Na drodze do realizacji wyzwań LHC

M. Turała

Instytut Fizyki Jądrowej PAN, Kraków

Plan referatu

- Wprowadzenie
- Akcelerator LHC
  - Stan prac i plany
- Detektory LHC
  - Wkład zespołów polskich
- Komputing dla LHC
  - Polski Tier2
- Fizyka LHC
  - Czego można oczekiwać w pierwszych latach?
- Podsumowanie

Wprowadzenie

The beginning

Successful exploration of SPS collider at CERN

- experience with complex pp-bar events and discoveries of W, Z

What could be done with high energy protons

- ideas on LHC and SSC

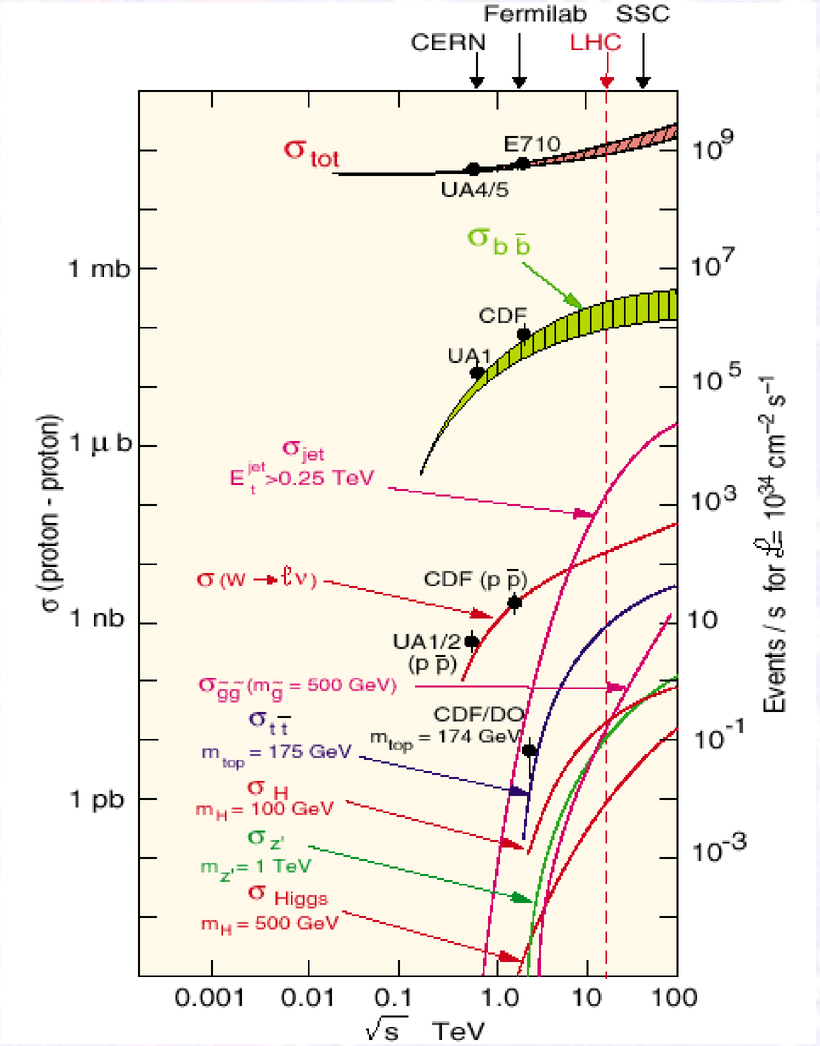
Vigorous R&D programme

- detectors and machine

Shaping of LHC collaborations

- ATLAS, CMS, … ALICE, … LHCb, … TOTEM…

Approval of LHC program (1995)



