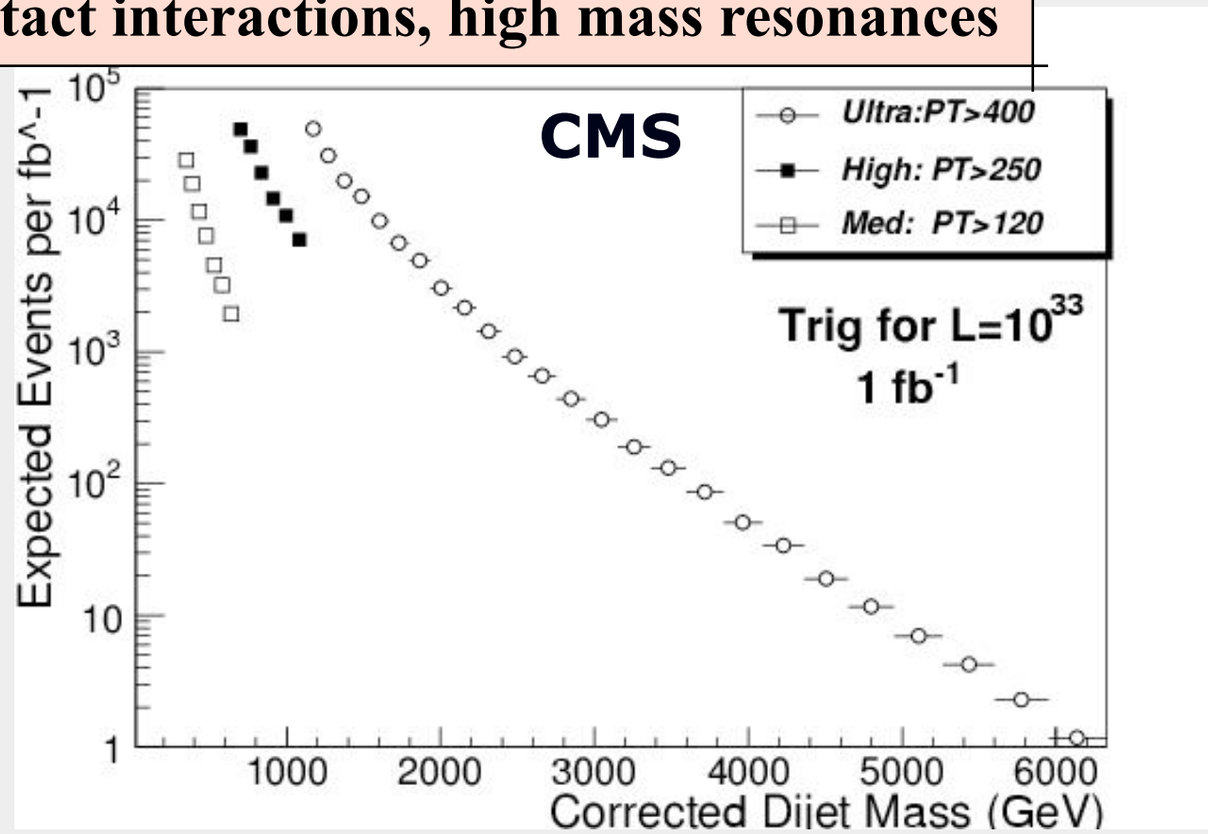

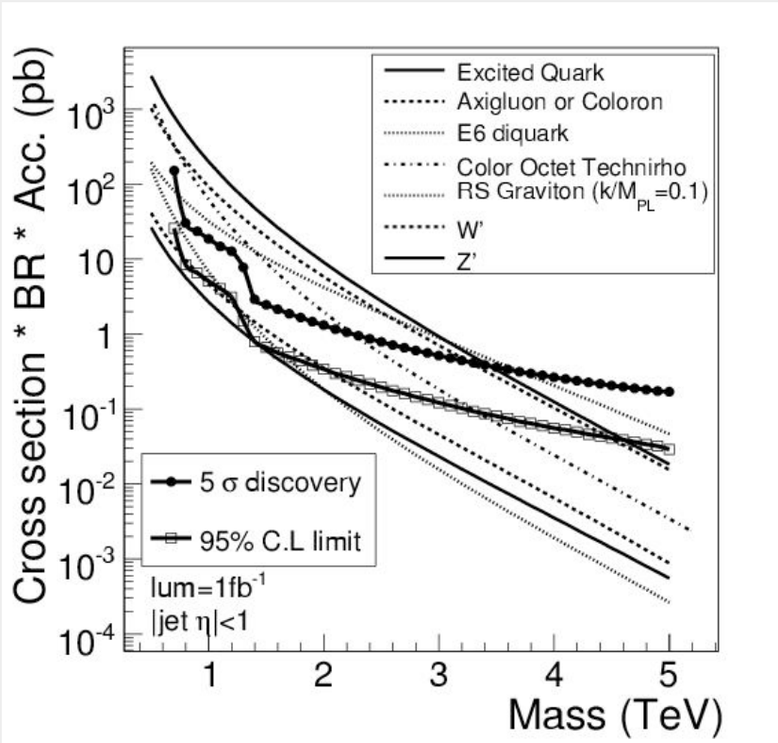

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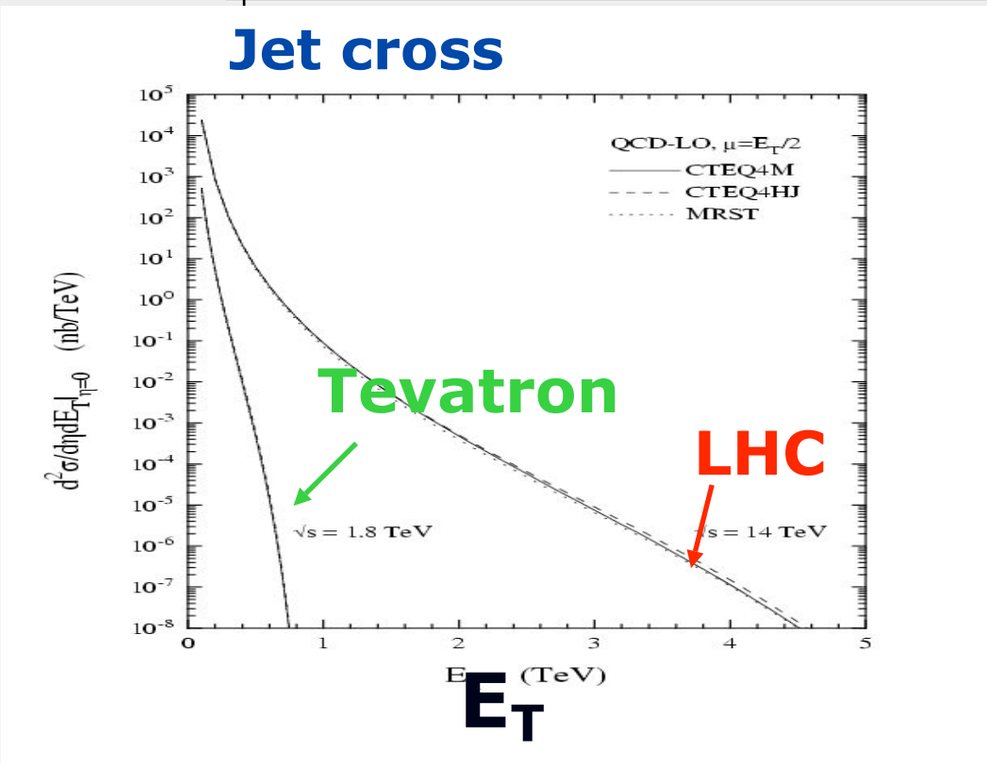
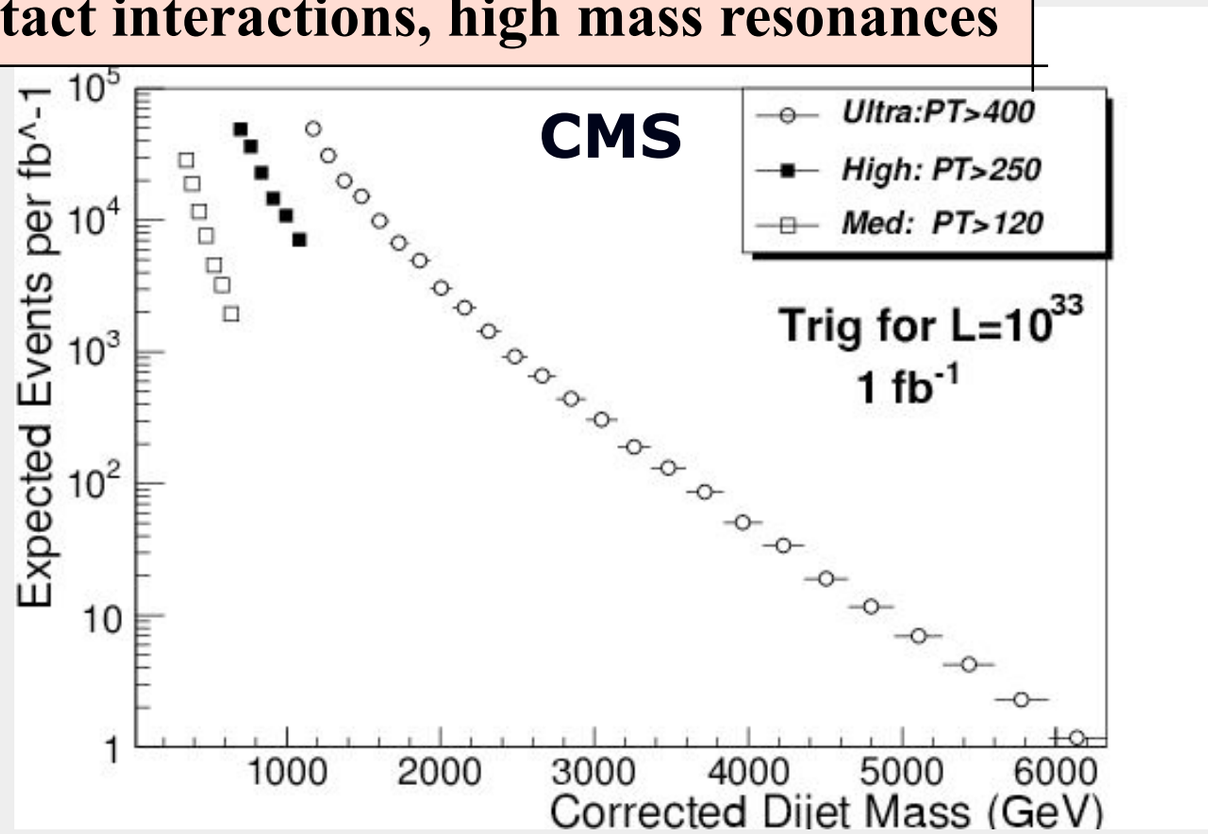
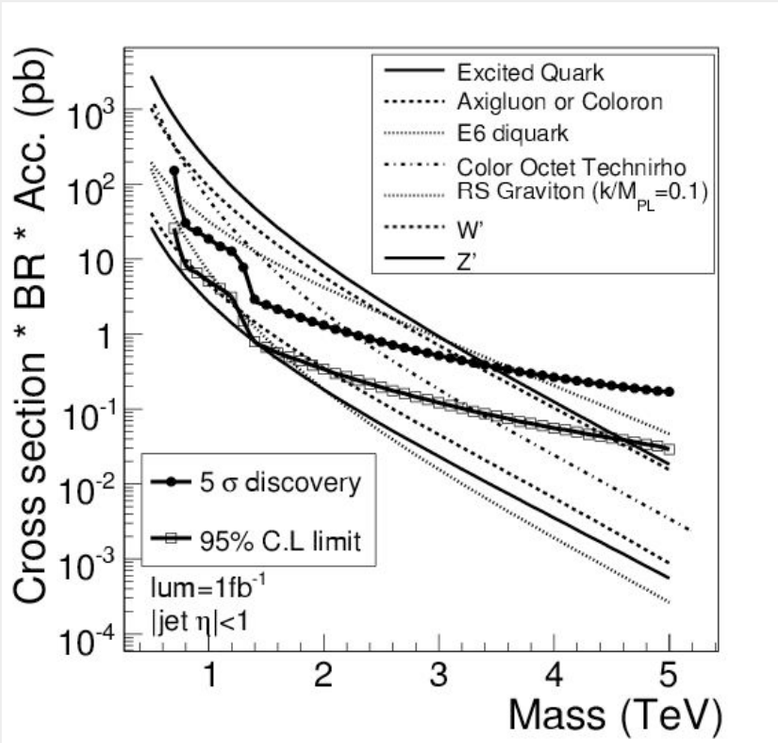
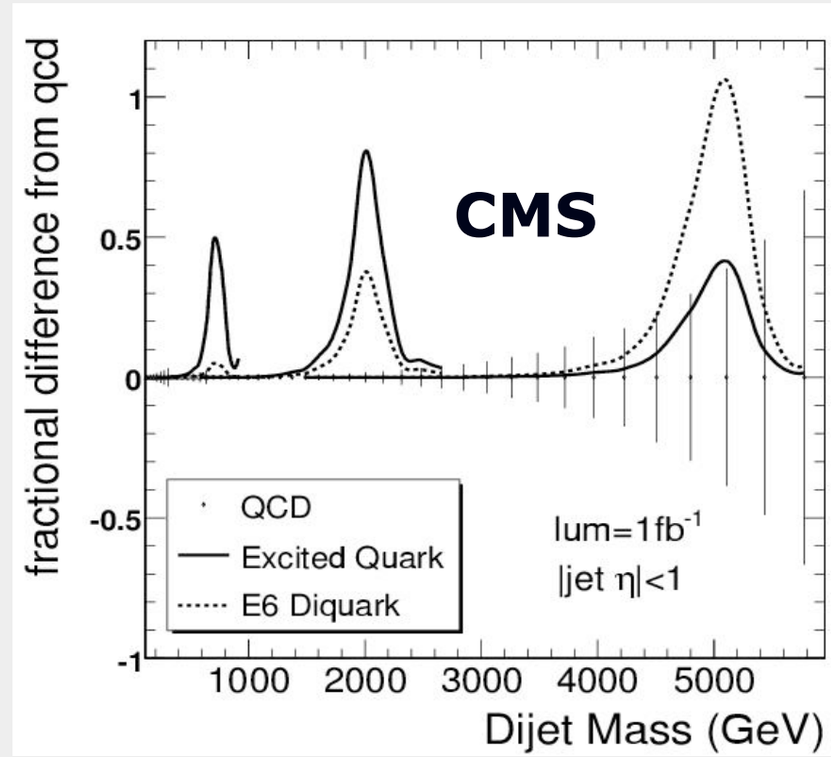


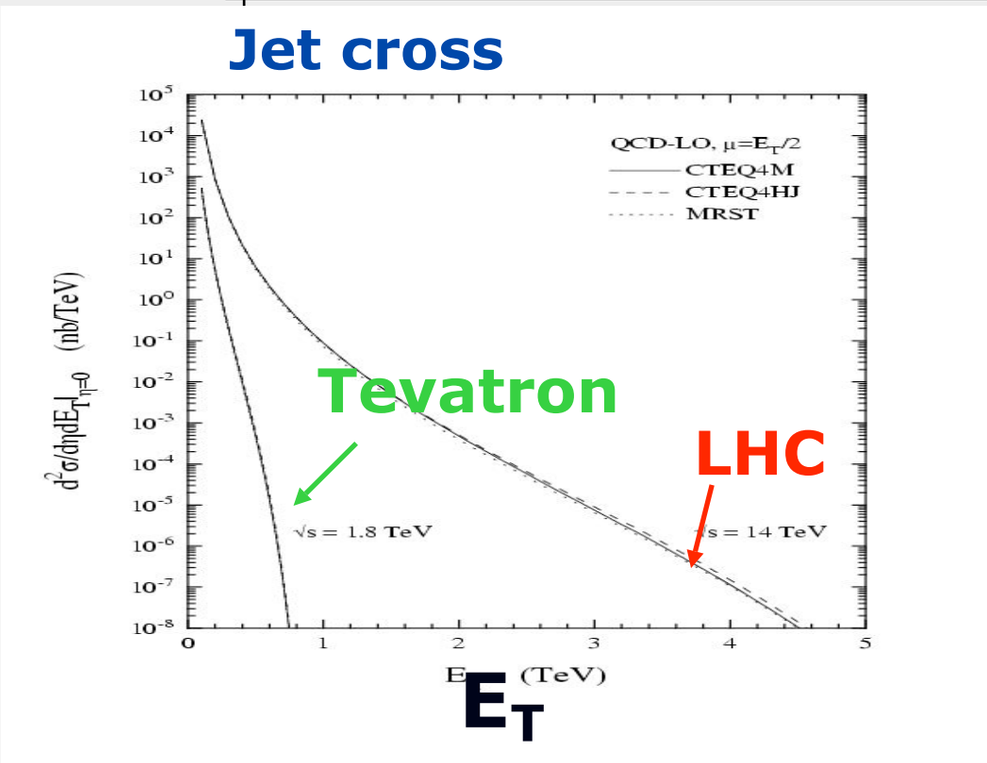


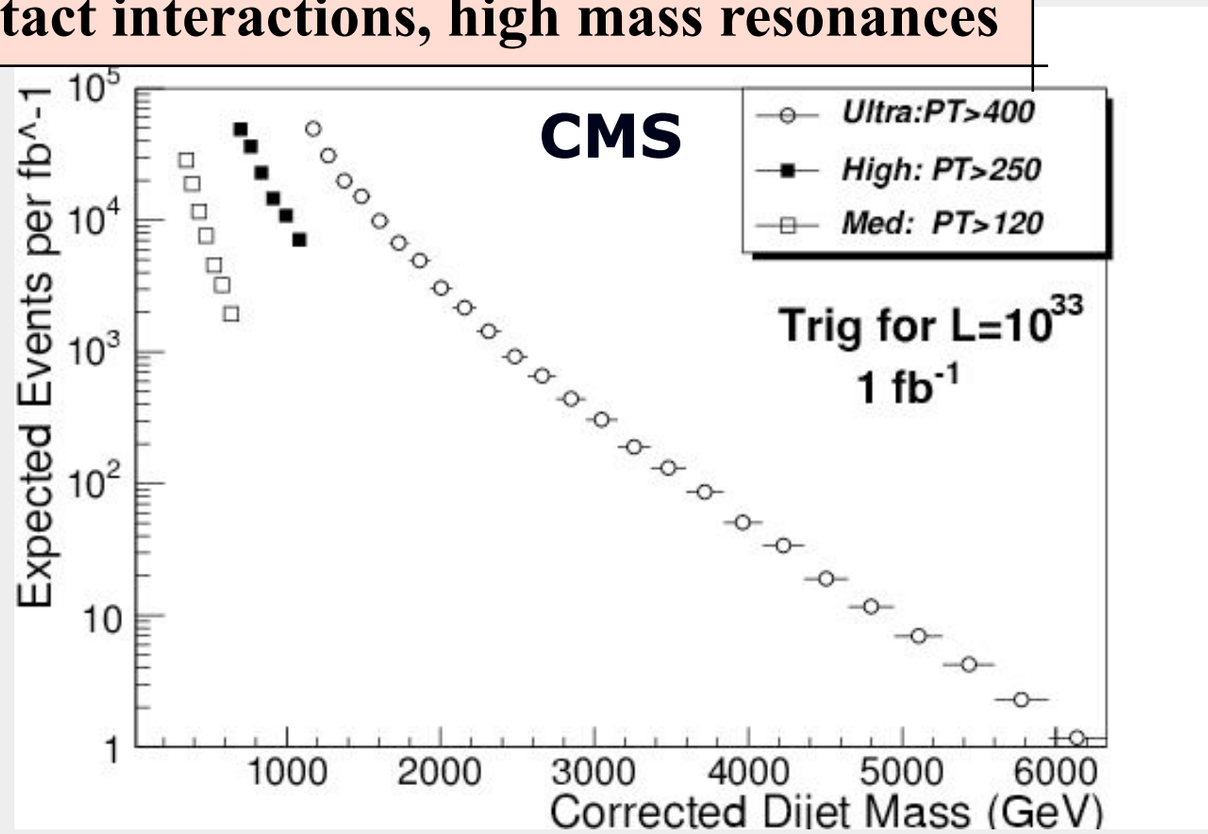


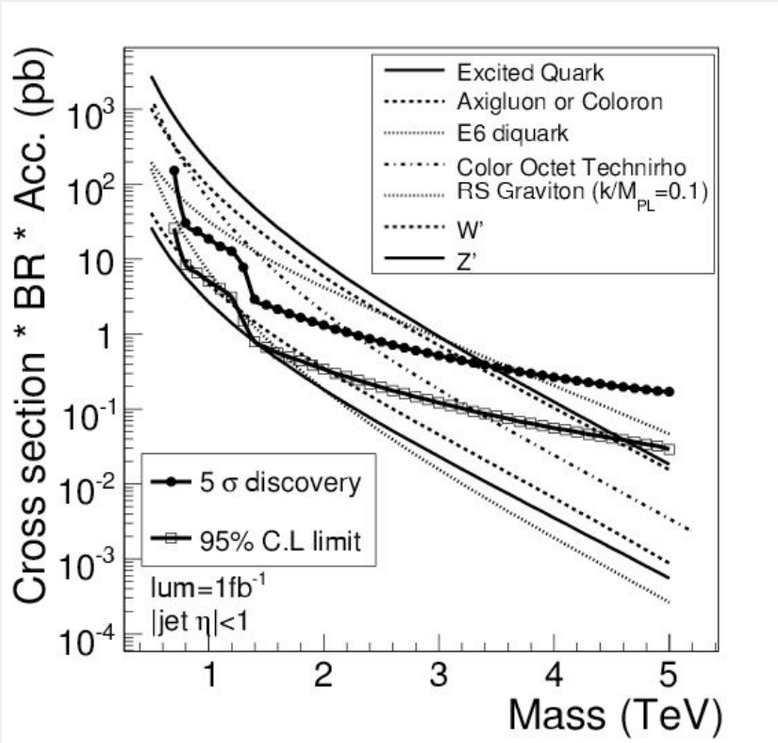


Possible early discovery: anomalies in high E_T QCD jets, di-jet masses

- **1 fb^{-1} : jets up to 3-3.5 TeV, di-jet masses up to 6 TeV: <u>new territory!</u>**
- **Sensitive to substructure, contact interactions, high mass resonances**