Akcelerator LHC

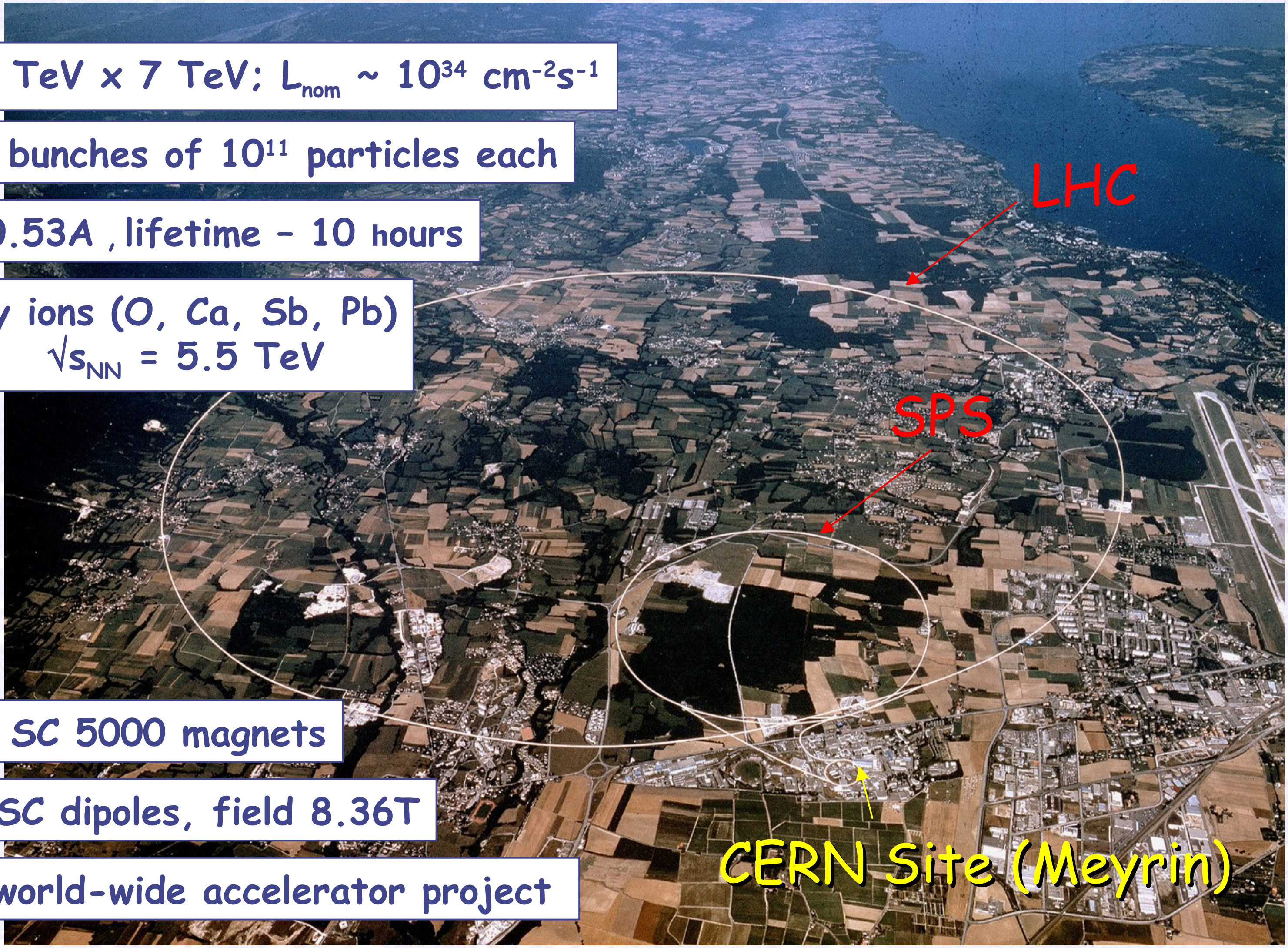
LHC collider at CERN

pp 7 TeV x 7 TeV; L_{nom} ~ 10^{34} $cm^{-2}s^{-1}$

2835 bunches of 10^{11} particles each

Ib= 0.53A , lifetime – 10 hours

Heavy ions (O, Ca, Sb, Pb)
$\sqrt{s_{NN}}$ = 5.5 TeV



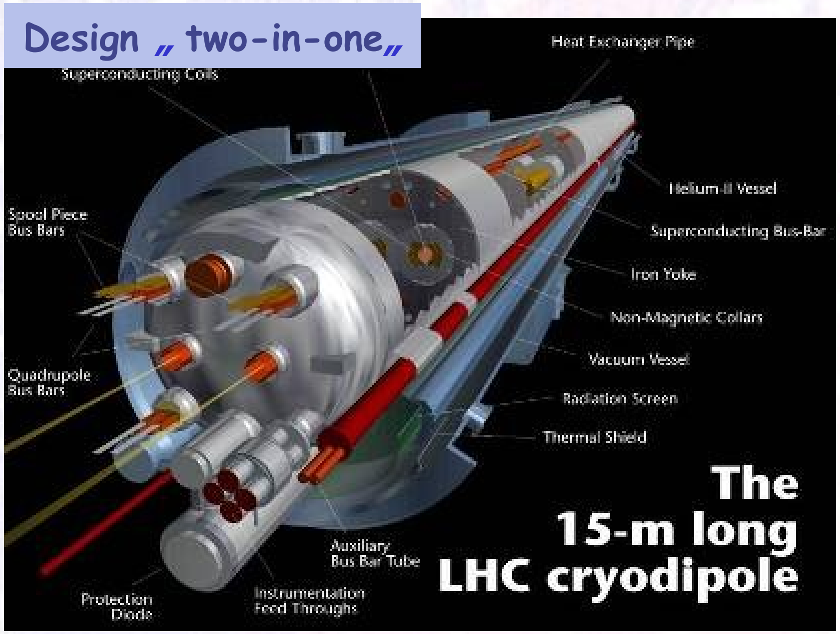
About SC 5000 magnets

1232 SC dipoles, field 8.36T

First world-wide accelerator project

LHC collider at CERN

Design „ two-in-one„



Delivers mangetic field of 8.5 T
Requires large cryoplant (~ 700 m³ of superfluid He !)

First full LHC cell (~ 120 m long) :
6 dipoles + 4 quadrupoles;
successful tests at nominal current (12 kA)

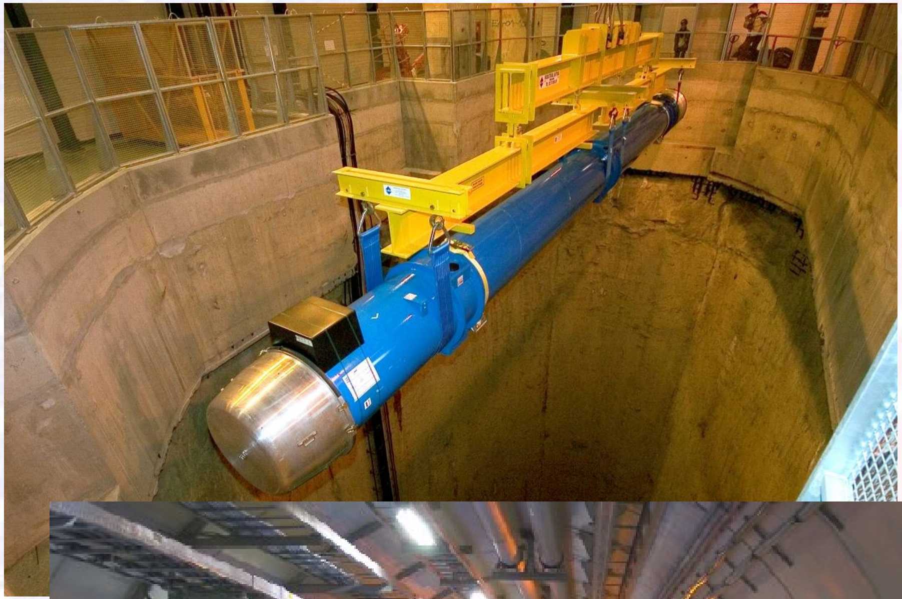
LHC collider at CERN

The magnet production proceeds very well and is on schedule, also the quality of the magnets is very good