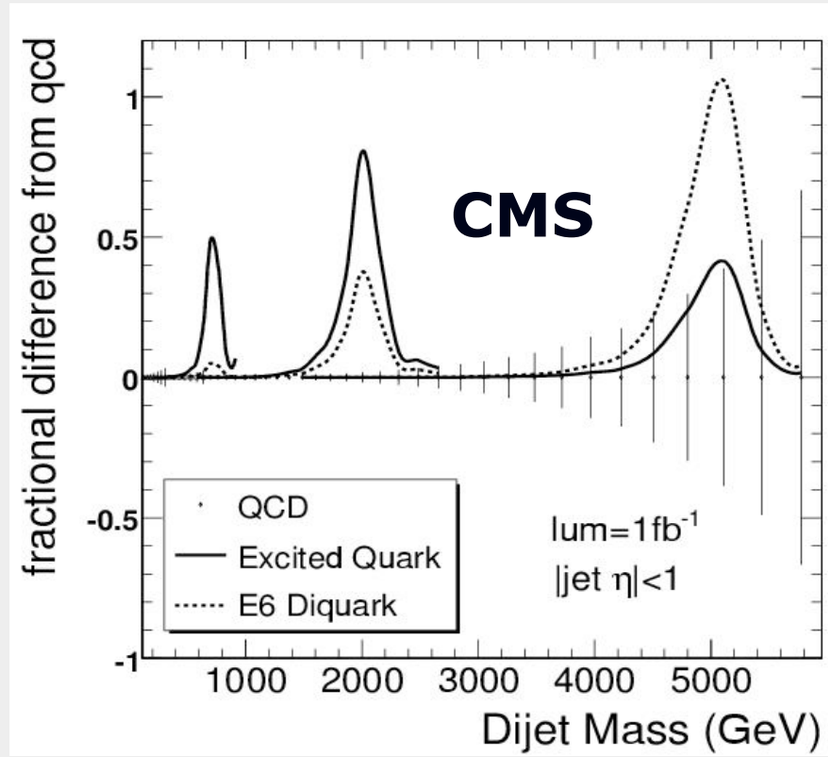




Challenges

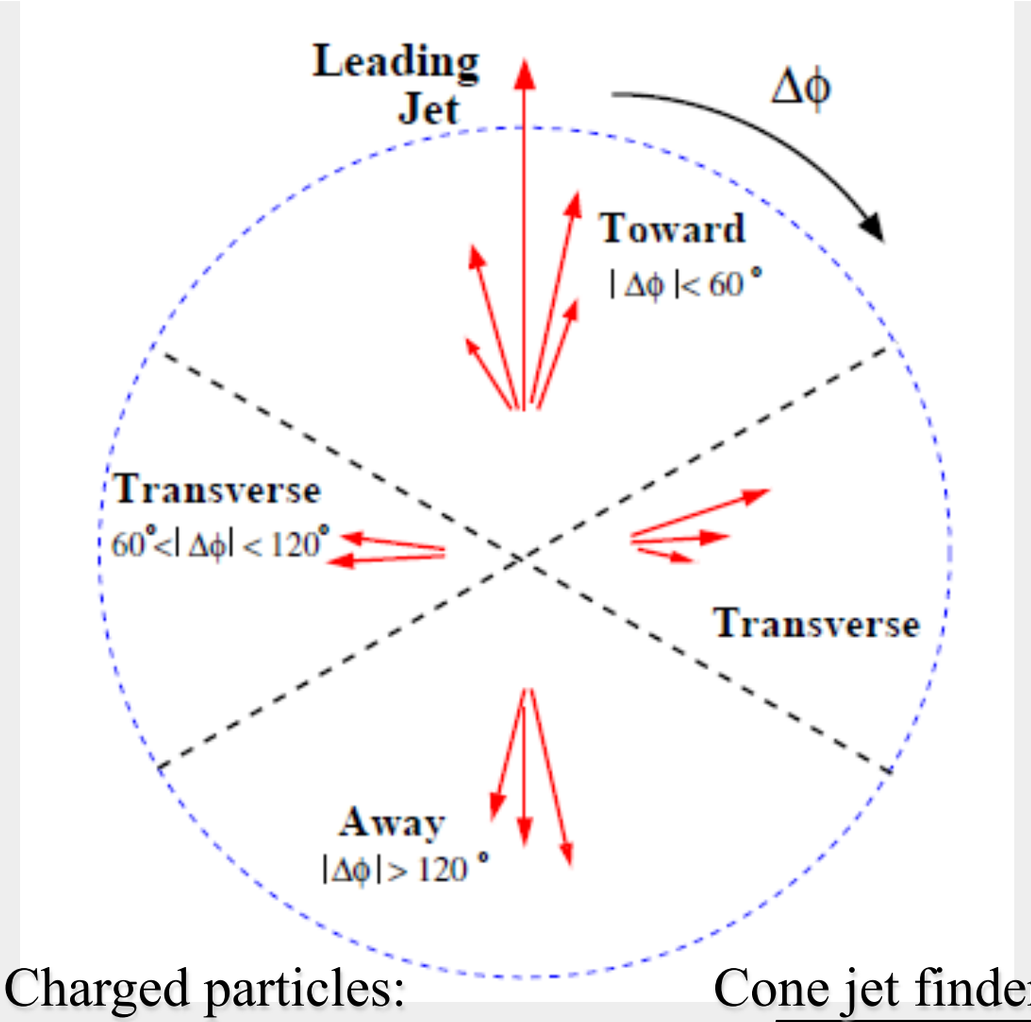
- **Jet energy scale,**
- **Parton density function (PDF)**

  (notably: gluon at high x)
- **underlying event, trigger,**
- **scale variation, hadronization**

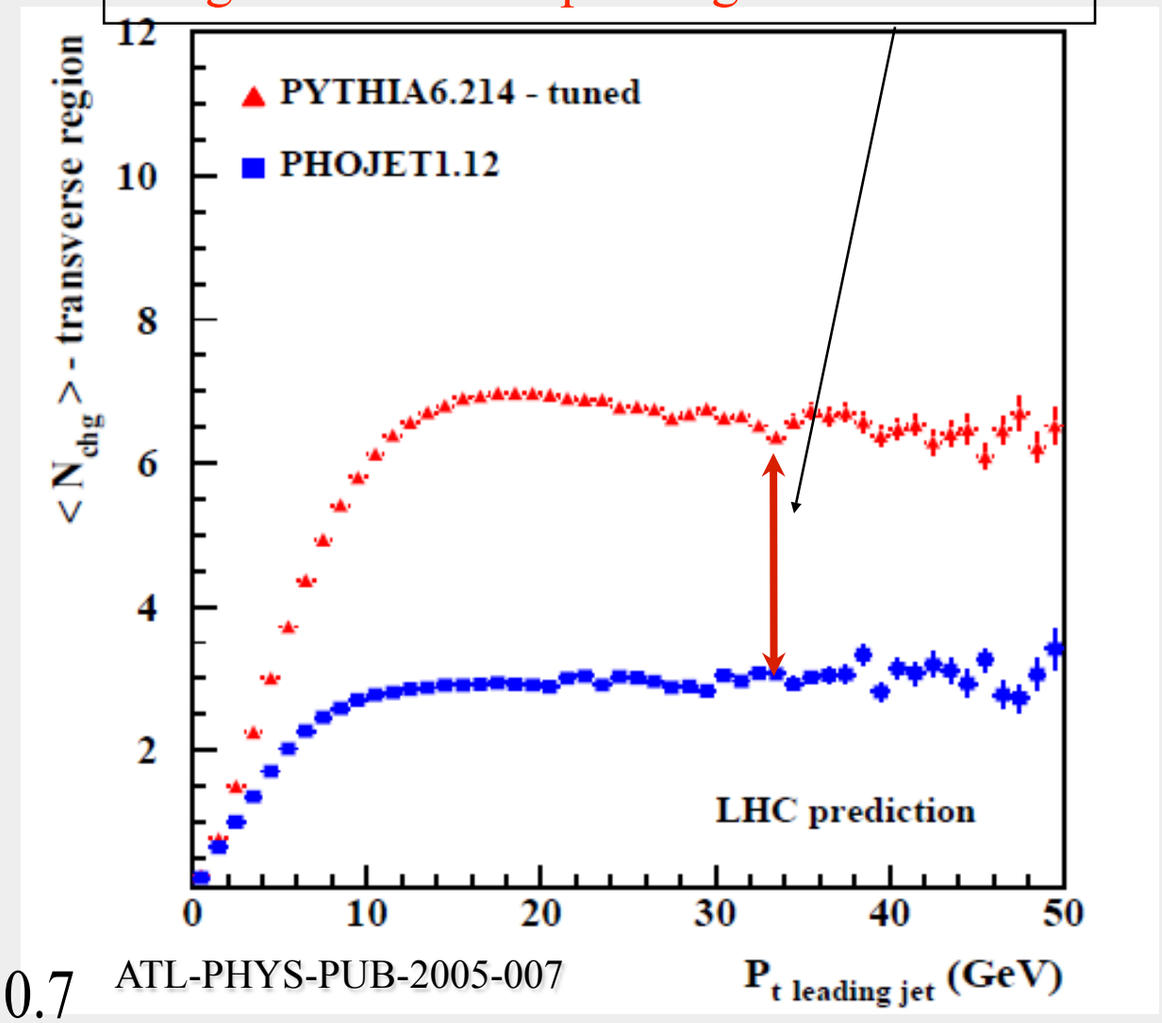


Underlying Event in pp collisions at √s = 14 TeV

Underlying Event particles come from region transverse to the leading jet.
(The underlying event is defined as everything in the collision except the hard process .)



Large difference depending on the models



ATL-PHYS-PUB-2005-007

Charged particles:
p_t>0.5 GeV and |η|<1

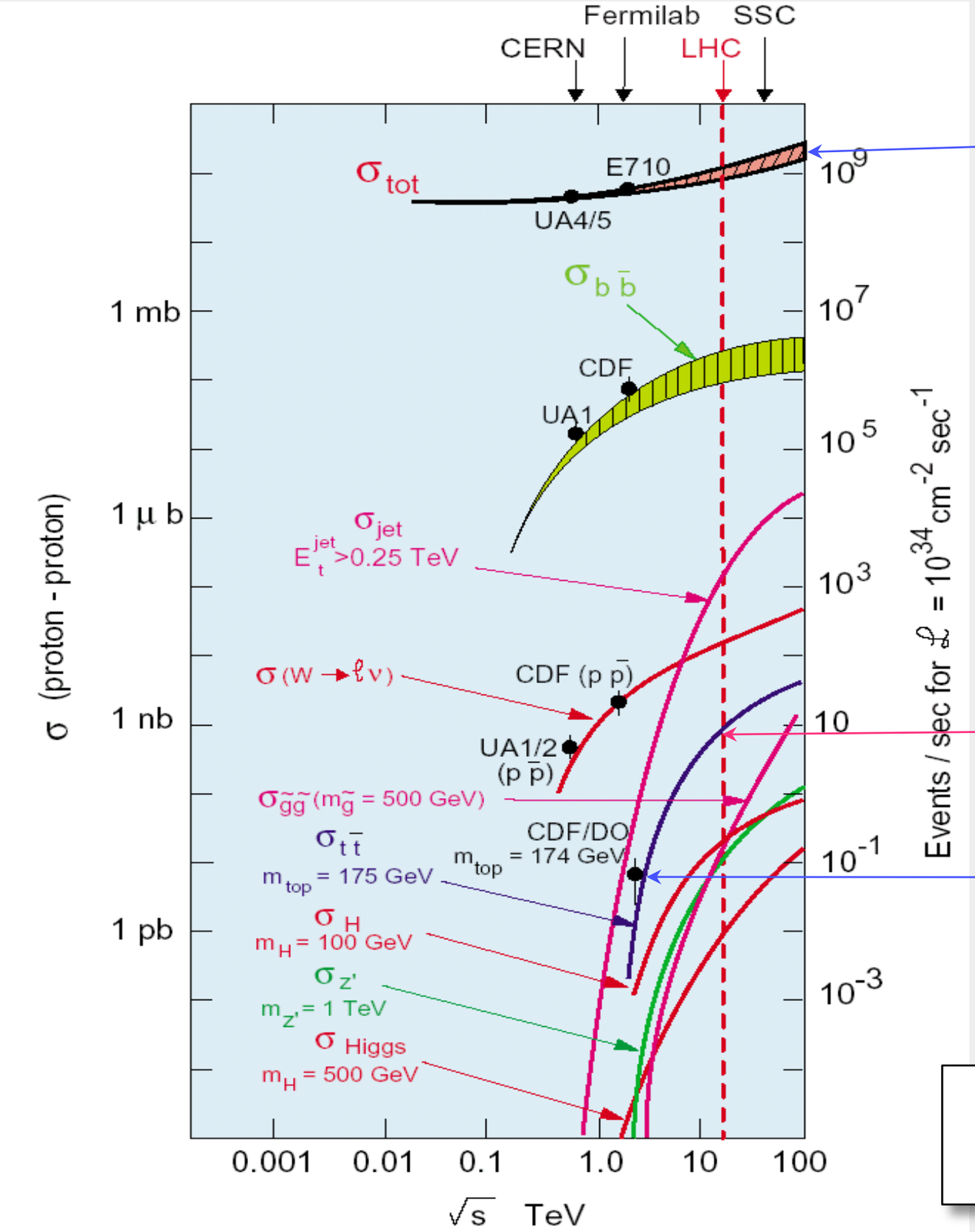
Cone jet finder:

$$R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} = 0.7$$

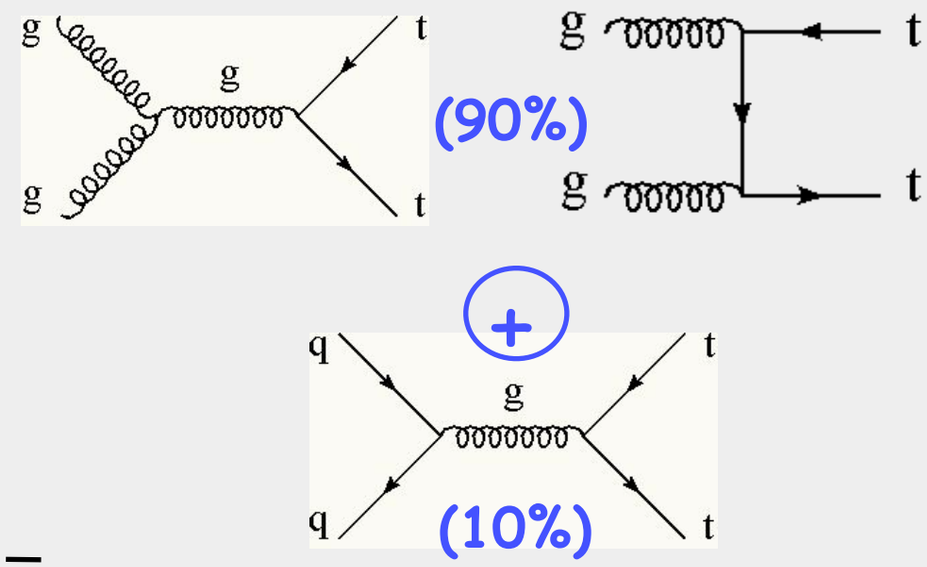
Extrapolation Uncertainties of UE:
➡Multiple interactions
➡ Radiation
➡ Fragmentation

Pile up and underlying events affect :
➡ isolation of leptons and jets,
➡ jet energy reconstruction ("pedestal")
➡ jet veto
➡ ....

LHC is a $t\bar{t}$ factory



Total production cross section



$t\bar{t}$ production cross section at LHC:

~833 pb

$t\bar{t}$ production cross-section at Tevatron:

6.7 pb

2 $t\bar{t}$ events per second !

> 8 millions $t\bar{t}$ events expected per year

Let's trigger the top… July 2008

- Trigger the Semi(Di)-Leptonic top is easy…
- …not the same for the fully hadronic (bTag is needed)
- Inclusive Trigger is preferable to include all of the known/unknown top scenario
  - Look for isolated leptons, jets and ME_T
    - Isolated e/μ stream is enough both for Semi(Di)-Leptonic Top Decay→ ~ 70% efficiency
    - MultiJet + bJet trigger for fully Hadronic events → ~ 15% efficiency
  - Trigger thresholds depends on the Luminosity…

Illustrative triggers @ 10^{33} for top

Trigger object	P_T/E_T HLT thresholds (GeV)	Rates (Hz)
Muon	19	26
Electron	26	24
Single Jet 2, 3, 4 Jets	400, 350, 195, 80	19

Trigger object	P_T/E_T HLT thresholds (GeV)	Rates (Hz)
Muon	20	40
Electron	25	20
Single Jet 2, 3, 4 Jets	160, 120, 65, 50	10

Early top studies : 100 pb^{-1}

Focus on semileptonic channel :

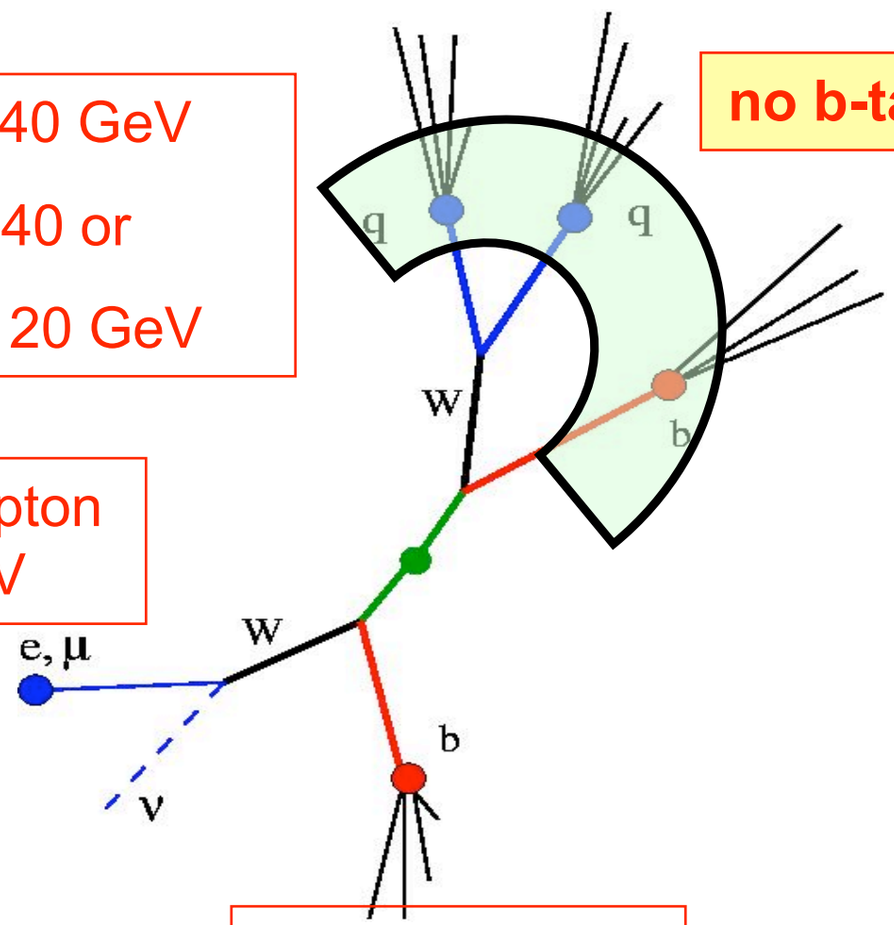
BR ($t\bar{t} \rightarrow WbW\bar{b} \rightarrow (l\nu b)(\bar{b}jj)$) ~30 %
Easy to trigger thanks to isolated lepton (e or μ)
Clean topology : t and $\bar{t}$ central and back-to-back

Typical event selection:

3 jets p_T >40 GeV

4th jet p_T >40 or 20 GeV

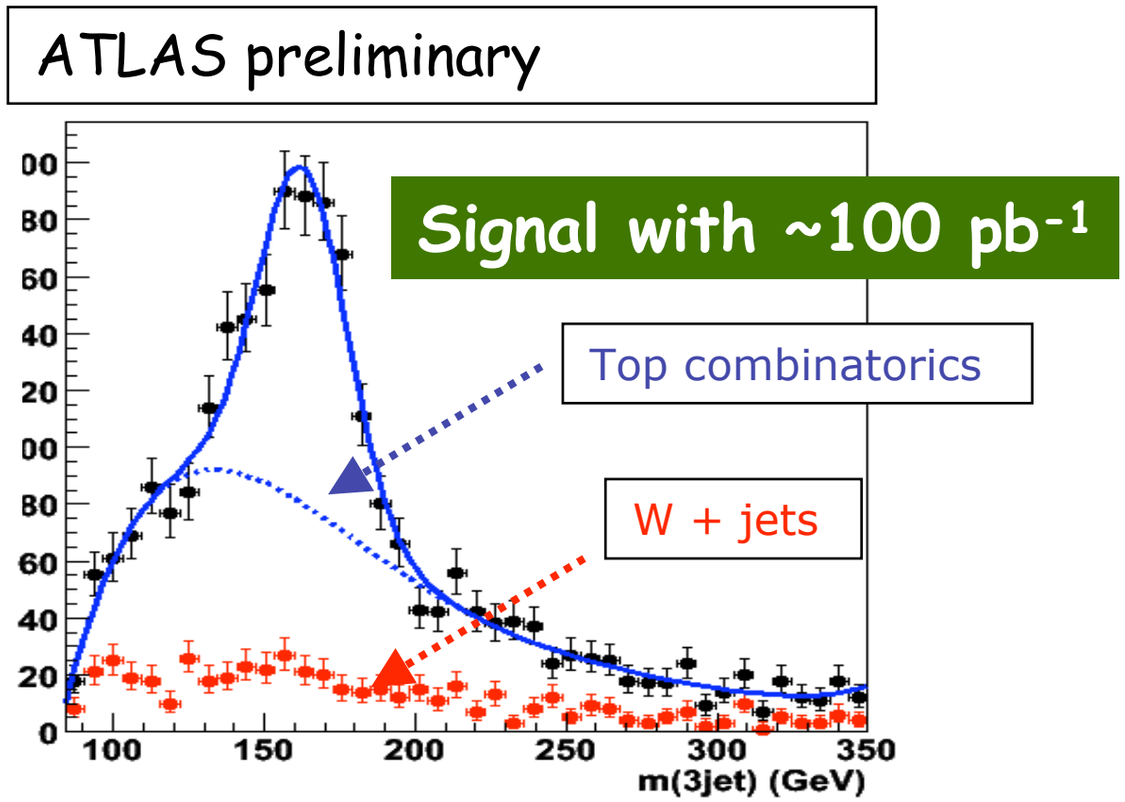
Isolated lepton pT>20 GeV



no b-tag !

E_T^{miss} > 20 GeV

Compute invariant mass of 3 jets with highest Σp_T :



If 2 b-jets requested :
BKG <2% : mainly W/Z+jets, WW, WZ, ZZ
Efficiency 1-2%

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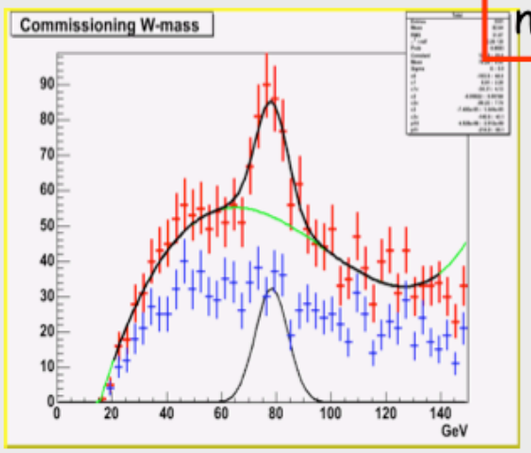
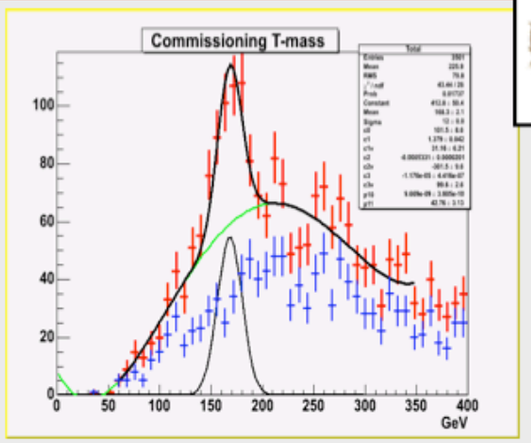
  - **Statistics is enough to study b Tagging...**
  - **Systematic errors are already our main concern...**

no bTag, few hours of data





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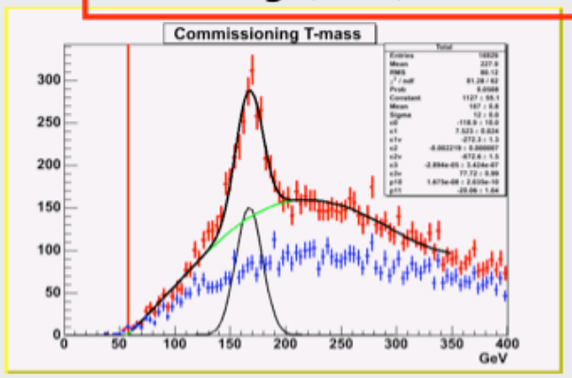

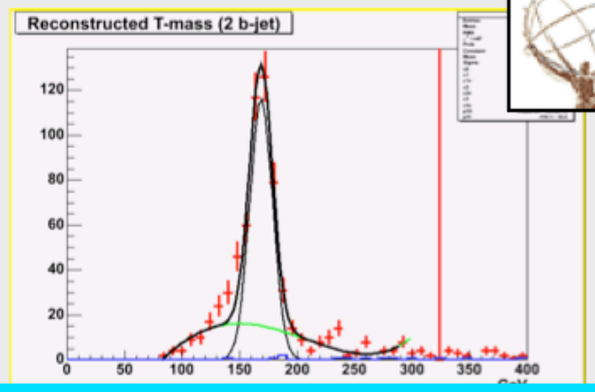

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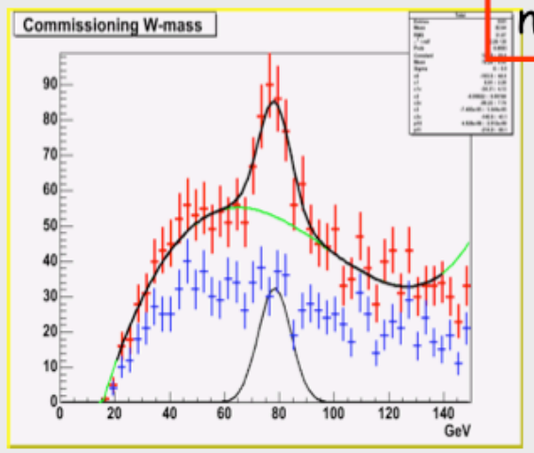

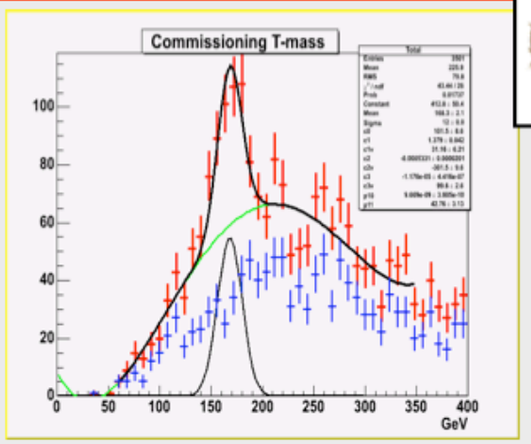

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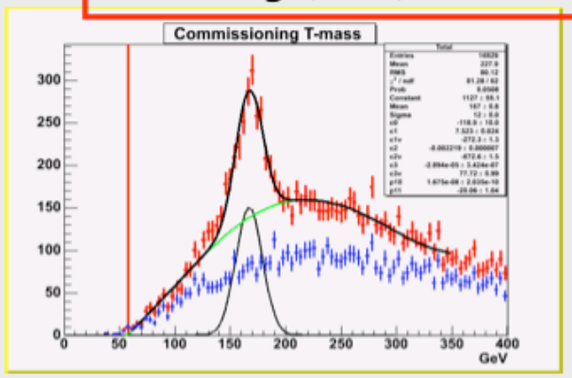

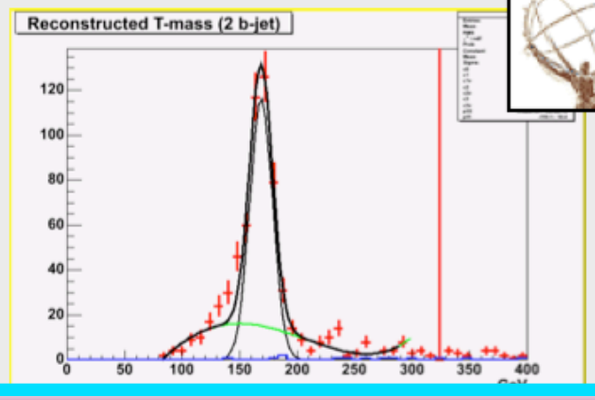

Dilepton channel

Clean channel but need to reconstruct 2 ν's (via 0C fit assuming m_W and 2 equal masses for top $m_{t1}=m_{t2}$ (6 eq. , 6 unknowns)

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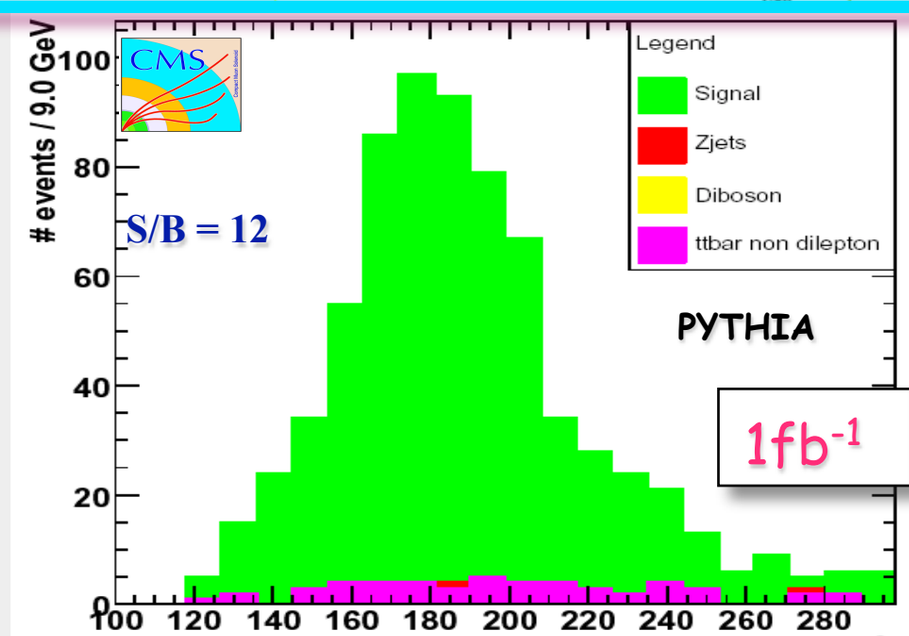

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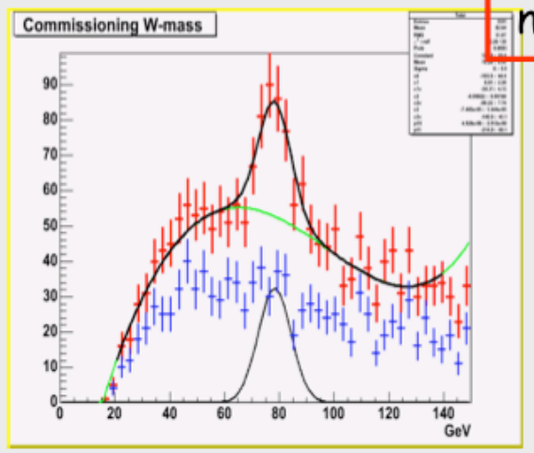

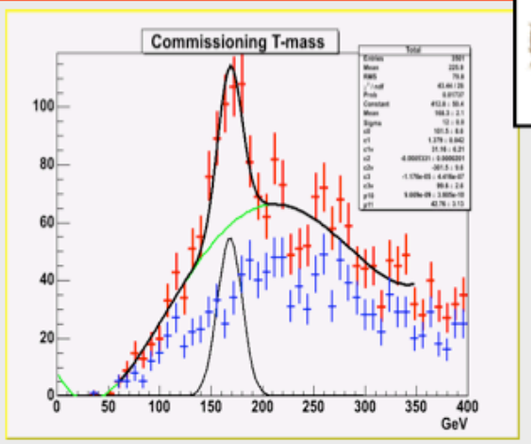

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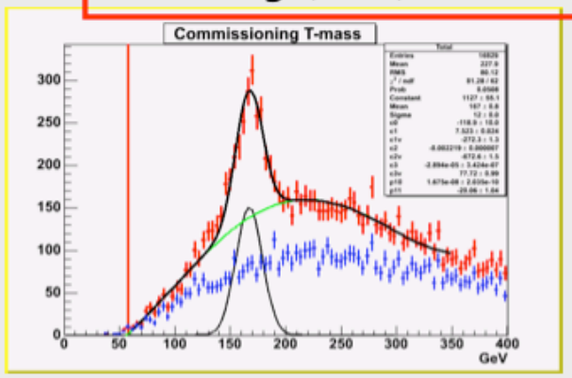

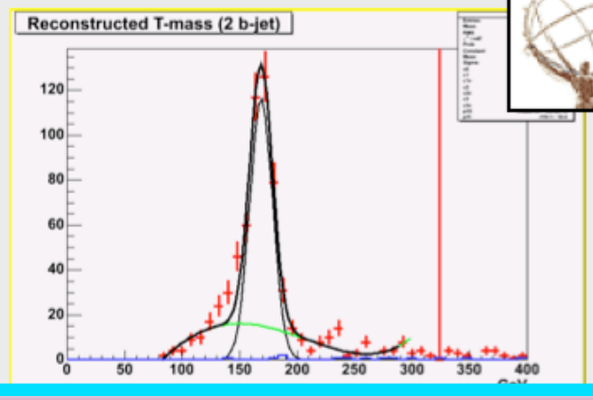

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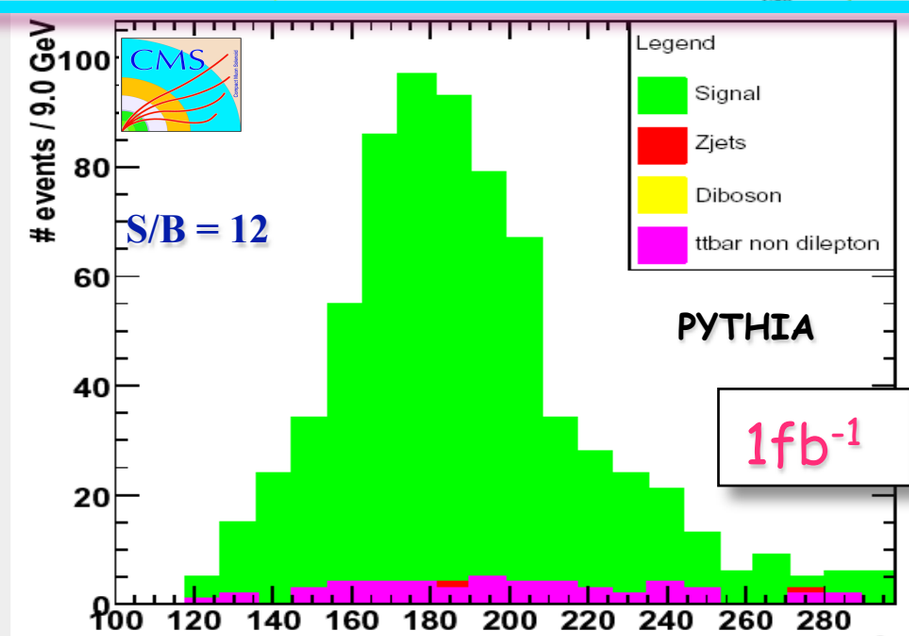

- **Top is there ... we can start to play!**

TOP at the LHC is important

- ATLAS and CMS goals in TOP sector are identical : a good knowledge of detectors
  - So the road to full detector commissioning pass through the TOP physics
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- Rediscovery the top… Commissioning in 2008
  - Light & bJet Jet Energy Scale
  - Overall Jet Calibration
  - bTag effciency
- Precise measurements in the top sector… EW probing in 2009 and over…
  - Precise measurements for m_t, σ_{tt}, $|V_{tb}|$, BR …
  - Constraints in the SM and beyond…
- New physics search… As soon as detectors are well understood …
  - both in the production and decay sectors: $t\bar{t}\rightarrow X$, $X\rightarrow t\bar{t}$, $t\bar{t}X$…
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  - Top quarks will be backgrounds to many new processes…

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  - Light & bJet Jet Energy Scale
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  - We could get top signal with ~ 100 pb^{-1}
  - $\sigma(tt)$ to ~13% and M_{top} to 1% with 1fb^{-1}

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Brief motivation for beyond SM searches

- However successful the Standard Model (SM) has been so far (it well describes all current experimental data), it is at the same time plagued by instabilities (divergent loop corrections at high energy).
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Extra dimensions

Has the SM interactions confined to four dimensions and gravity occupying the extra dimensions

Supersymmetry

- Symmetry between bosons and fermions

SM Particles	SUSY Particles		
quarks: q	q	squarks: $\tilde{q}$	
leptons: l	l	sleptons: $\tilde{l}$	
gluons: g	g	gluino: $\tilde{g}$	
charged weak boson: $W^{\pm}$	$W^{\pm}$	Wino: $\tilde{W}^{\pm}$	$\tilde{\chi}^{\pm}_{1,2}$ chargino
Higgs: H^0	$H^{\pm}$	charged higgsino: $\tilde{H}^{\pm}$	
	h^0, A^0, H^0	neutral higgsino: $\tilde{h}^0, \tilde{A}^0$, $\tilde{H}^0$	higgsino
neutral weak boson: Z^0	Z^0	Zino: $\tilde{Z}^0$	$\tilde{\chi}^0_{1,2,3,4}$ neutralino
photon: γ	γ	photino: $\tilde{\gamma}$	

- Possible candidat to explain the dark matter
  The lightest sparticle ("LSP") is stable

- Allows the Grand Unification
- But introduce a new set of parameters
- and has to be broken at an energy scale of 1 TeV

Supersymmetric events

- In hard processes, strongly interacting sparticles (squarks, gluinos) dominate production
  - **~100 events/day (for squarks/gluions masses of ~1TeV at 10^{33} $cm^{-2}s^{-1}$)**
  - **Discovery possible with only 1 fb^{-1}**
- Heavier sparticles than sleptons, gauginos... have cascades decays to the lightest SUSY particle (LSP)
- Long decay chains and large mass differences between SUSY states
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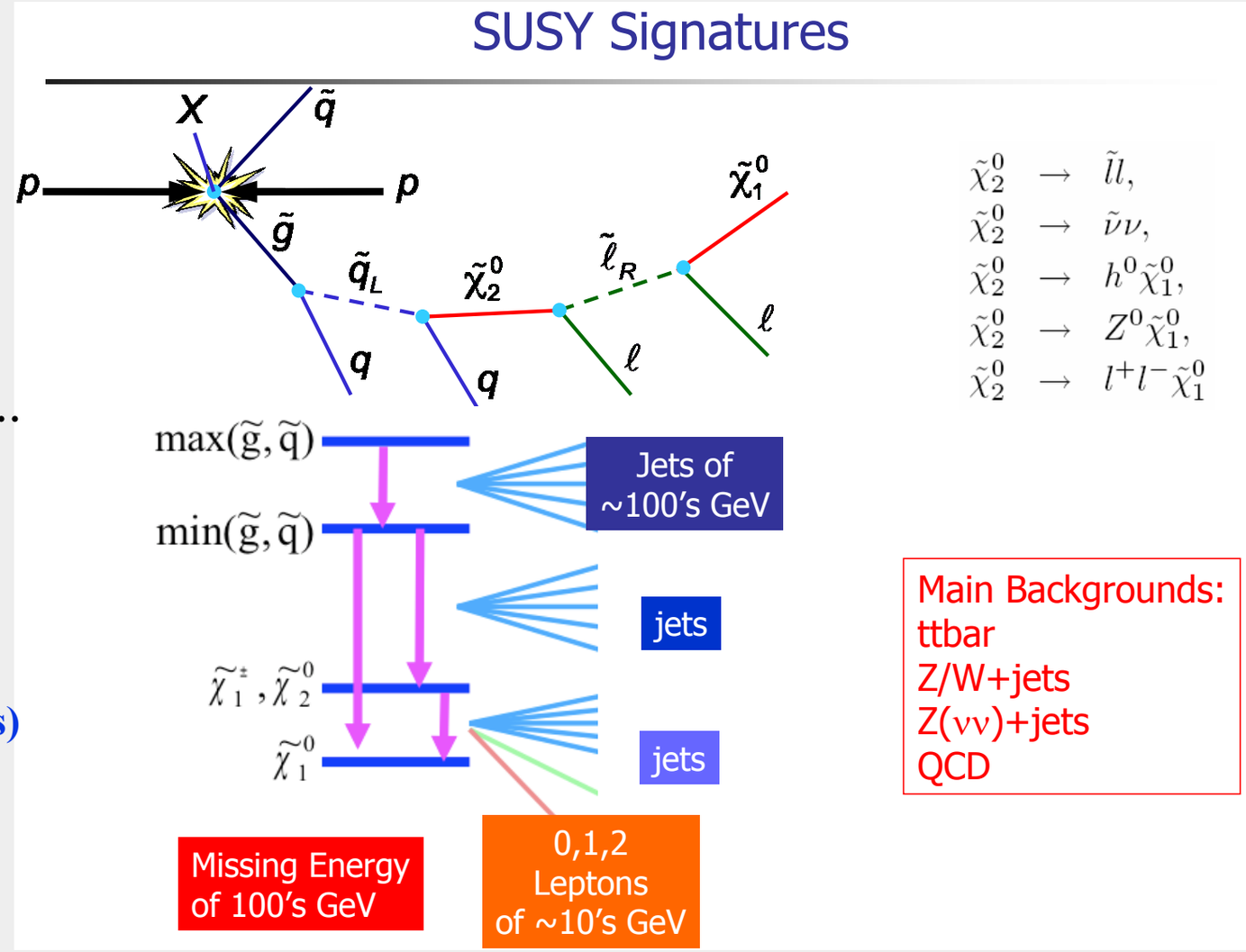