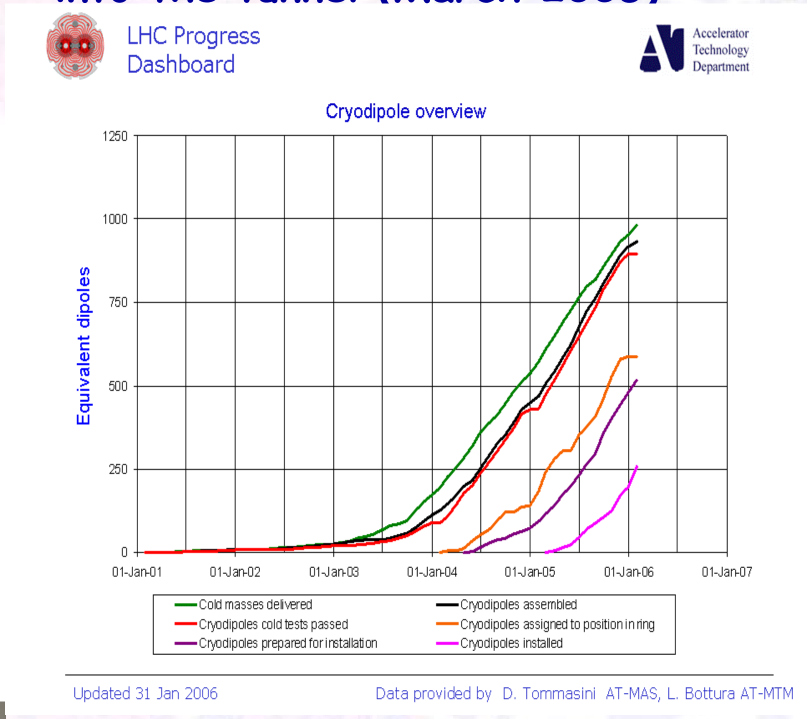
CERN Control Centre taking shape

In February 2006 dipole #1000 has arrived

LHC collider at CERN



Lowering of the first dipole into the tunnel (March 2005)



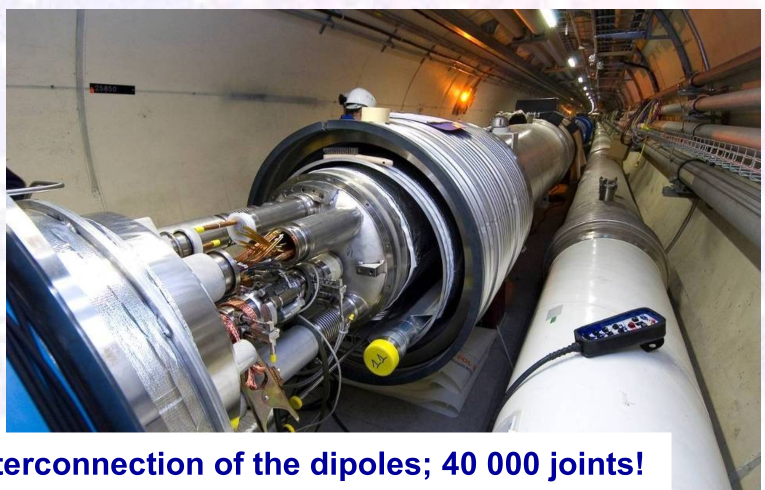
June 05: 49 dipoles installed

31 August 05: 90 dipols installed

31 Jan. 06: 250 dipoles installed

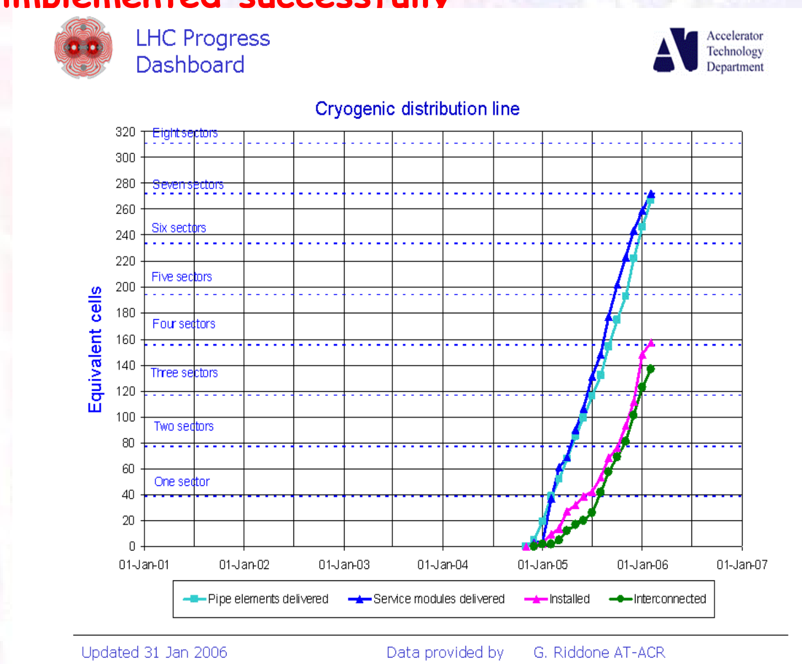
LHC collider at CERN

Cryogenics (QRL) in the tunnel



Interconnection of the dipoles; 40 000 joints!