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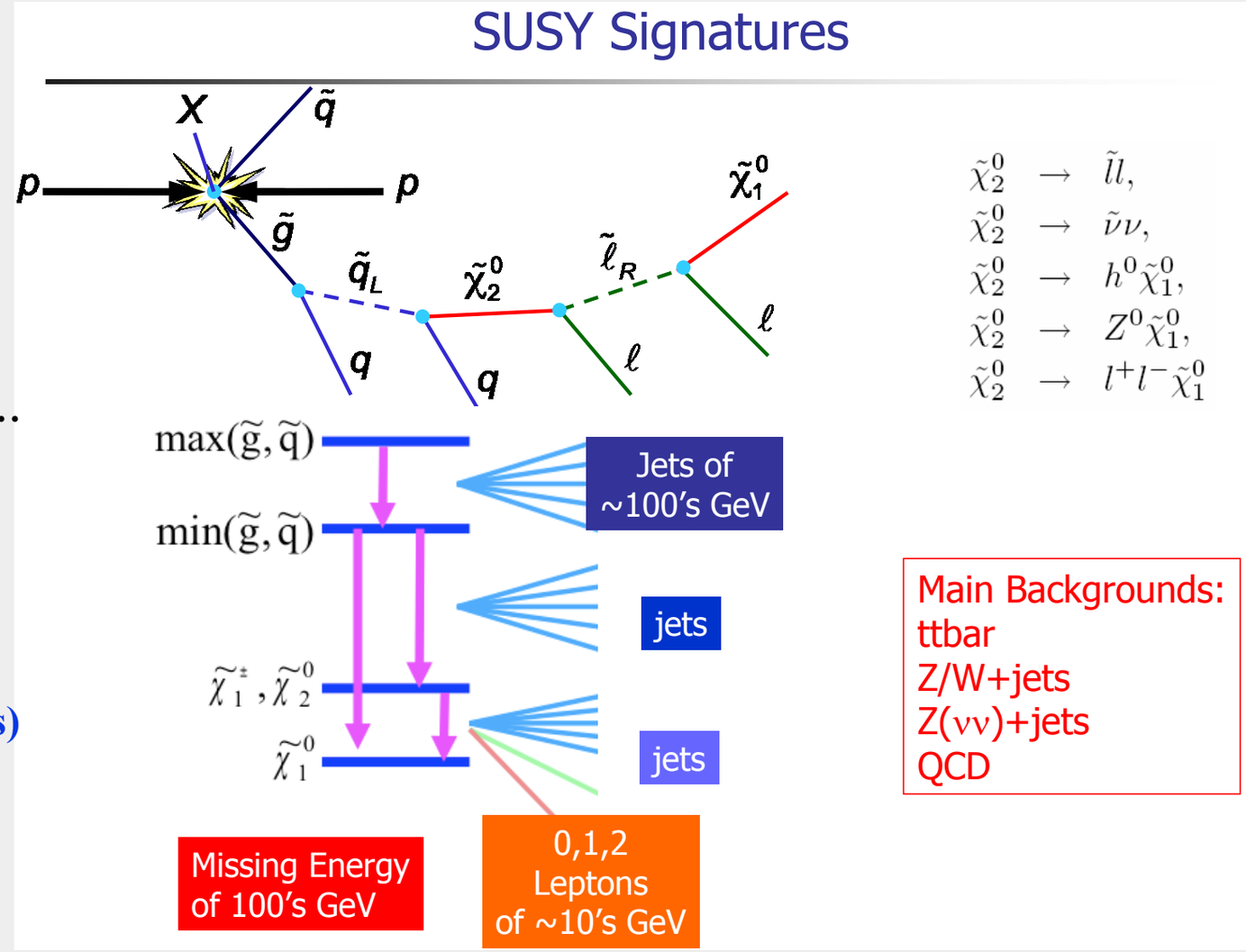
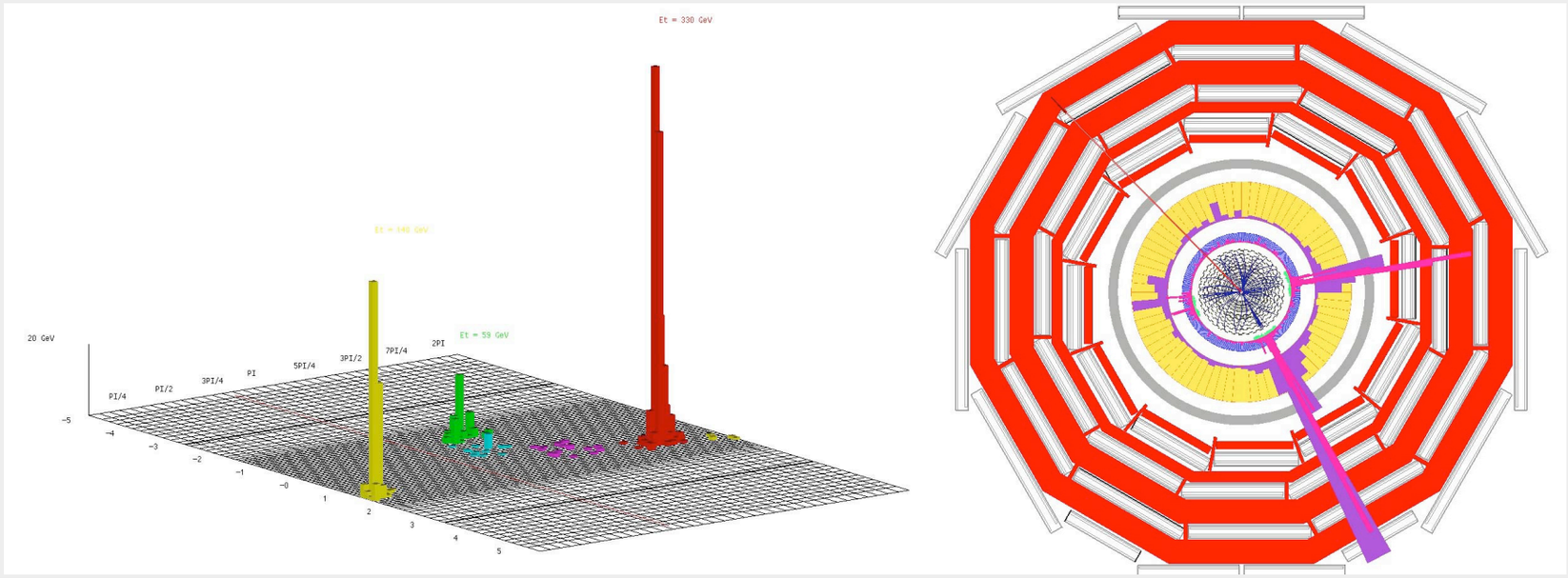
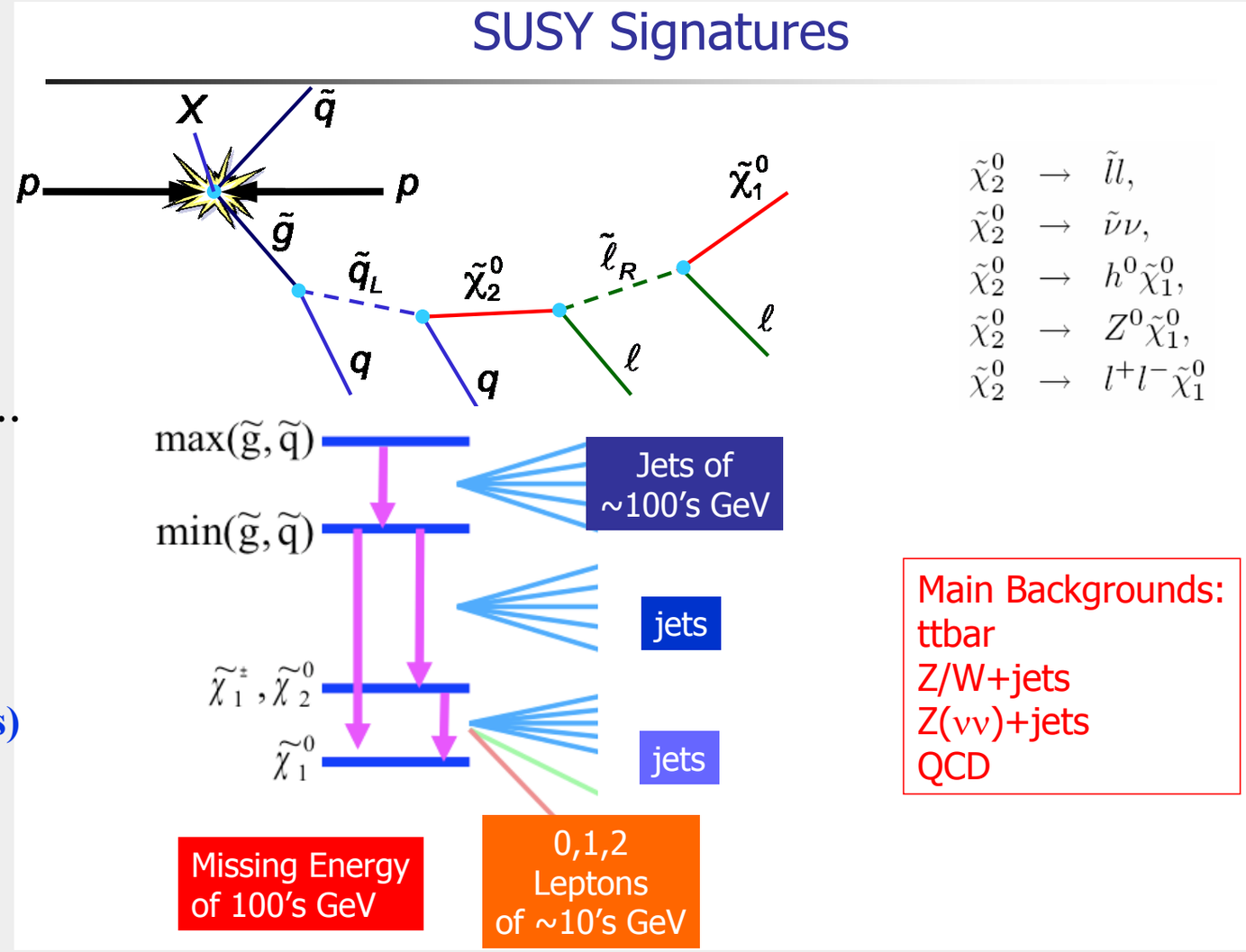
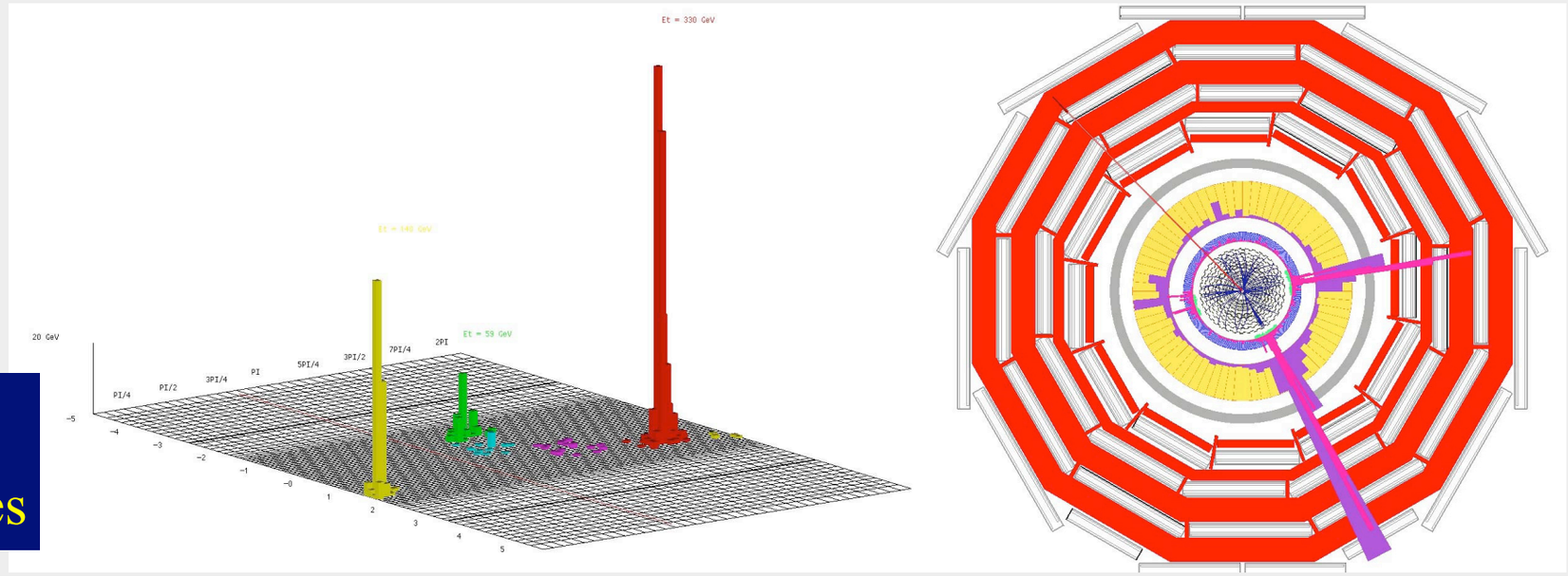




Supersymmetric events

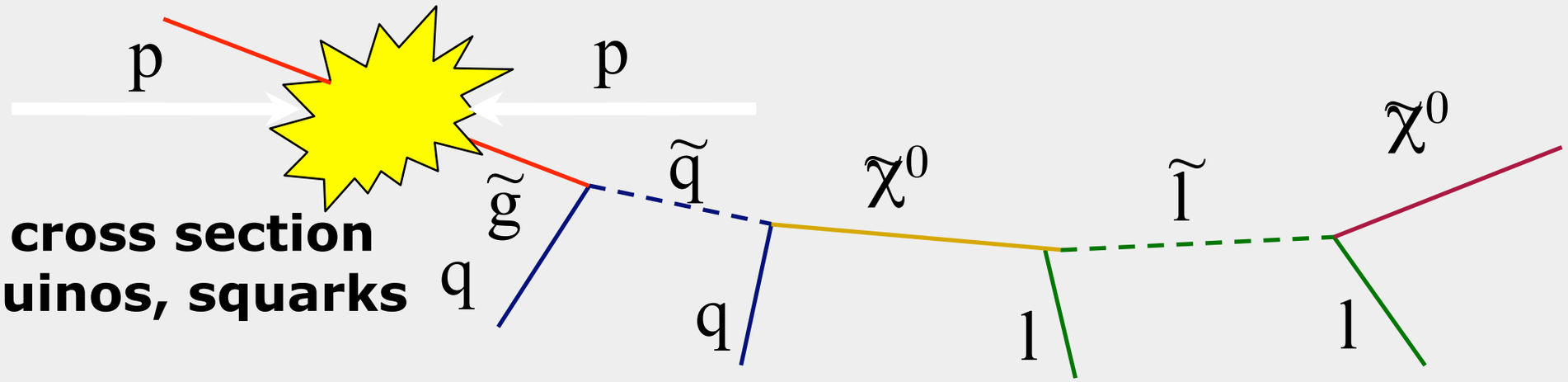
- In hard processes, strongly interacting sparticles (squarks, gluinos) dominate production
  - **~100 events/day (for squarks/gluions masses of ~1TeV at 10^{33} $cm^{-2}s^{-1}$)**
  - **Discovery possible with only 1 fb^{-1}**
- Heavier sparticles than sleptons, gauginos... have cascades decays to the lightest SUSY particle (LSP)
- Long decay chains and large mass differences between SUSY states
  - **Many high p_T objects observed (leptons, jets, b-jets)**
- If R-Parity is conserved LSP is stable and sparticles pair are produced
  - **Large E_T^{miss} signature**
- The largest physics background is neutrino emission (eg. Z->νν)



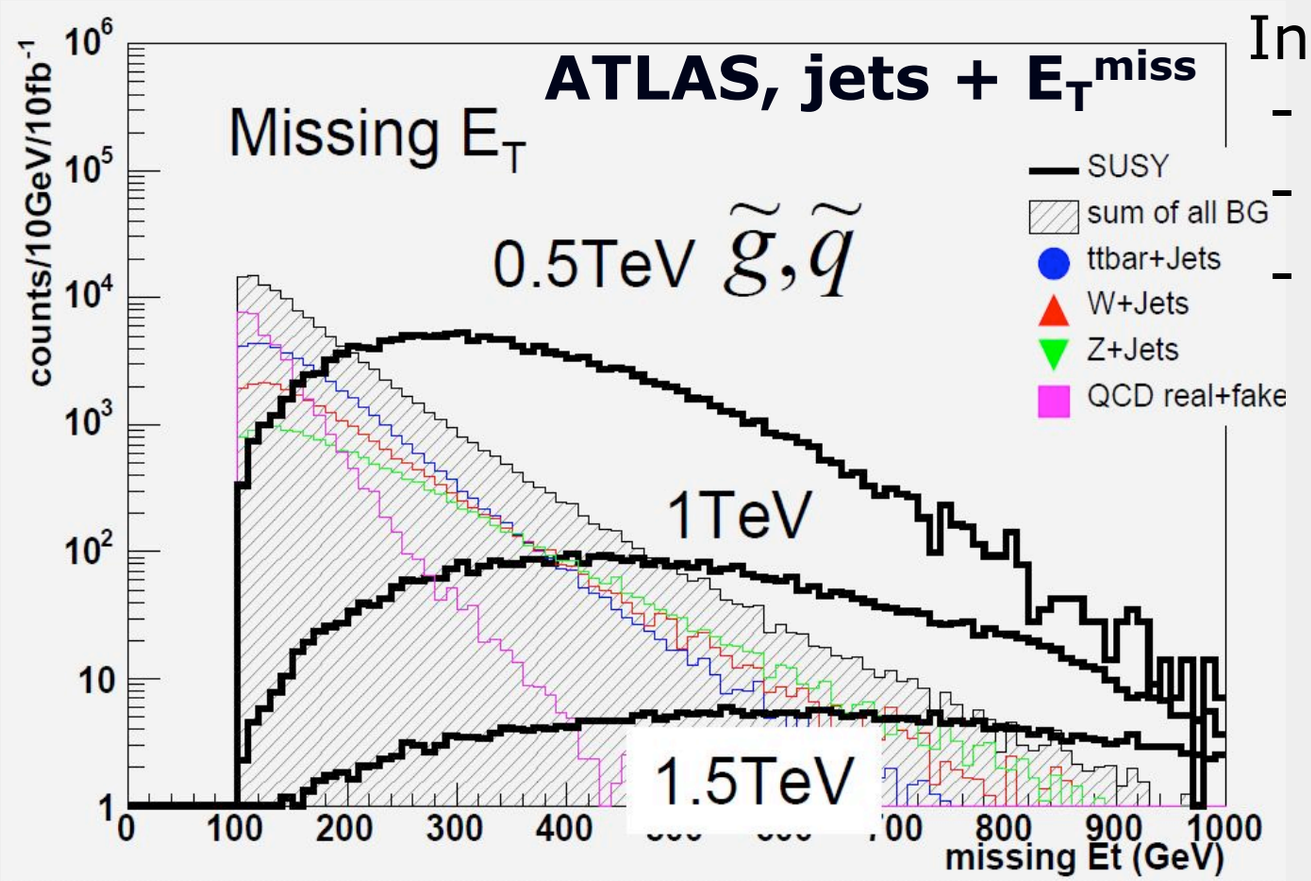


Missing transverse energy carried away by dark matter particles

SUSY in (lepton+)jets+E_T^{miss} final state



Large cross section for gluinos, squarks

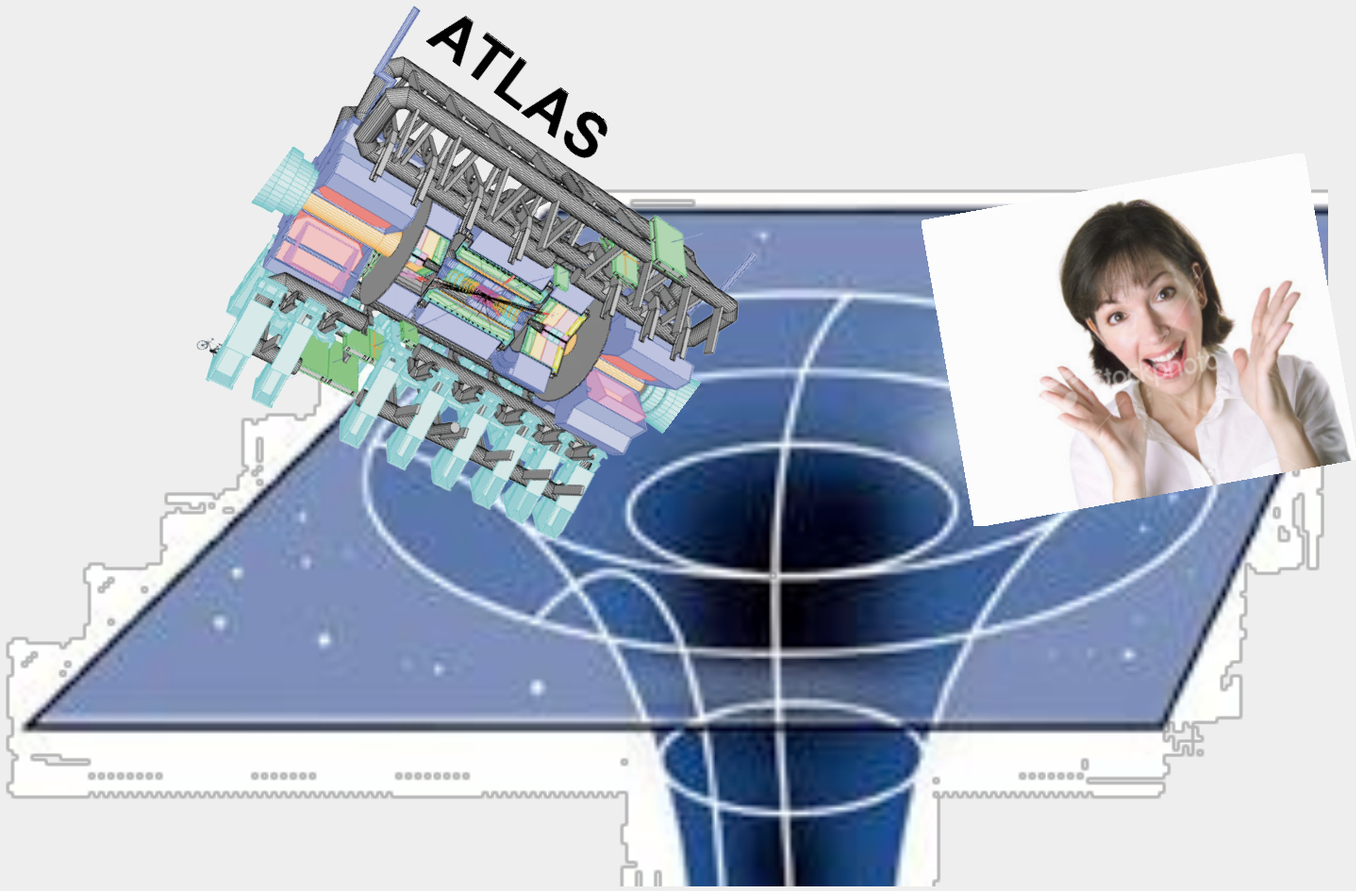


Inclusive searches:
- high p_T jets
- large E_T^{miss}
- optional: high p_T lepton(s) (QCD)

SUSY could show up in:
- E_T^{miss}
- H_T
- M_{eff}

Backgrounds:
QCD, top-pair, W, Z production

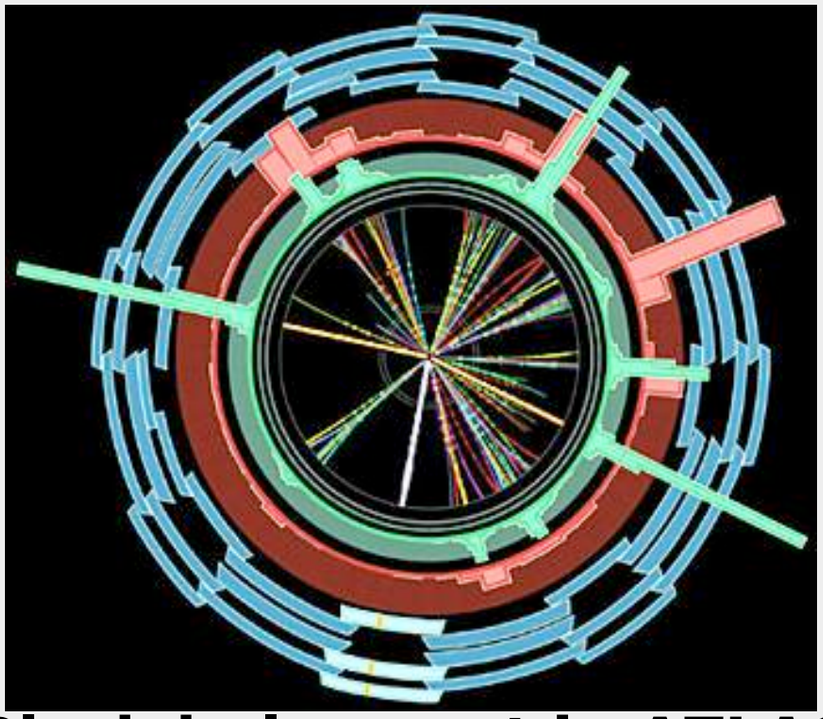
Maybe nature has some REAL SURPRISES in store…



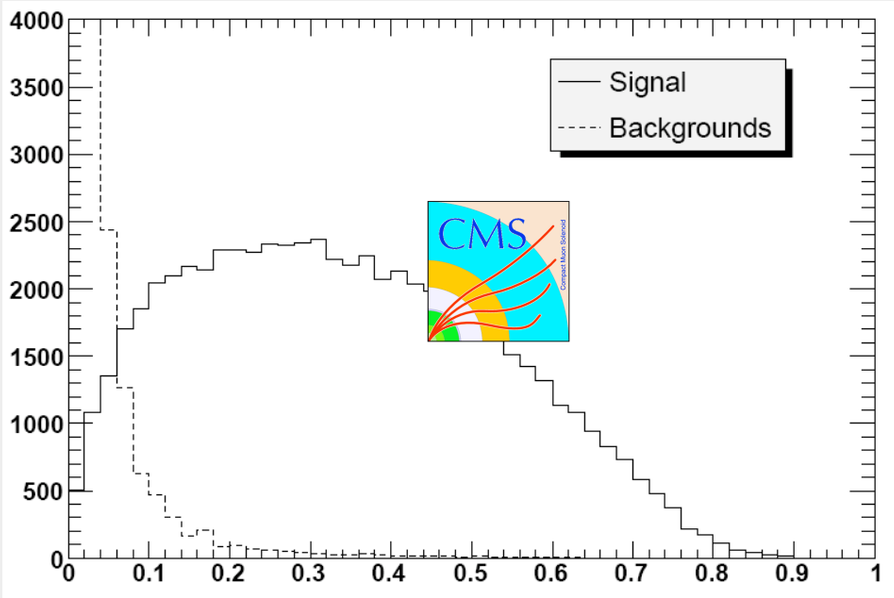
Large extra dimensions, Planck scale ~ EW scale

Possible micro black hole production; decay via Hawking radiation into photons, leptons, jets…

CMS and ATLAS might see this with 1-100 pb^{-1} !



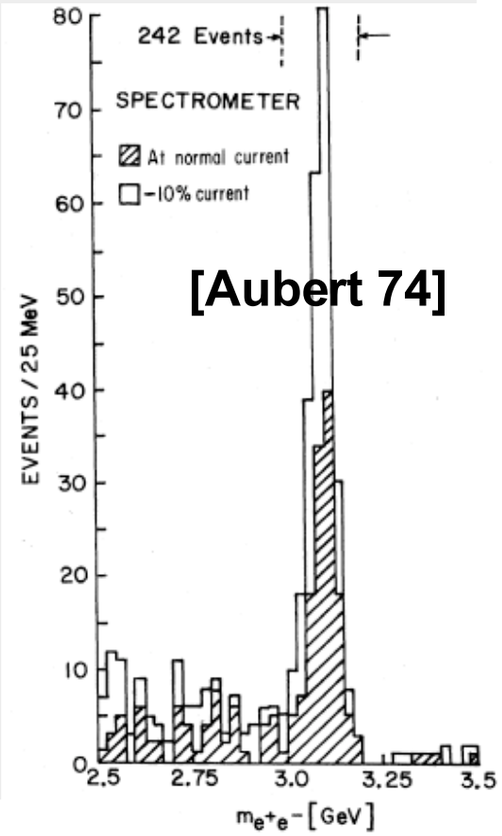
Black hole event in ATLAS



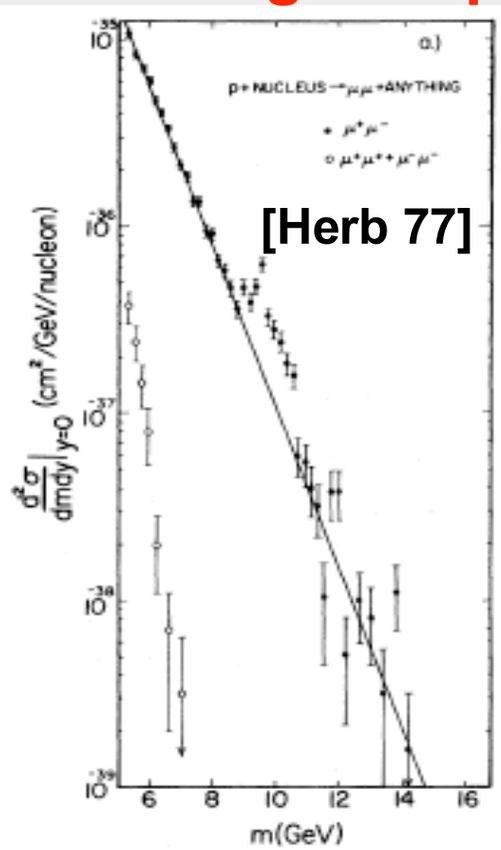
sphericity

$\ell^+ \ell^-$ resonances

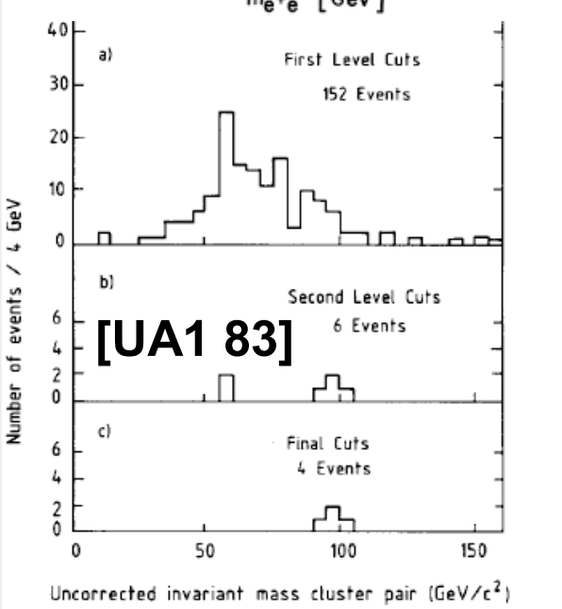
Historically, dilepton resonances have been key in understanding new physics.



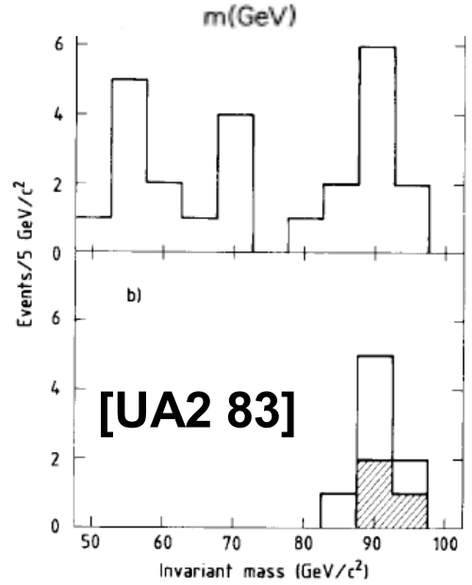
[Aubert 74]



[Herb 77]



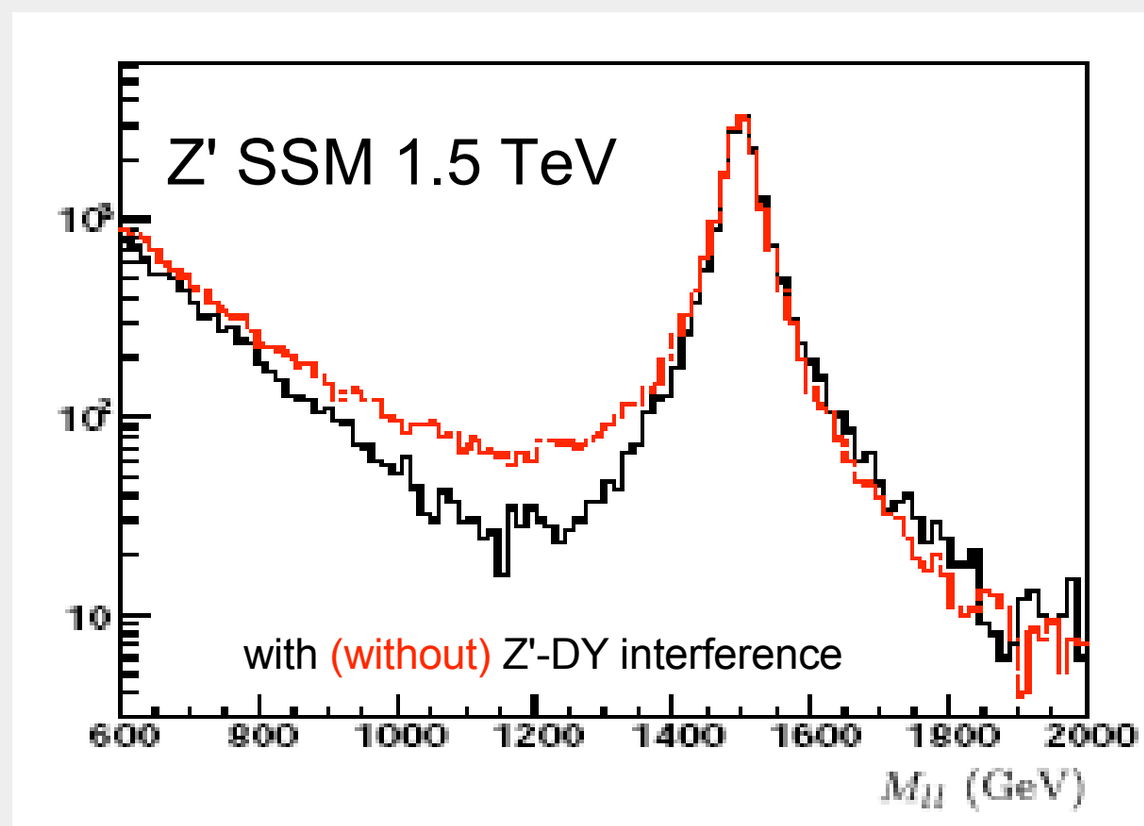
[UA1 83]



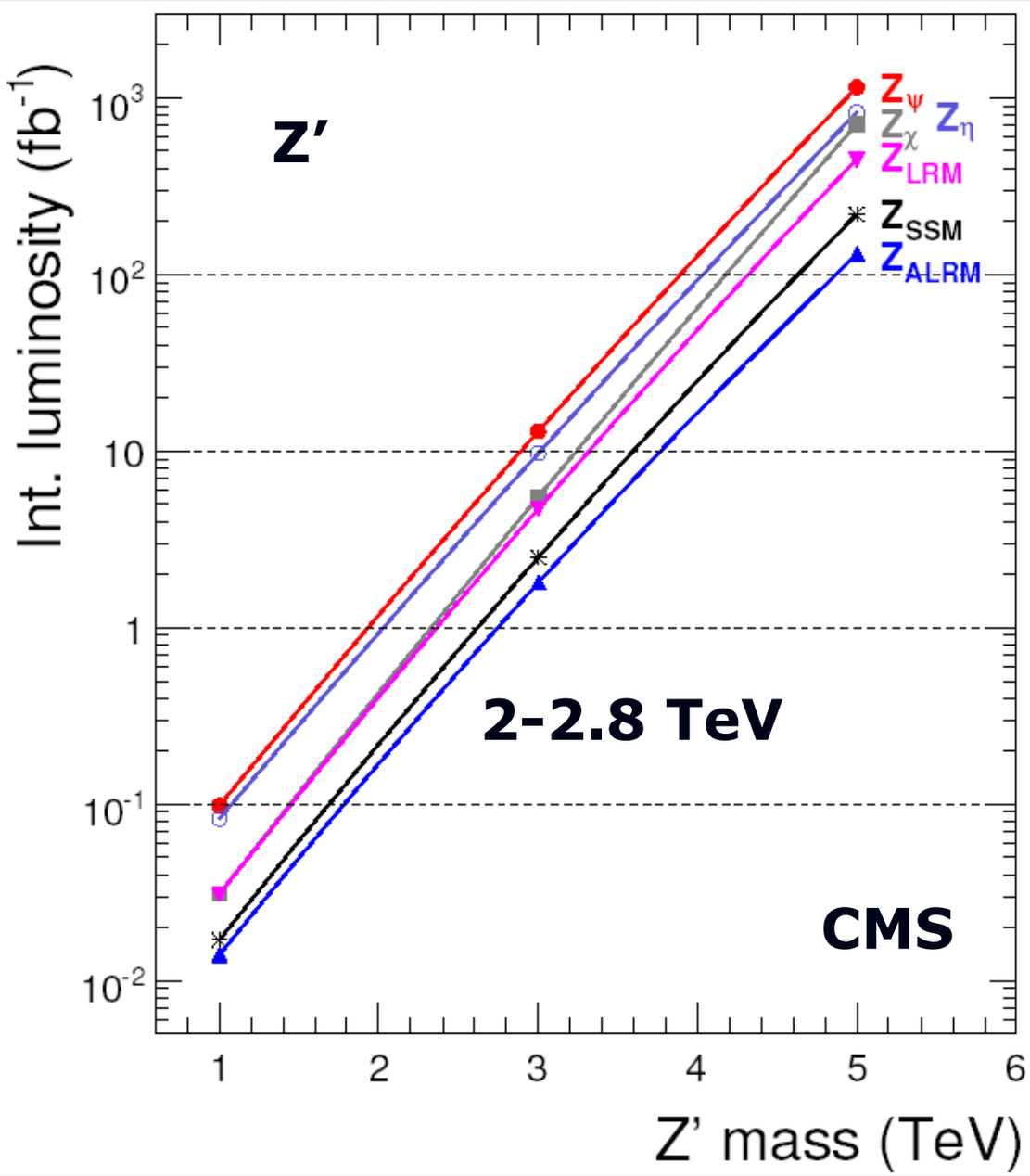
[UA2 83]

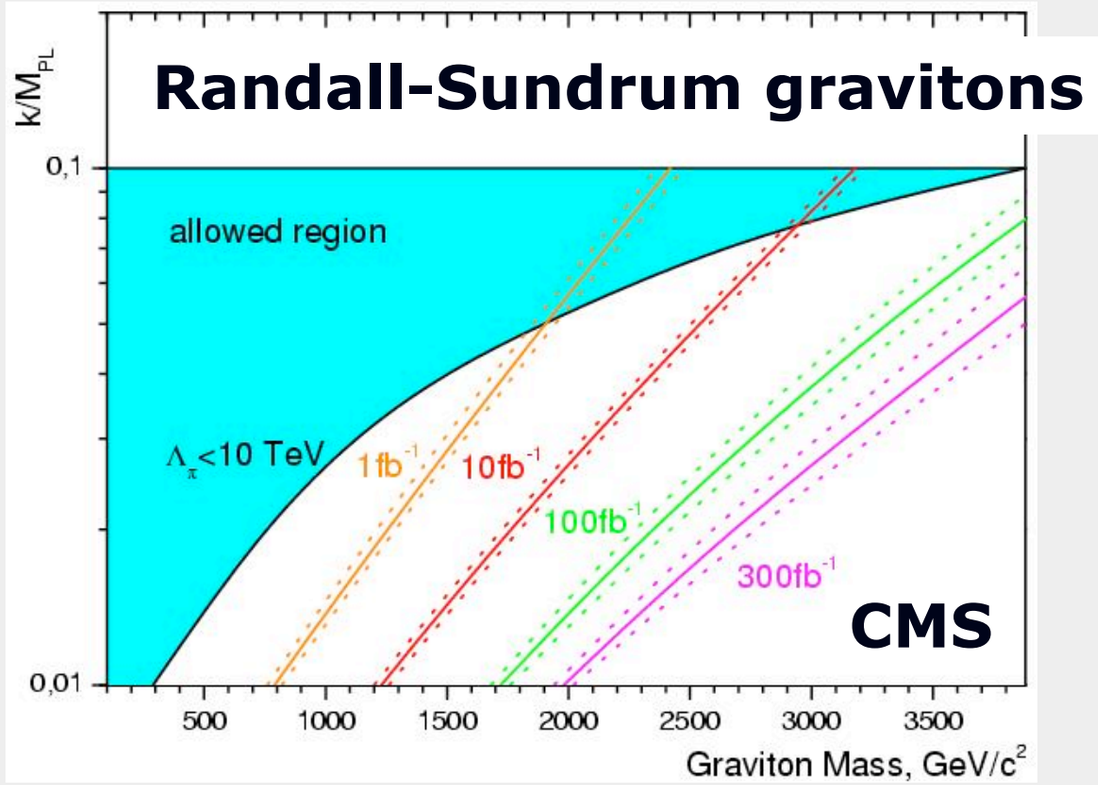
Today, dilepton resonances arise in many BSM scenarios such as:

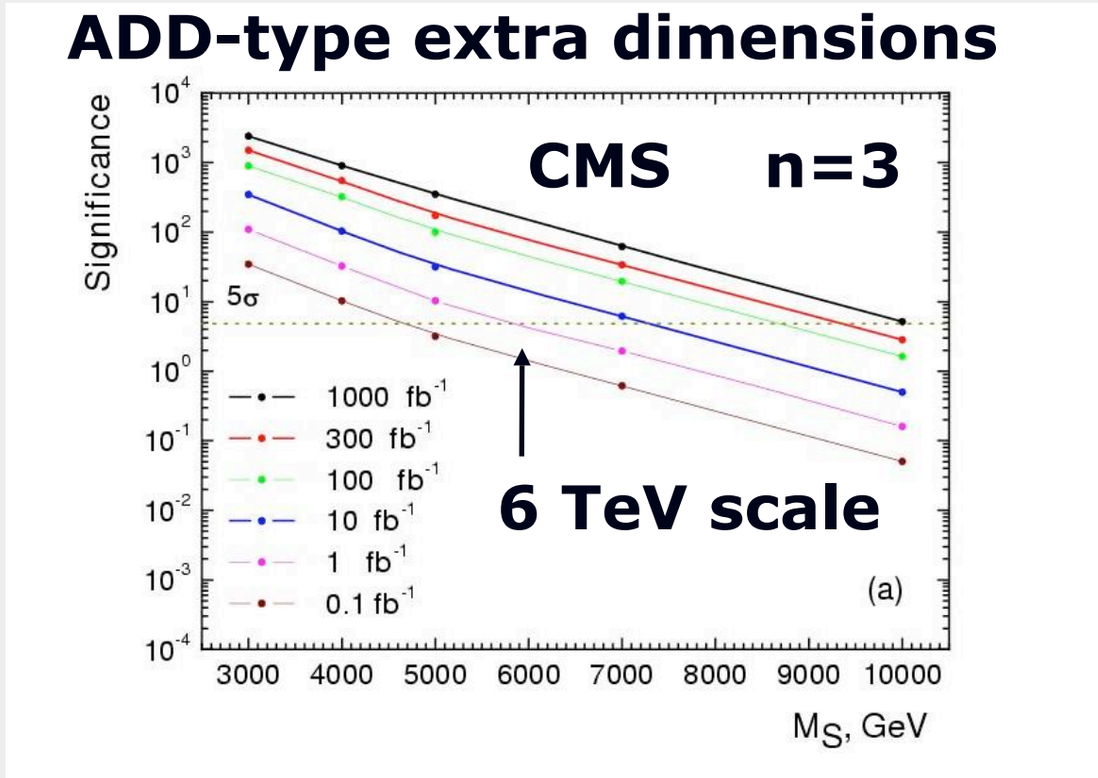
- **Z' gauge boson from extended symmetry (GUTs)**
- **Z_H in Little Higgs models**
- **Kaluza-Klein excitation of**
  - **gauge boson (extra dimensions)**
  - **graviton (Randall-Sundrum)**
- **...**