On the critical path for the first collisions, is the installation of the LHC in the tunnel, in particular due to delays in the cryogenic services lines (QRL) which initially had problems, and for which a recovery plan was implemented successfully



Polish engineers and technicians from AGH-UST and IFJ PAN Cracow are participating in testing

LHC collider at CERN

Objectives for the Pilot RUN

Reach a Luminosity of 10^{32}

Low Luminosity run at 25 ns separation

„Difficult to speculate further on what the performance might be in the first year. As always, CERN accelerators departments will do their best ! "

Lyn Evans

STAGE 1
INITIAL COMMISSIONING
43 x 43 -> 156 x 156 $3x10^{10}$ per bunch
Zero to Partial squeeze

STAGE 2
75 ns OPERATION
3-4 x 10^{10} per bunch
Partial squeeze

STAGE 3
25 ns OPERATION
3-4 x 10^{10} per bunch
Partial to near full squeeze

STAGE 4
25 ns OPERATION
push to nominal per bunch
Partial to full squeeze

Activity	Month	Year
	April	2007
Hardware commissioning	May	
	June	
Machine checkout	July	
	August	
Beam commissioning	September	
	October	
Pilot proton run	November	
	December	
Shutdown	January	2008
	February	
Machine checkout	March	
75ns commissioning	April	
First ION run	May	
75ns run	June	
	July	
	August	
Low intensity 25ns run	September	
	October	
	November	
Shutdown	December	
	January	2009
	February	
Machine checkout	March	
Startup and scrubbing	April	
	May	
Half intensity 25ns run	June	
	July	
	August	
	September	
	October	
Shutdown	November	
	December	
	January	2010
	February	
Machine checkout	March	
Startup and scrubbing	April	
	May	
	June	
Push to nominal 25ns	July	
	August	
	September	
	October	
	November	
Shutdown	December	
	January	2011
	February	
Machine checkout	March	
Startup and scrubbing	April	
	May	
	June	
Nominal 25ns	July	
	August	
	September	
	October	
	November	
	December	