Sensitivities for various new physics models

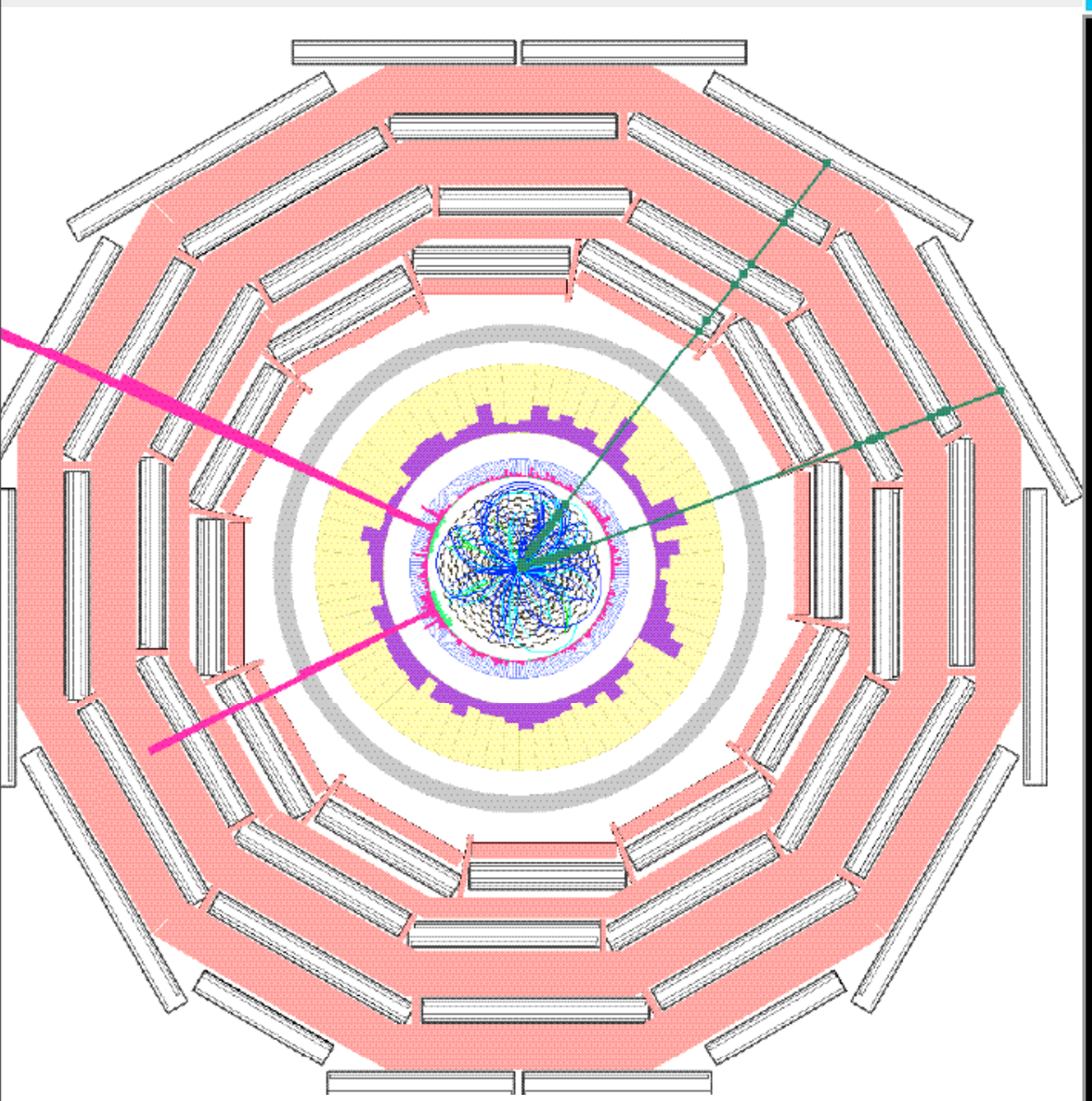






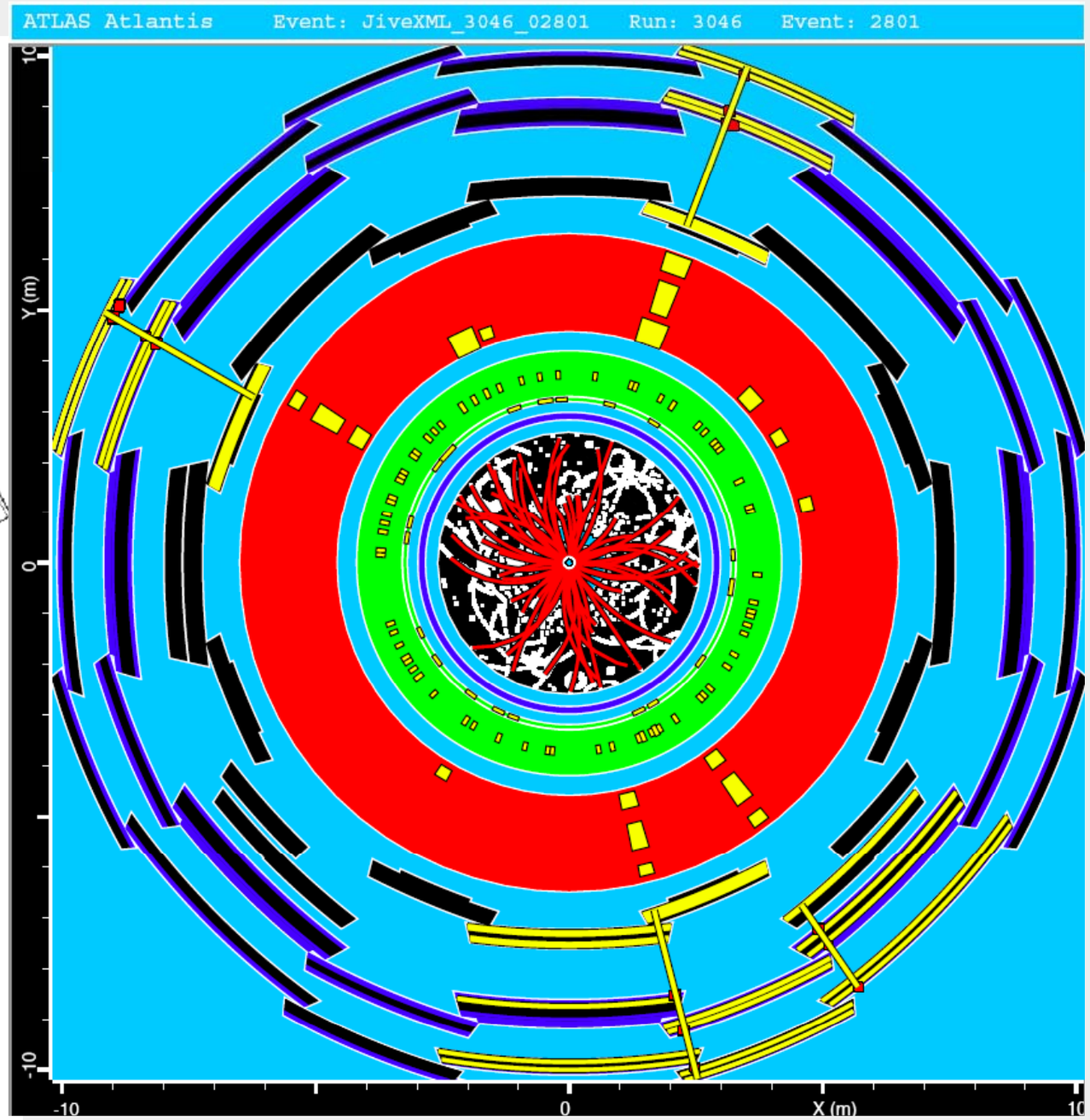
Higgs event displays

CMS



$H \rightarrow ZZ \rightarrow ee\mu\mu$

Atlas



$H \rightarrow ZZ \rightarrow 4\mu$

Origine of mass: the Higgs mechanism

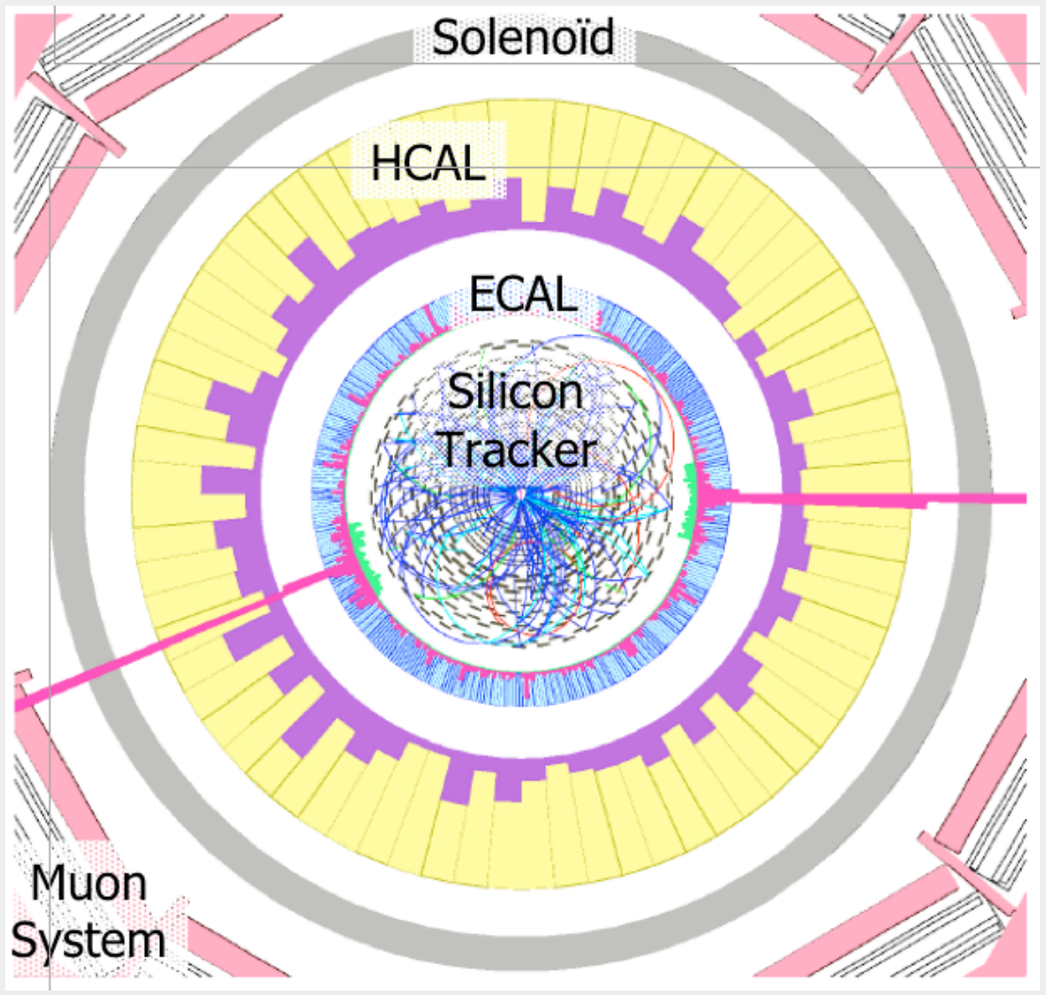
- **In the basic theory => Particles are massless**
- **One suppose that there exist in the Univers a specific Field**
- **All particles interacting with that field are getting their mass. It's value is related to the strength of the interaction.**
- **The quantum of that Field is the Higgs boson**
- **The observation of the Higgs boson will establish the existence of the Field and so the origin of the particles mass.**

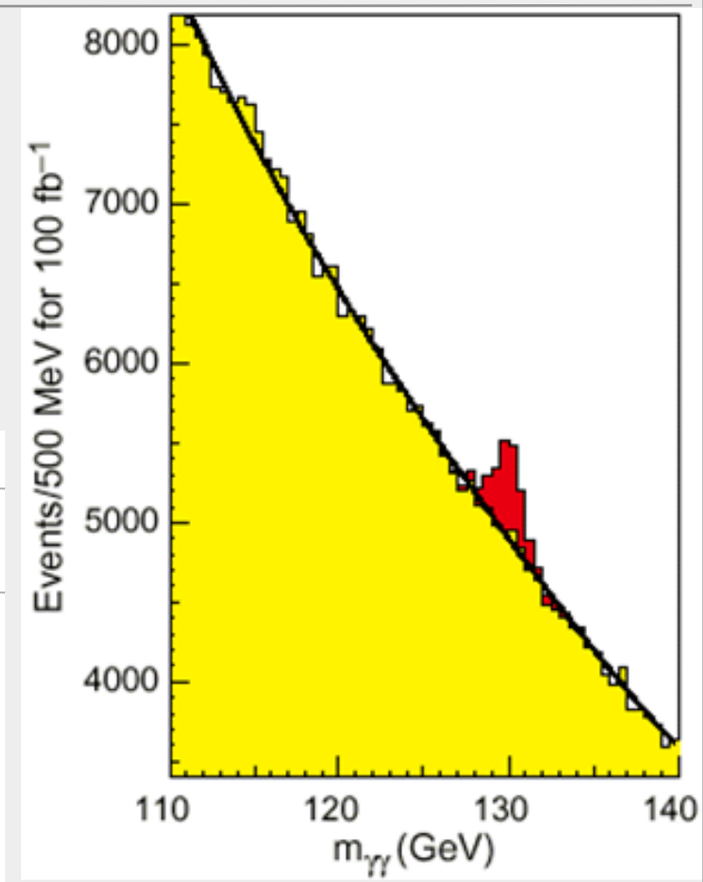
Search for H→γγ

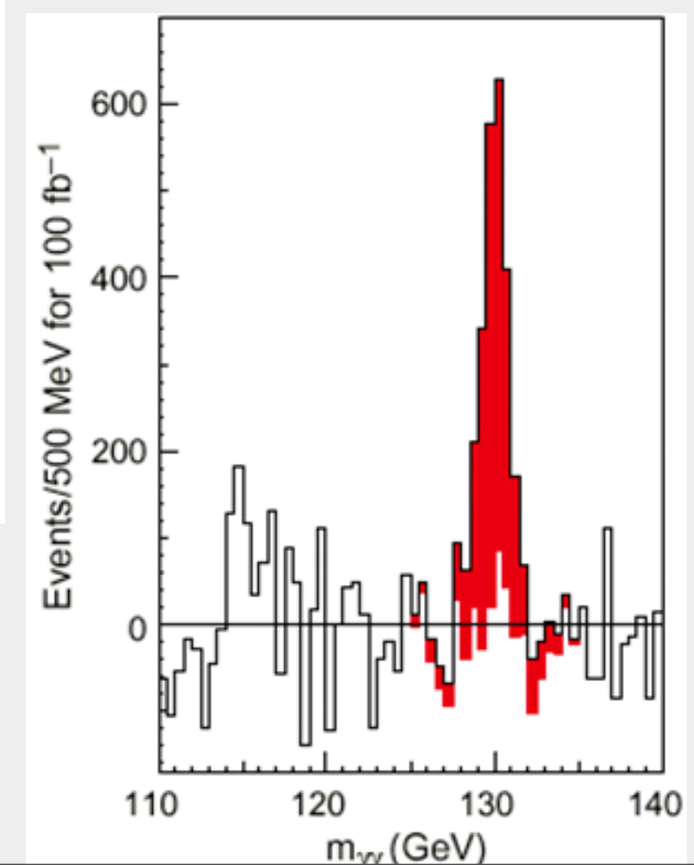
- Narrow peak over a hudge smooth background
  - Higgs' width negligible for low masses
  - Relies on photon id, energy resolution and primary vertex determination
- Powerful at low m_H (6 to 8σ @ 30fb^{-1})

==> Key points:

- Photon id
  - ATLAS: high granularity → high γ/π^0 separation
  - Isolation cuts
  - Recovery of conversions
- Different strengths, similar sensitivity
  - ATLAS: photon id, angle
  - CMS: energy resolution

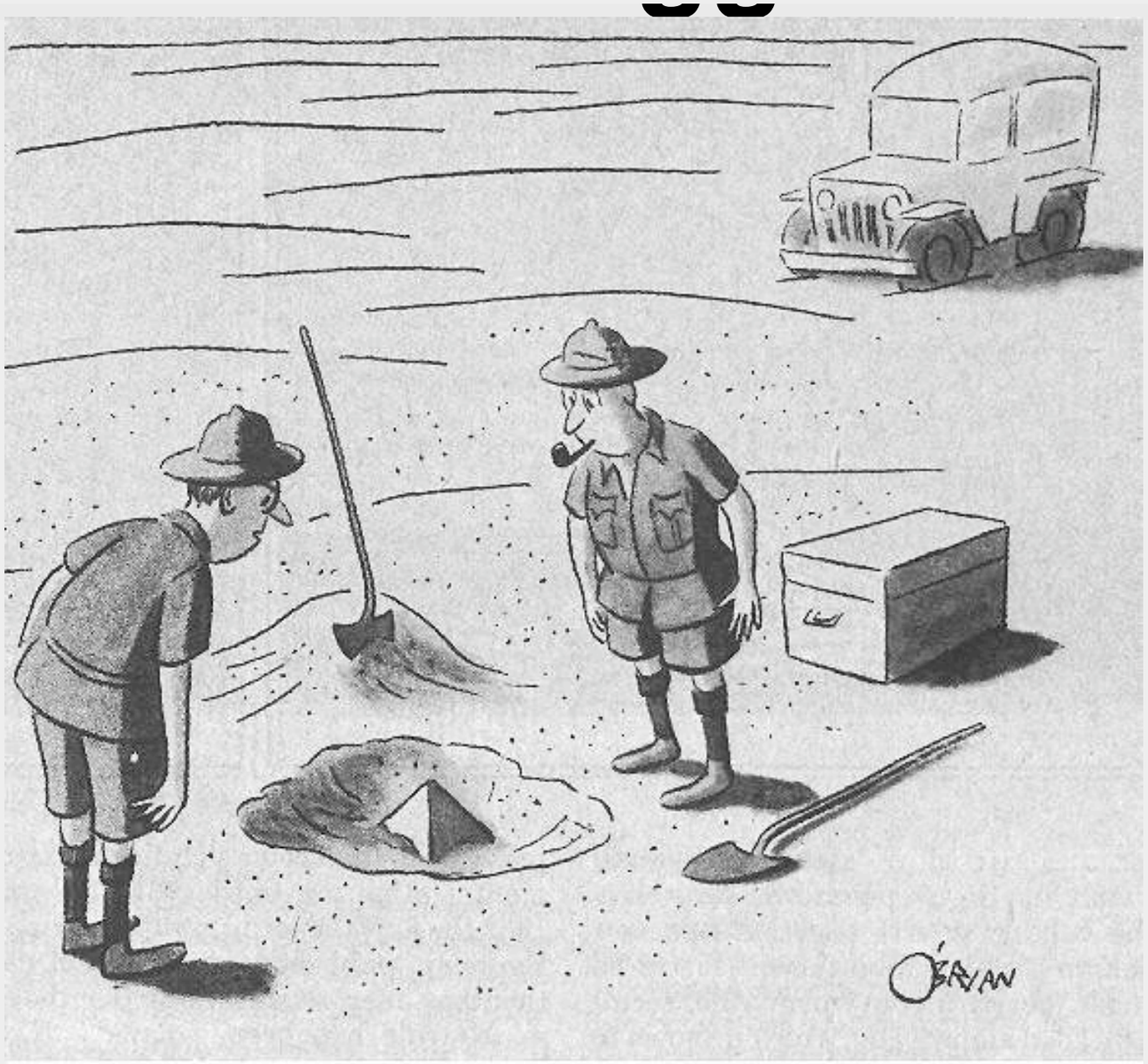






Higgs or not....

An excess of events is observed, that could be a Higgs Boson...



"This could be the discovery of the century. Depending, of course, on how far down it goes."

What is it ?

Something is seen in Standard Model discovery modes :

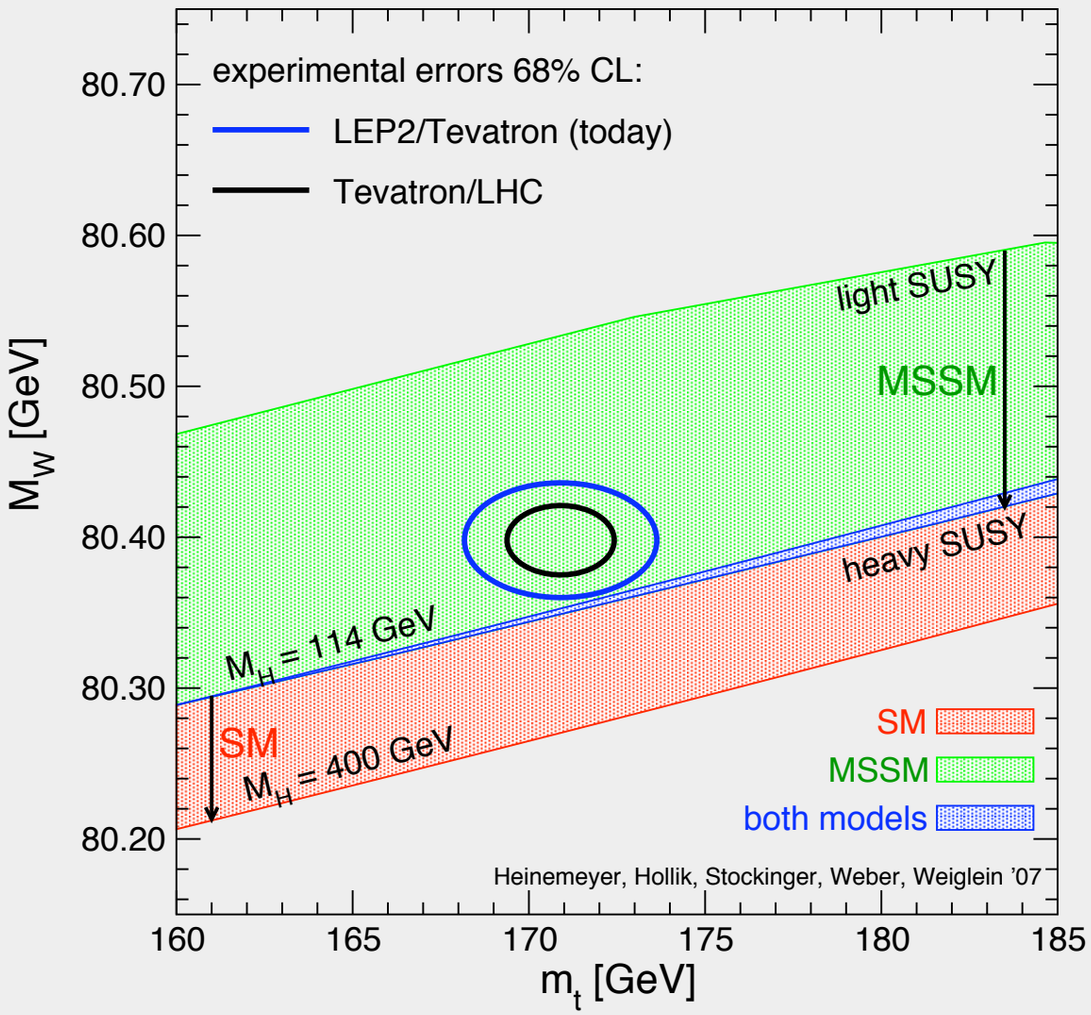
- The pessimist (1) : it's standard model background
- The pessimist (2) : it's the standard model Higgs Boson
- The optimist : it's the first of 26 completely new particles (e.g. in total 42 fundamental particles)
- The realist : it might be the (Standard Model) Higgs Boson, we will have to analyze carefully to make sure
  - ➔ What is the mass and width (charge??)
  - ➔ Production processes / cross sections
  - ➔ Branching ratios, couplings, self-coupling?
  - ➔ Spin, CP, tensor structure of couplings

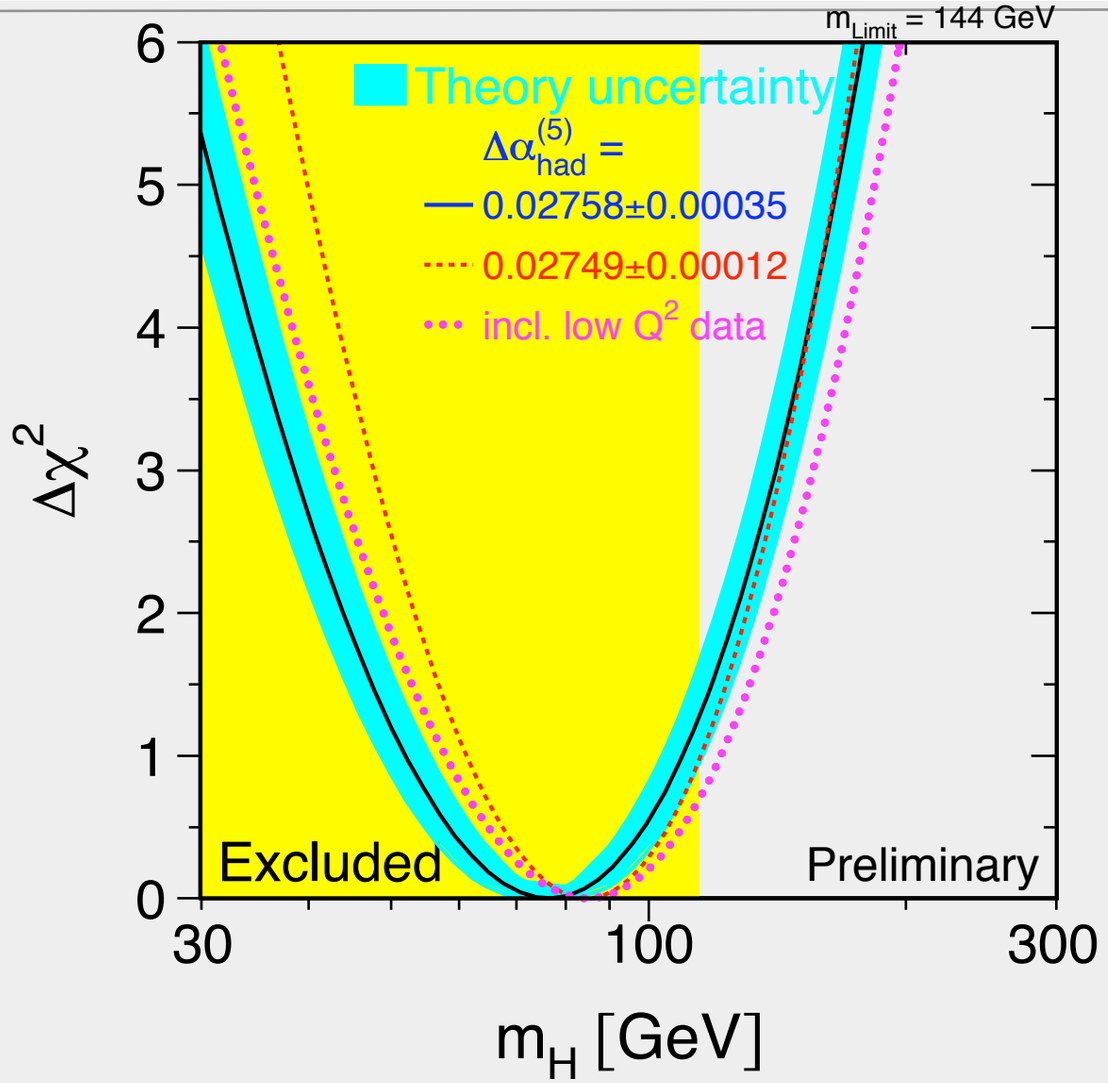
  (e.g. we have to work hard for a long time)

Something is seen in an “exotic” discovery mode :

- Not a Standard Model Higgs Boson, next step will be all possible measurements, but hard to make any predictions now...

Prediction of m_H, Verification of Higgs Mechanism





$m_H = 76\,^{+33}_{-24}$ GeV; $m_H < 144$ GeV at 95% C.L.

Recent improvements

- m_W up from 80392 to 80398 MeV
- Uncertainty from 29 to 25 MeV
- SM prediction for Higgs from:

85^{+39}_{-28} GeV $\Rightarrow 76^{+33}_{-24}$ GeV LEPEWG

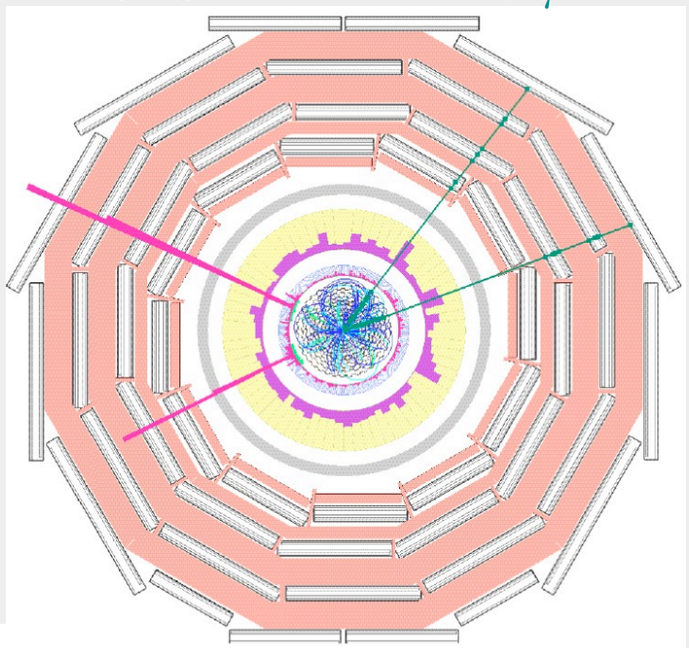
- The 95%CL upper limit on m_H drops from 199 to 182 GeV
  - Includes direct search lower bound and recent top mass

$H \rightarrow ZZ^{(*)} \rightarrow 4l$: signal

GOLDEN MODE

3 final states : $H \rightarrow ZZ^{(*)} \rightarrow$ e+e- e+e- ("4e")
e+e- μ+μ- ("2e2μ")
μ+μ- μ+μ- ("4μ")

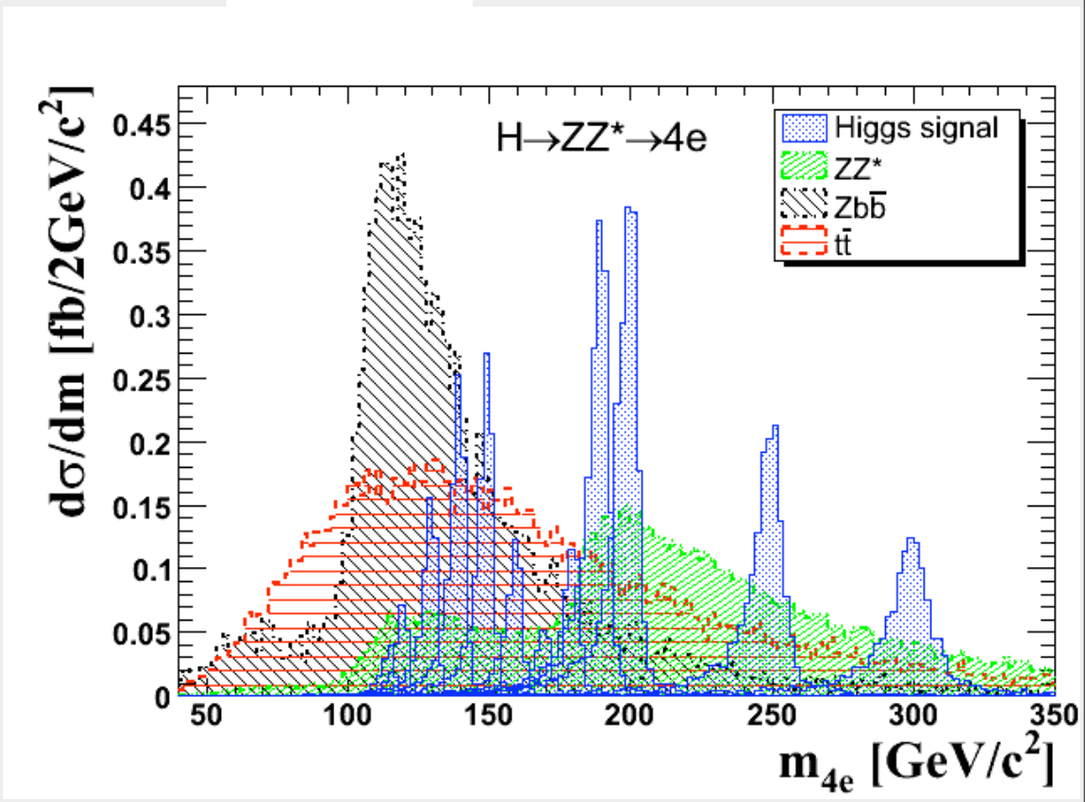
CMS : $H \rightarrow ZZ^{(*)} \rightarrow 2e2\mu$



- *clean and simple experimental signature :*
  - ☆ 2 pairs of oppositely charged and isolated same-flavour leptons
  - ☆ same primary vertex
  - ☆ di-lepton invariant mass compatible with Z-boson mass
- *narrow resonance in 4-lepton invariant mass spectrum*
- *relatively small backgrounds*

  (S/B = 5-12 for m_H=150 GeV/c^2)
- *measurement Higgs boson properties :*

  mass, width, spin + CP eigenvalue, ...



$H \rightarrow ZZ^{(*)} \rightarrow 4l$: backgrounds

- *3 main sources :*

NLO cross section (pb)				
signal m_H *(GeV/c²)*		*backgrounds*		
150	200	*ZZ*	*Zbb*	*tt*
30	18	29	278	840

reducible : Zbb, tt

☆ $Zb\bar{b}$: $Z^{(*)}/\gamma^* \, b\bar{b} \rightarrow 2l \, b\bar{b} \rightarrow 4l$

☆ $t\bar{t}$: $W^+bW^-\bar{b} \rightarrow 2l2\nu \, b\bar{b} \rightarrow 4l$

main characteristic :

2 leptons inside b-jets ⇨ at least one non-isolated and rather soft lepton pair

⇨ displaced vertices

↳suppress by p_T- cuts, isolation and impact parameter criteria

tt: further reduction requiring M(*l*+*l*-) to be close to nominal Z-boson mass

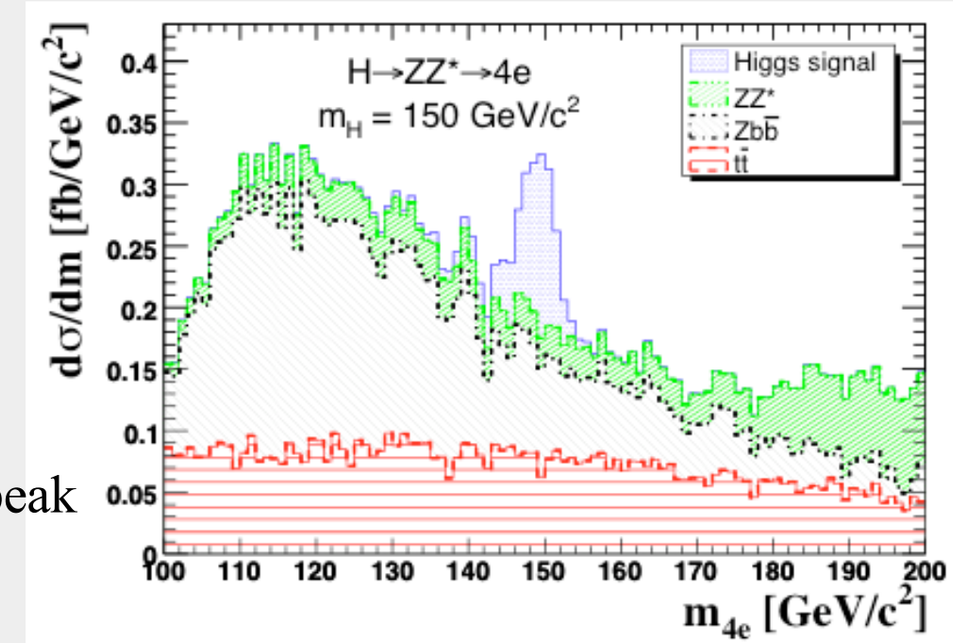
irreducible : ZZ = dominant background

☆ *ZZ* : $Z^{(*)}/\gamma^* \; Z^{(*)}/\gamma^* \rightarrow 4l$

main characteristic :

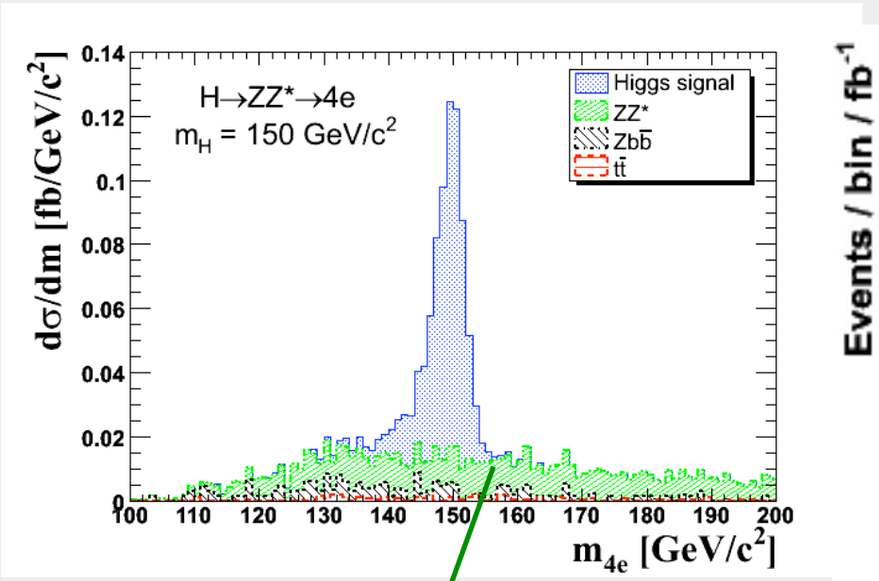
non-resonant Z-pair production ⇨ broad M(*4l*) spectrum

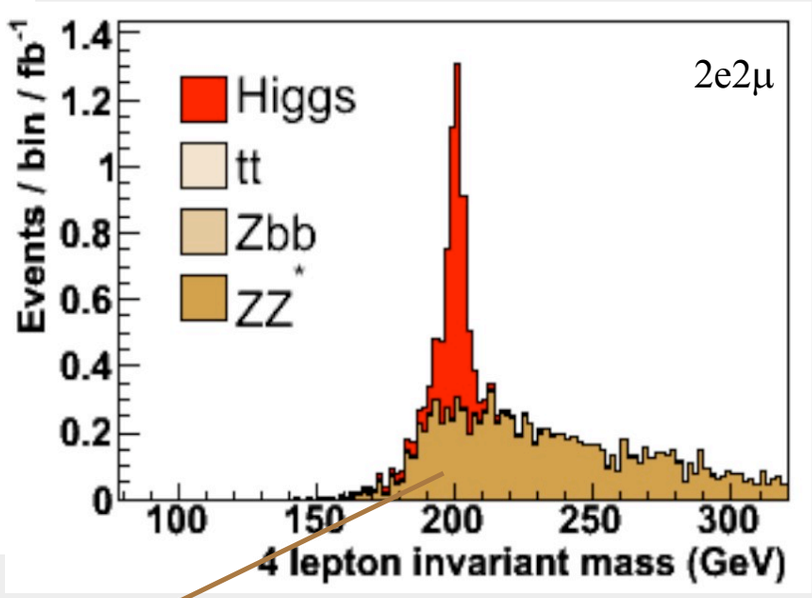
↳restrict to narrow M(*4l*)-window centered on Higgs signal mass peak

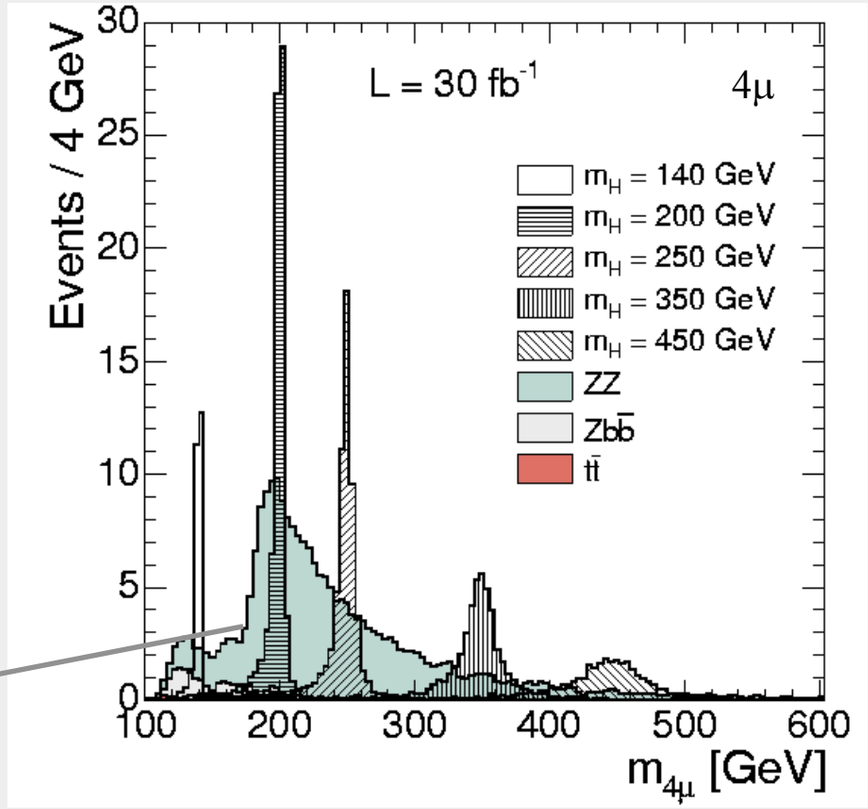


- *found negligible :* bbbb, bbcc, cccc, Zcc, Wbb, Wcc , single top, "fake" leptons or π/K decay leptons in QCD bkg

Selection : summary







- ***ZZ dominant or sole remaining background after all cuts***

  > 75 % of total background over full mass range
  > 95 % for $m_H > 2.m_Z$

- *Zbb relevant for low masses :*

  20-15 % for low masses
  < 2 % for $m_H > 2.m_Z$

- *tt small over whole mass range :*

  7-5 % for low masses
  < 0.6 % for $m_H > 2.m_Z$

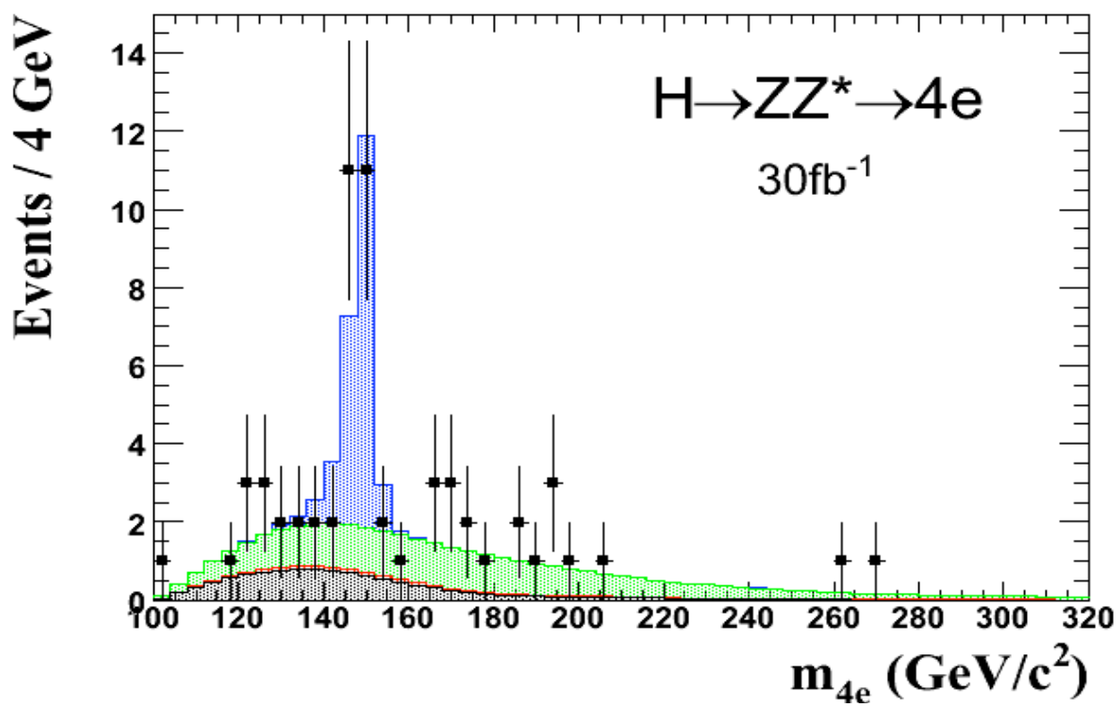
Typical full selection performance:

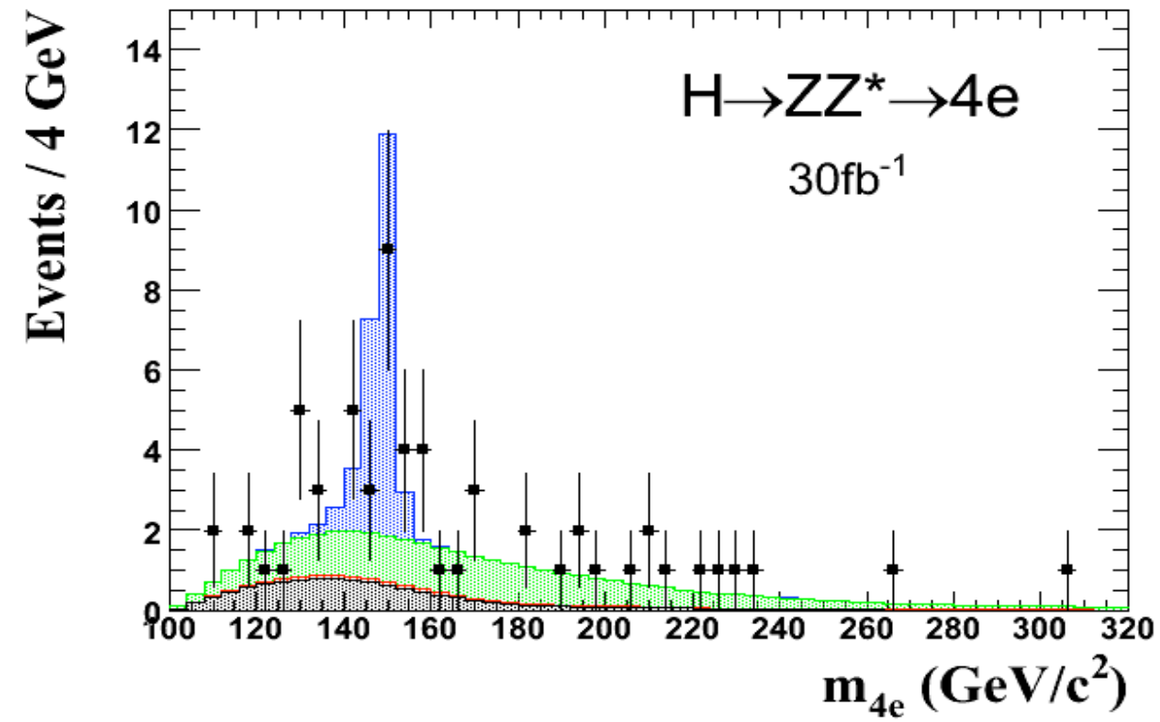
background rejection : 2×10^3- 10^4 on *tt*
500 - 10^5 on *Zbb*
20 - 4 on *ZZ*

signal efficiency : 25- 50 %

Lucky or not ...