LHC collider at CERN

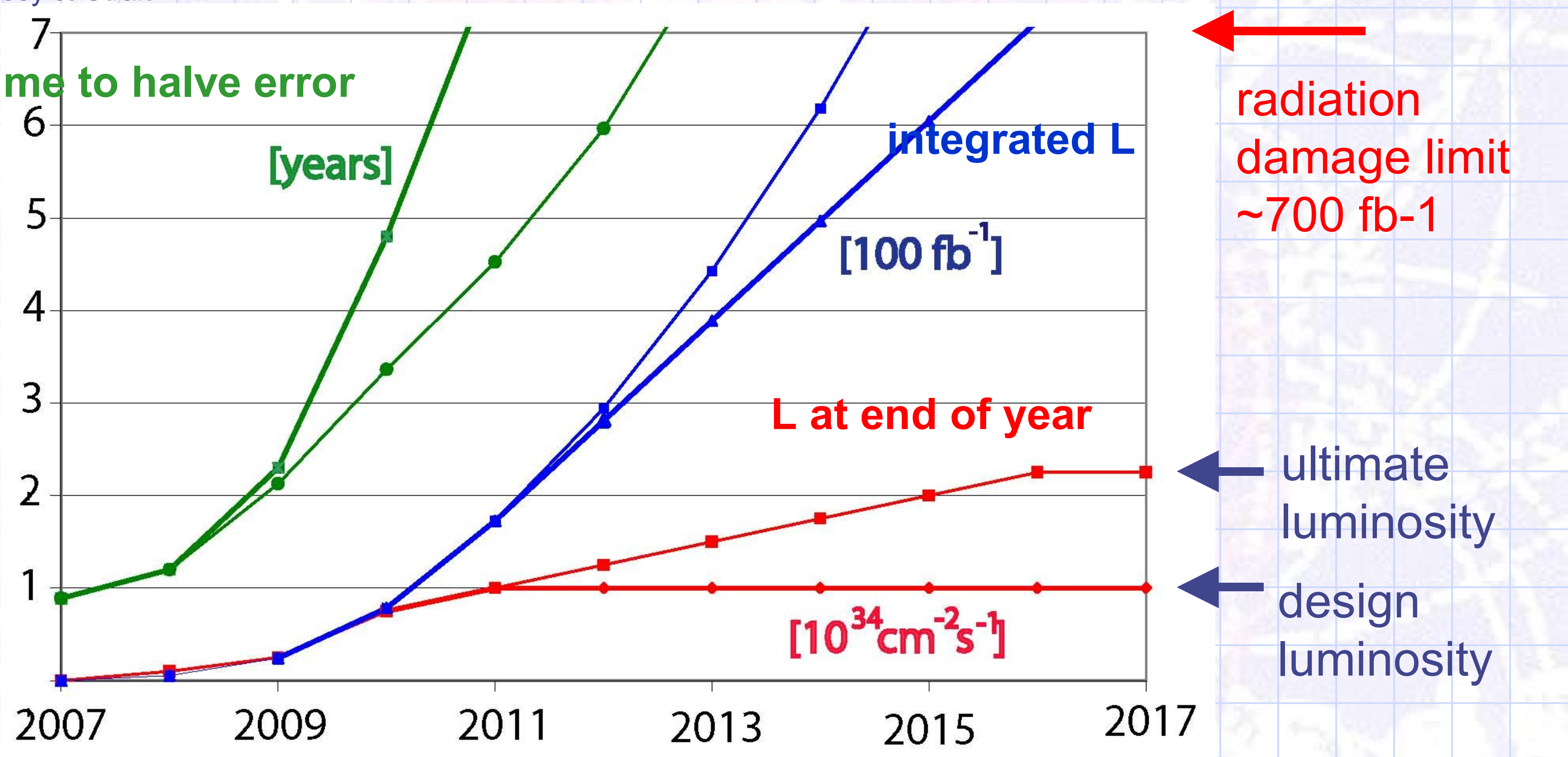
Super LHC

Possible scenarios

- $\sqrt{s}$ = 14 TeV and L = 10^{35} $cm^{-2}s^{-1}$
  - needs substantial modification of LHC detectors
  - works in this direction have started in ATLAS and CMS
    (e.g. http://agenda.cern.ch/displayLevel.php?fid=350)
- $\sqrt{s}$ = 28 TeV and L = 10^{34} $cm^{-2}s^{-1}$ or 10^{35} $cm^{-2}s^{-1}$
  - more speculative…
  - needs serious R&D programme for the machine
  - Studies in this direction started at CERN in 2001
    e.g. recent Workshop on Beam Dynamics in Future Hadron Colliders and Rapidly Cycling High-Intensity Synchrotrons
    (http://care-hhh.web.cern.ch/CARE%2DHHH/HHH%2D2004/)

Super LHC - time scale of an LHC upgrade

from F. Ruggiero and F. Zimmermann
courtesy J. Strait



(1) ***life expectancy of LHC IR quadrupole magnets*** is estimated to be <10 years due to high radiation doses

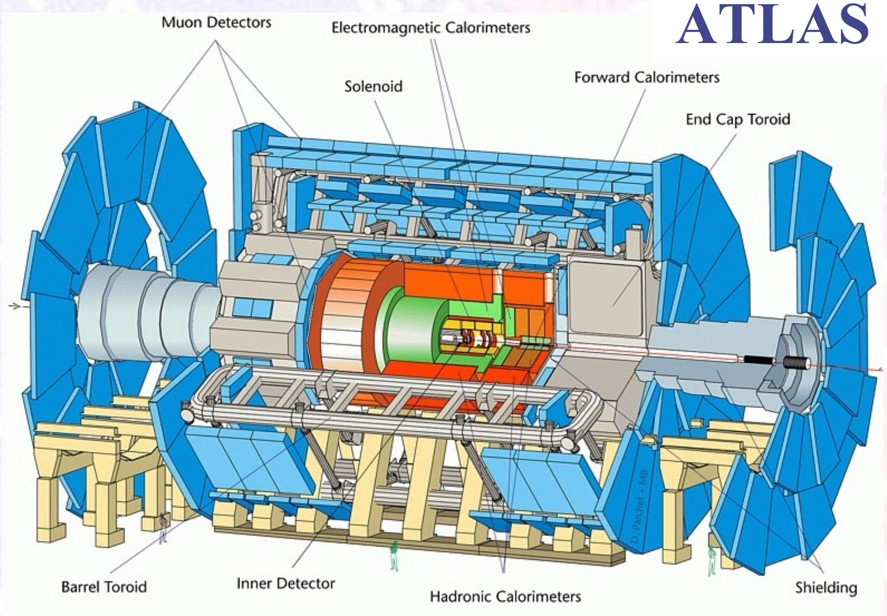
(2) the ***statistical error halving time*** will exceed 5 years by 2011-2012

(3) therefore, it is reasonable to plan a ***machine luminosity upgrade based on new low-β IR magnets before ~2014***

Detektory LHC

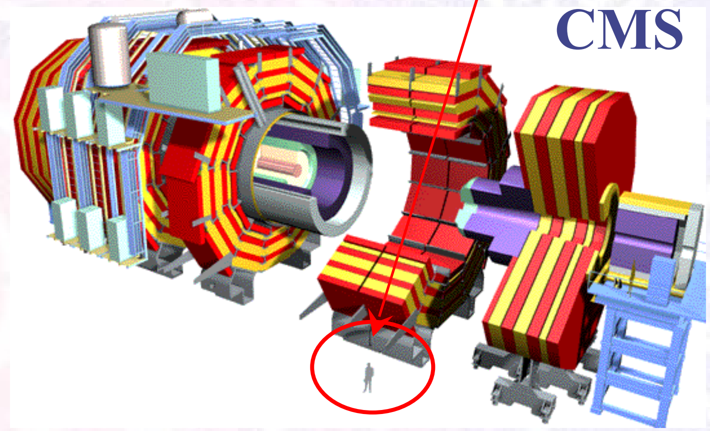
LHC experiments

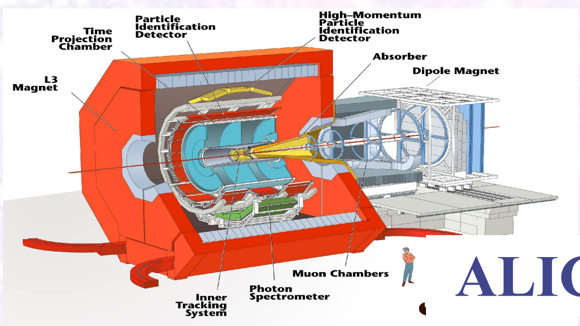
ATLAS



CMS

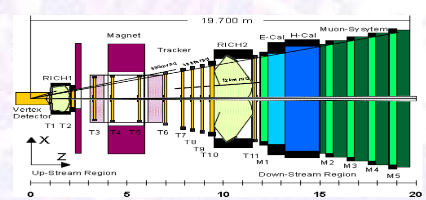
standard
sized
scientist





ALICE

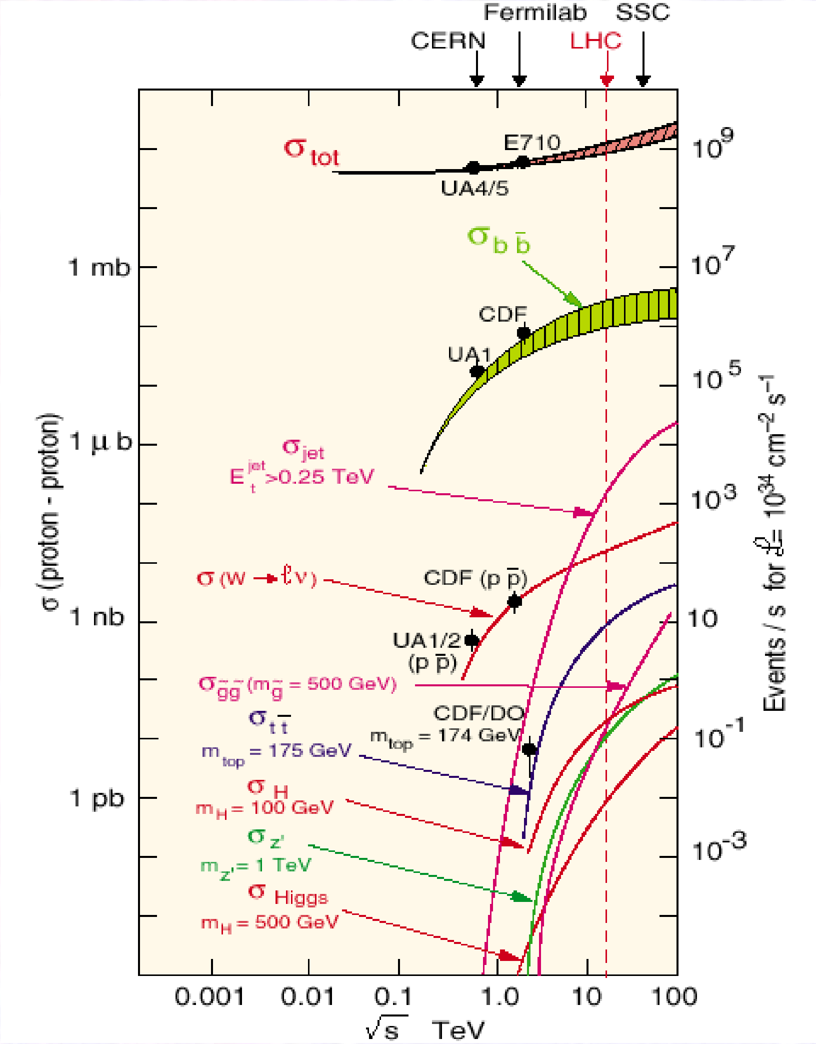
LHC*b*

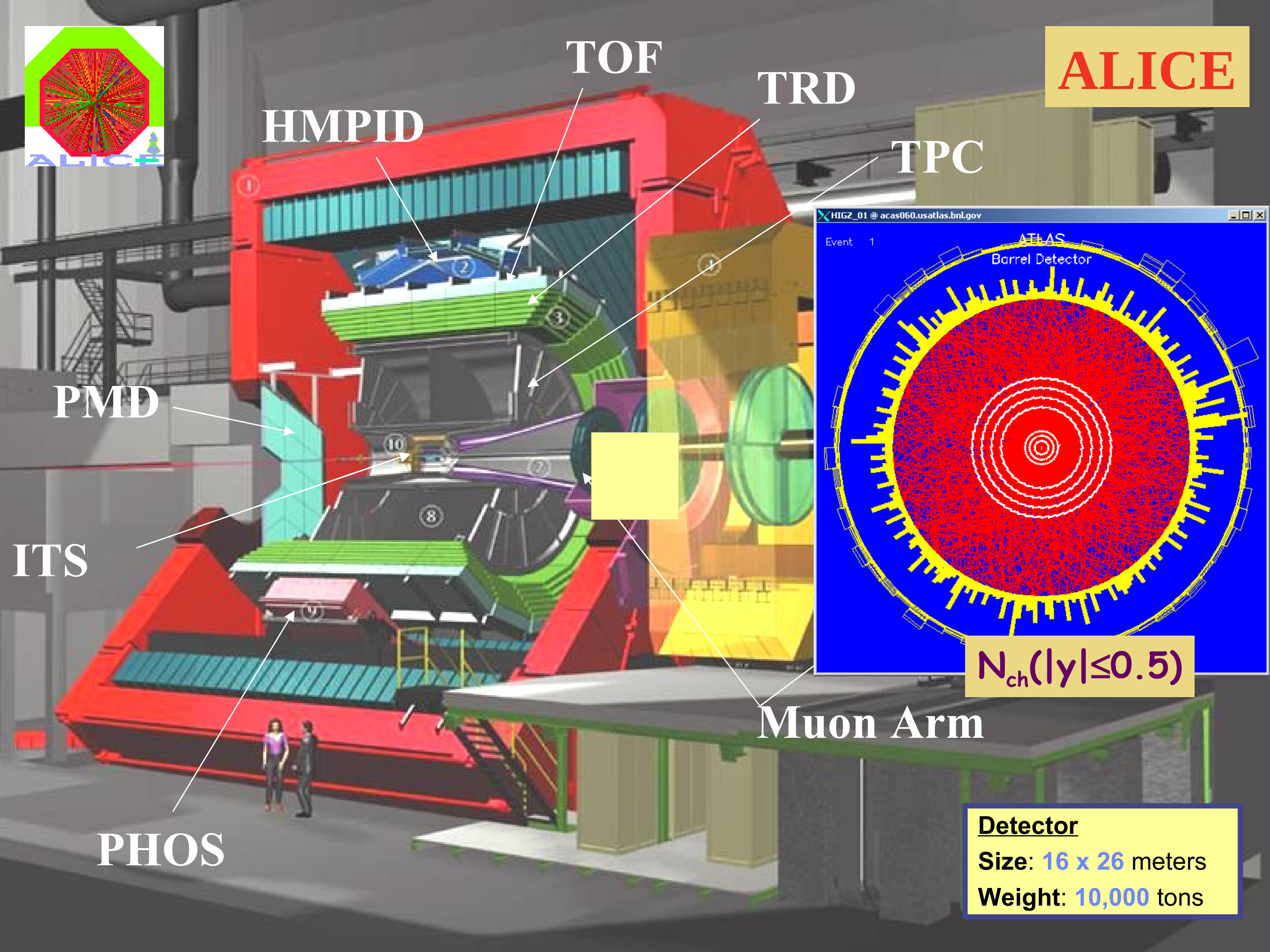


LHC experiments

Major challenges

- very rare events (-> high luminosity and high preselection)
- very high radiation
- complex events (-> granularity)
- particles of high energies/ momenta (-> dimensions)
- enormous volume of the data
- world-wide access to the data
- large, disperse collaborations
- very long lifetime (documentation!)




ALICE
TOF
TRD
HMPID
TPC
HIGZ_01 @ acas060.usatlas.bnl.gov