Single MC experiments for 30 fb^{-1}



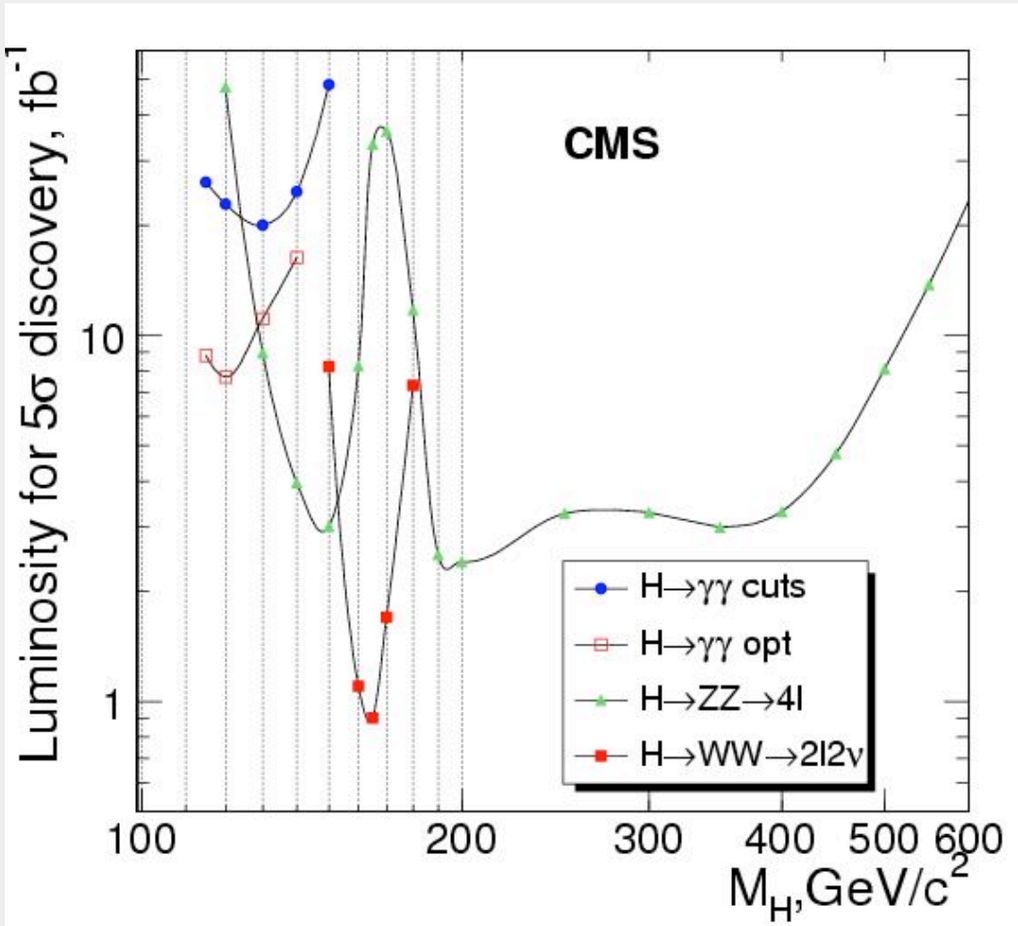


8.5% probability
for equally or more pronounced peak

23.5% probability
for equally or less pronounced peak

Early discovery... with some luck

A SM Higgs boson with a mass of 165 GeV



No mass peak: counting experiment

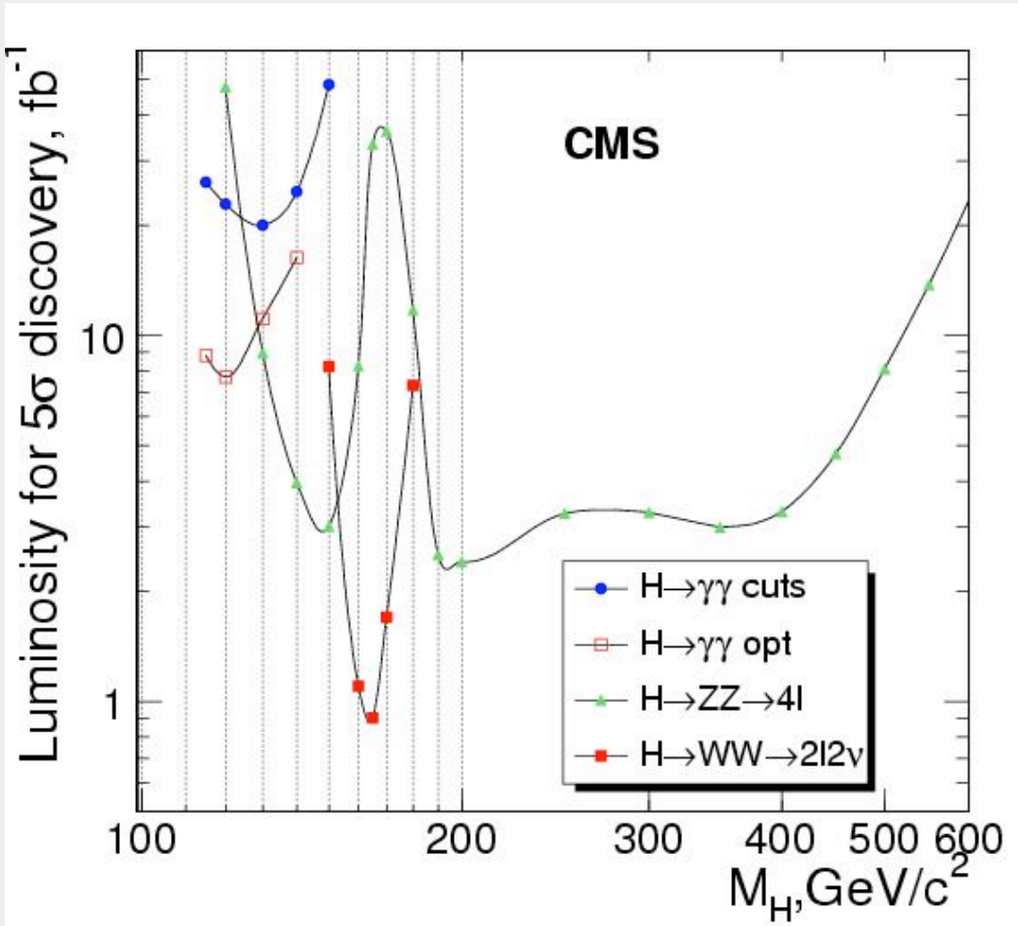
Challenge: extremely good knowledge of background needed

Backgrounds: qq→WW, gg→WW, tt→WWbb, tWb→WWb(b),
ZW→lll, ZZ→ll,νν

Get background from data itself: control samples: tt, WW, WZ

Early discovery... with some luck

A SM Higgs boson with a mass of 165 GeV



No mass peak: counting experiment

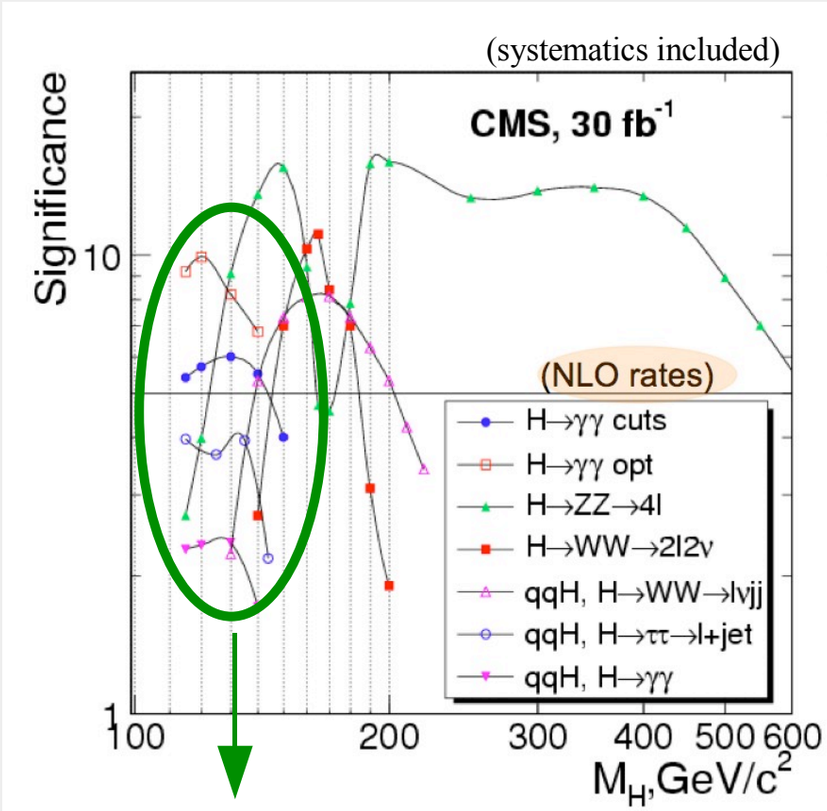
Challenge: extremely good knowledge of background needed

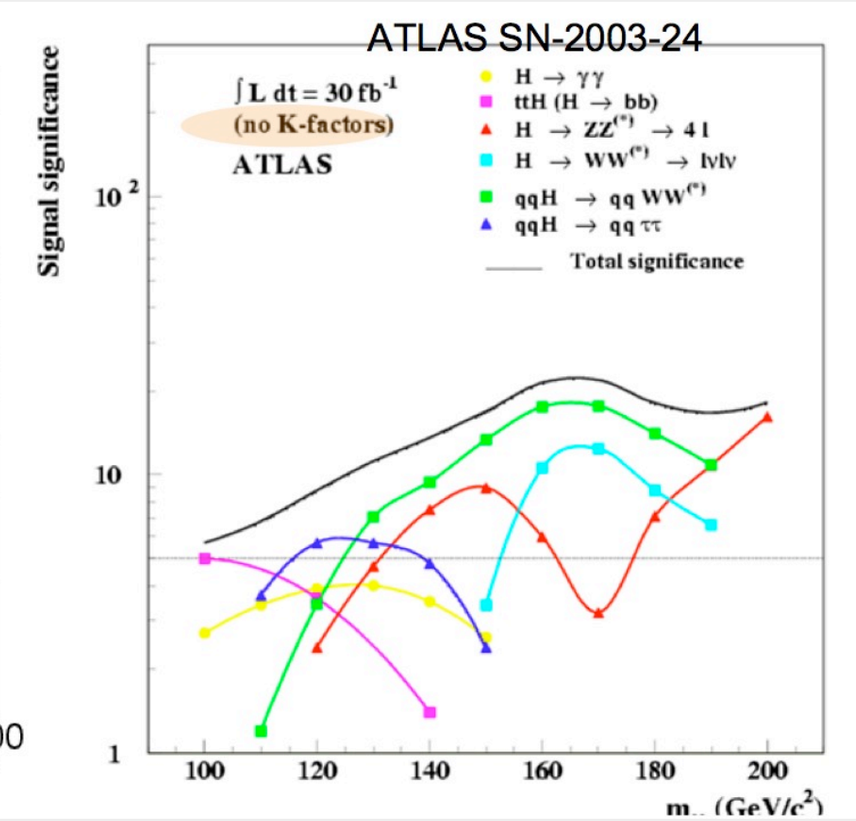
Backgrounds: qq→WW, gg→WW, tt→WWbb, tWb→WWb(b),
ZW→lll, ZZ→ll,νν

Get background from data itself: control samples: tt, WW, WZ

Challenge: understanding of control samples
control of systematics
keep theory uncertainties small

Discovery potential : $H \rightarrow ZZ^{(*)}$ in a larger picture

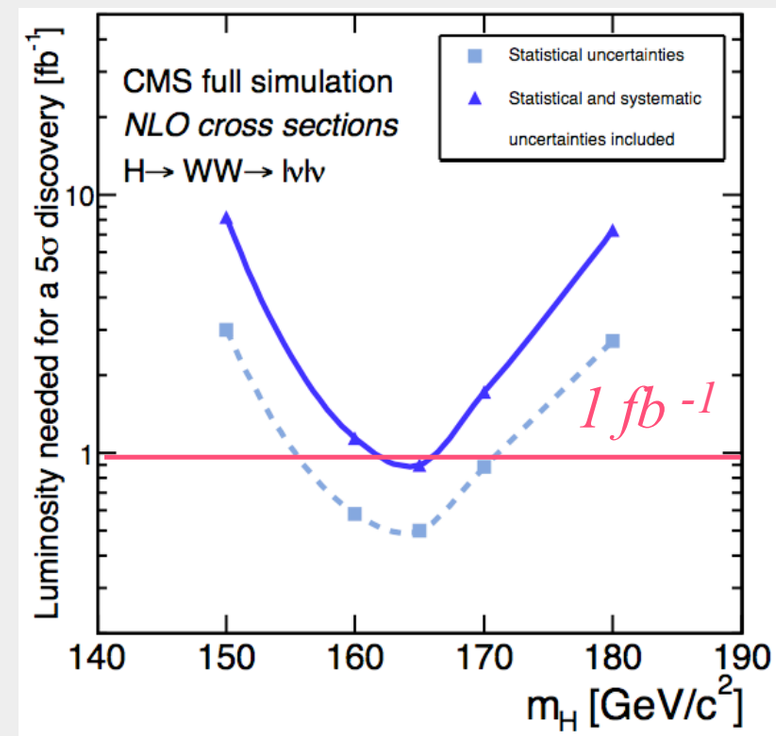




gap 160 < m_H <180 GeV/c^2 :

↳filled by fast discovery channel

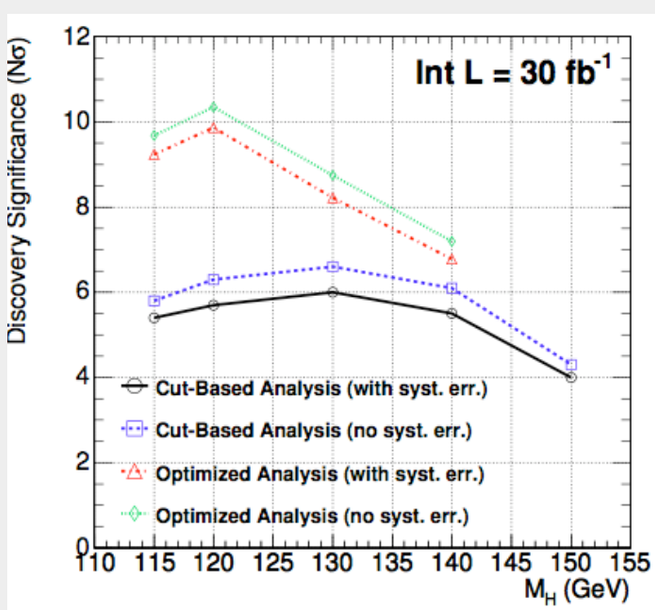
H→ WW → 2l2ν

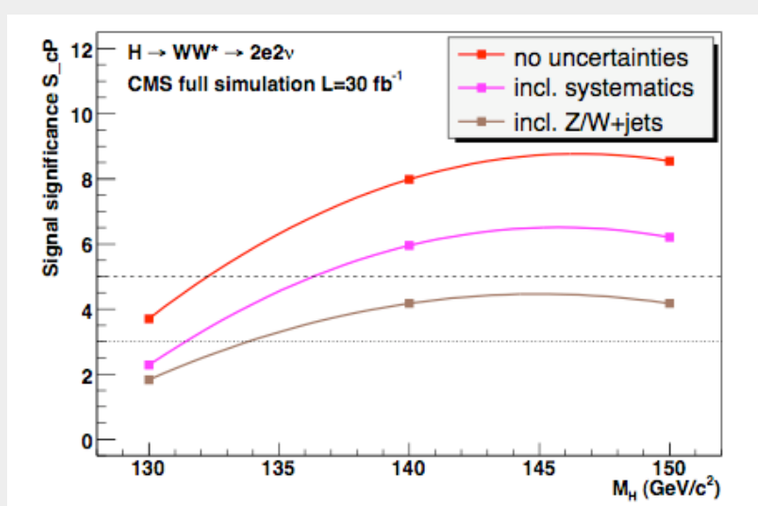


less than ~1 fb^{-1} needed for 5σ discovery

m_H < 150 GeV/c^2 : complementary measurements with e.g.

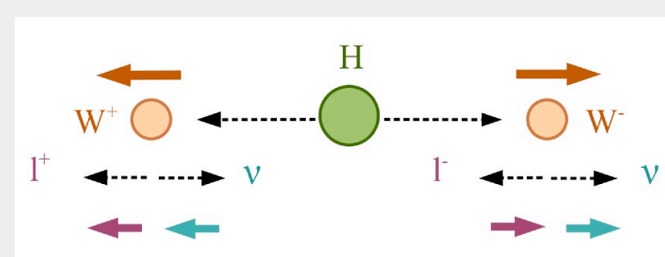
H→ γγ and *H→ WW → 2l2ν*





several 10 fb^{-1} needed for 5σ discovery

except m_H=120 GeV/c^2 : 7.7 fb^{-1} in *H→ γγ*



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- But essential: put everything in place to get reliable results quickly when more luminosity will be available.

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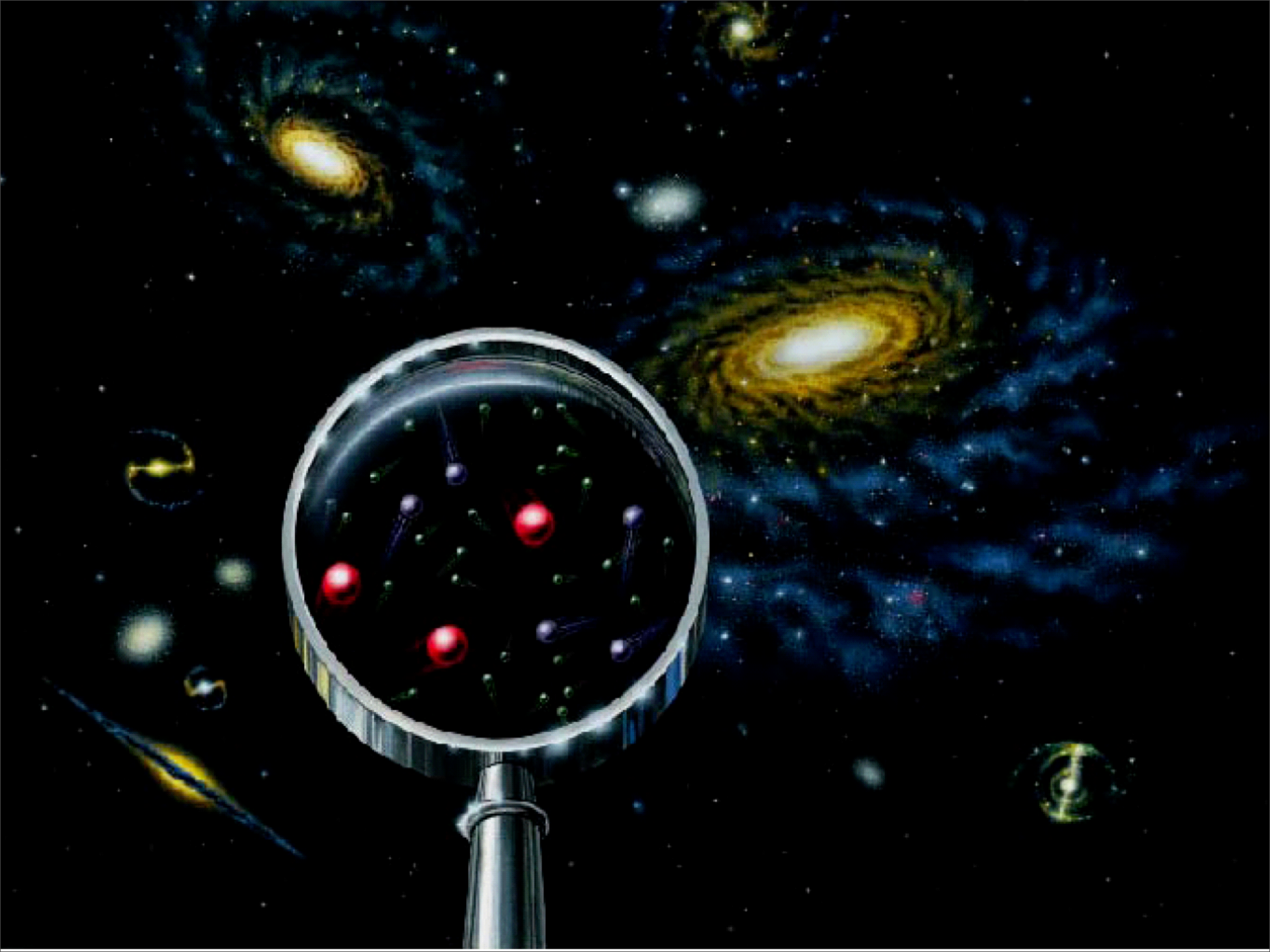
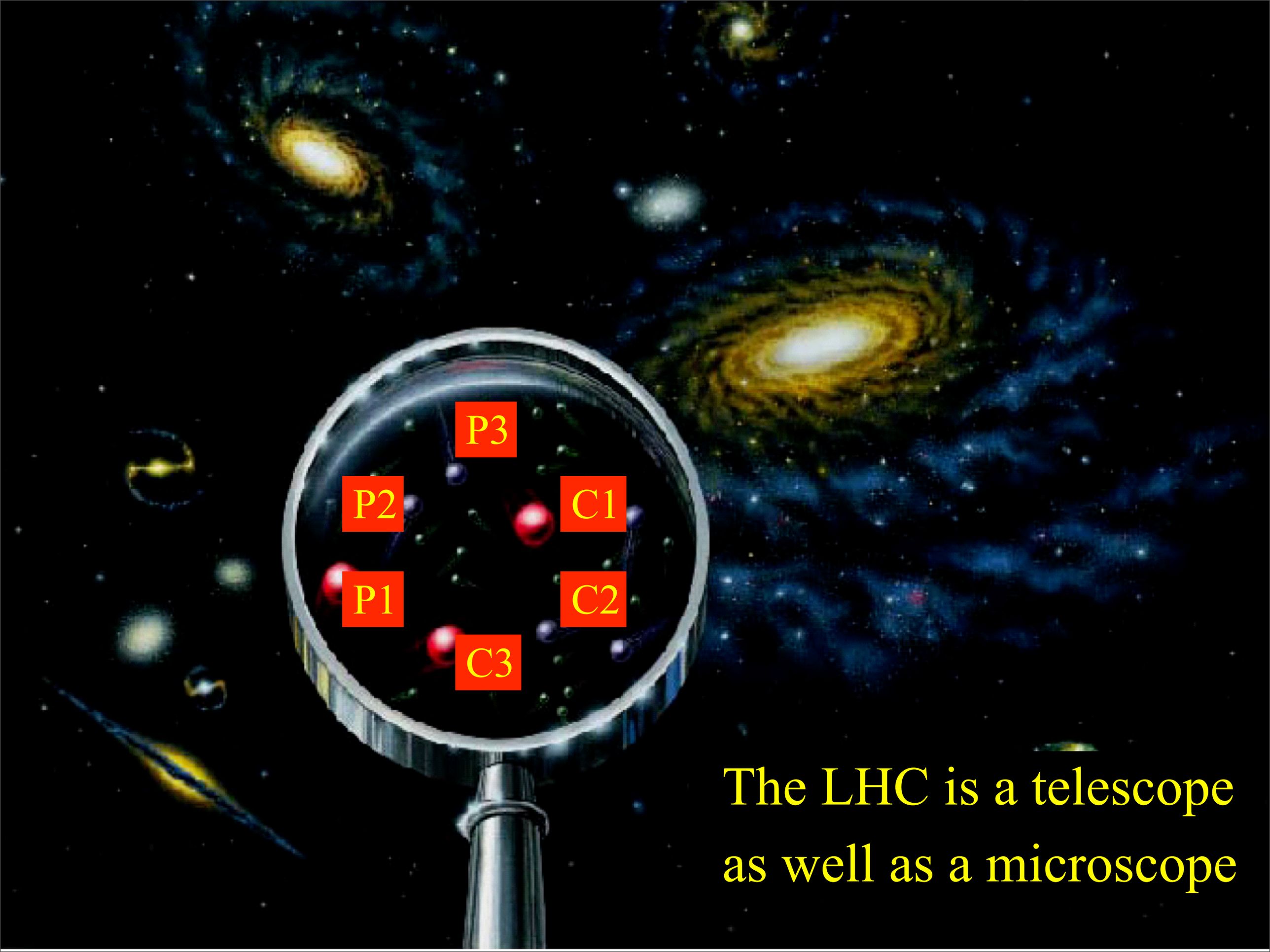
- There may even be a revolution in physics
- In one Year from now, first data will be available.





The LHC is a telescope
as well as a microscope

Thanks

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