Event 1
ATLAS
Barrel Detector
PMD
ITS
Nch(|y|≤0.5)
Muon Arm
PHOS
Detector
Size: 16 x 26 meters
Weight: 10,000 tons

LHC experiments – ALICE

Main challenges

- high multiplicity (40
  ->largest ever TPC (
- particle ID (dE/dx,
  RICH, TRD)
- largest warm magnet

In February 2006 Alice Space Frame was lowered into the pit

Status

- 'initial detector' well on track for collisions in summer 2007
  - Pb-Pb L_{init} ~ few 10^{25} $cm^{-2}s^{-1}$
  - global event properties in few days (RICH)
- aim for '<u>complete detector</u>' (50% of TRD, 60% PHOS) for collisions in 2008

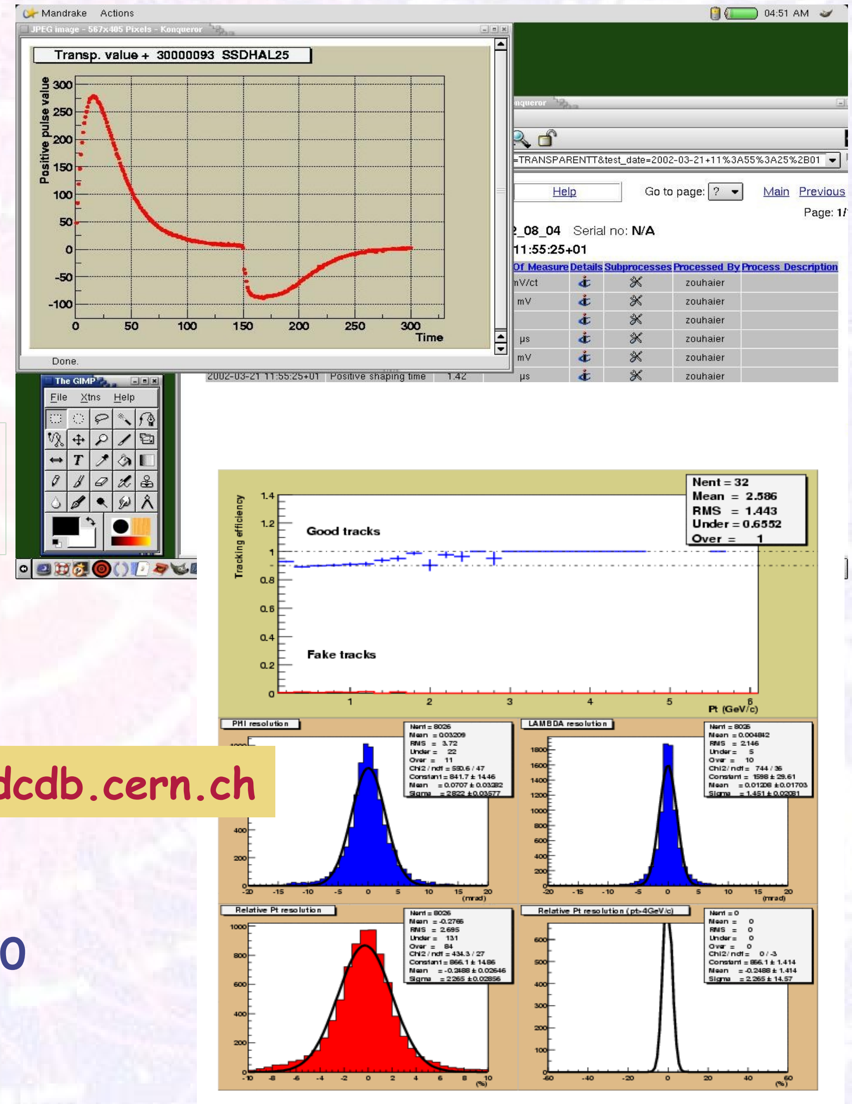
In the fall of 2005 the dipole magnet of the muon arm was tested in the final position

LHC experiments – ALICE

Polish contribution

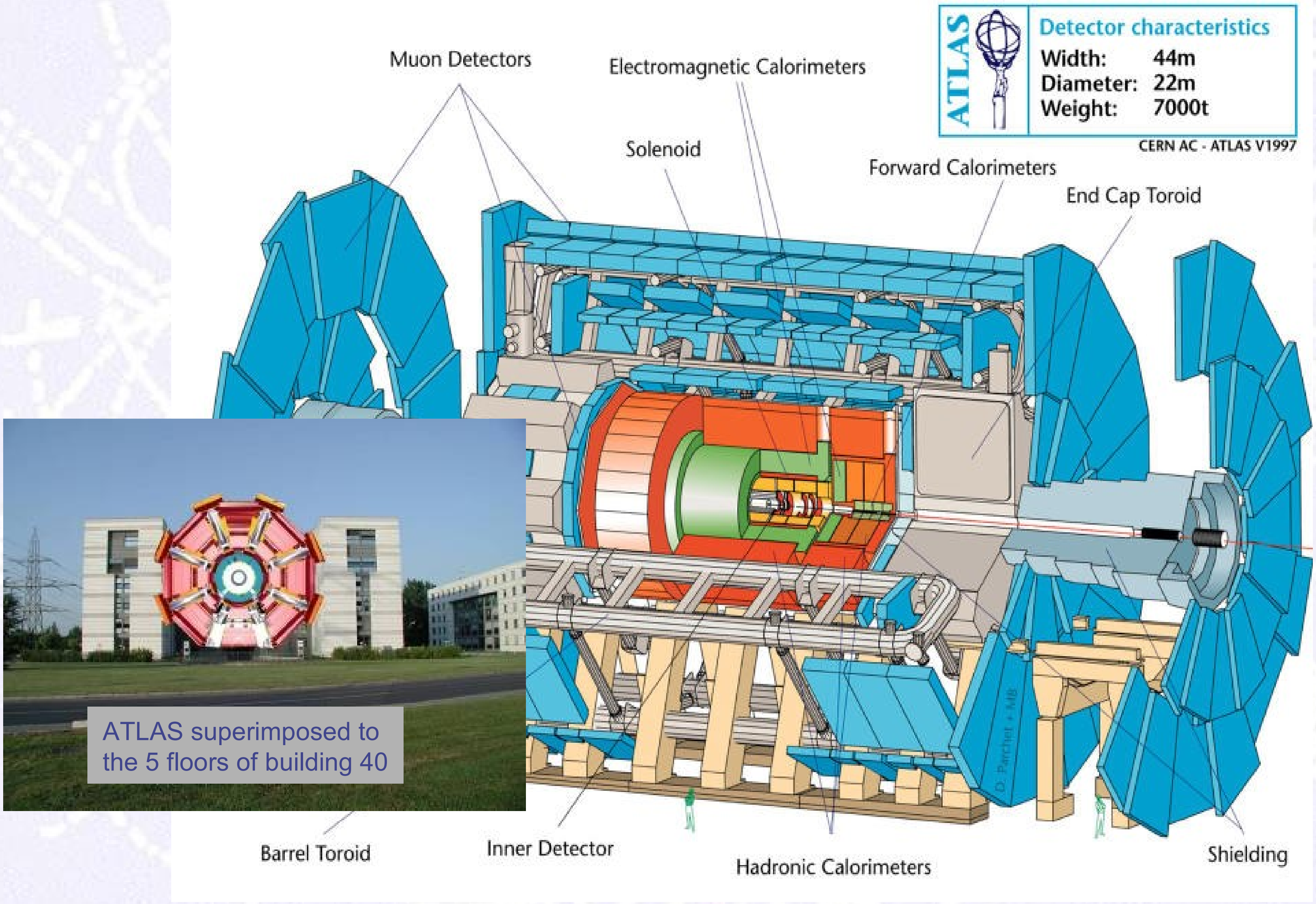
IFJ PAN Cracow, IEF WU Warsaw and IF WUT Warsaw

- **Physics**
  - **particle correlations** (Physics Performance Report)
- **Software**
  - **TPC simulation** (detector design, optimization of readout electronics, performance predictions, …)
  - **DCS for T0**
  - **DAQ and monitoring for SSD**
  - **data reconstruction and analysis software**
  - **Detector Construction Database**
- **Hardware**
  - **development of fast electronics for T0**
  - **purchasing of TPC readout electronics and low voltage power supplies**



http://dcdb.cern.ch

LHC experiments - ATLAS



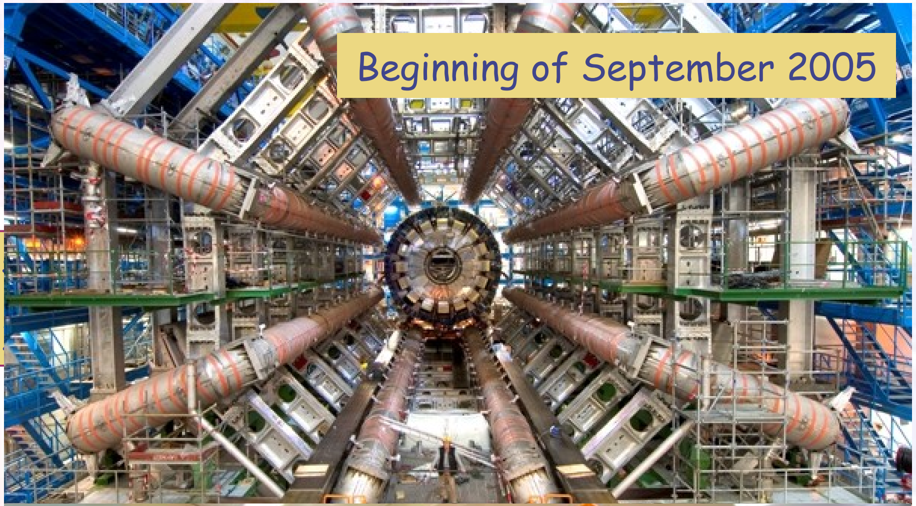
LHC experiments - ATLAS

Main challenges

- very large muon spectrometer with SC toroids

Status

- barrel toroids successfully installed
- construction of several subsystems completed
- full 'vertical slice' of ATLAS tested on CERN H8 beam
- first cosmic rays in hadronic calorimeter and muon chambers in the pit observed
- barrel silicon and straw tubes trackers assembled
- components staged: pixels, ID TRT end-caps, part of T/DAQ
- ATLAS on track for first collisions and physics in 2007

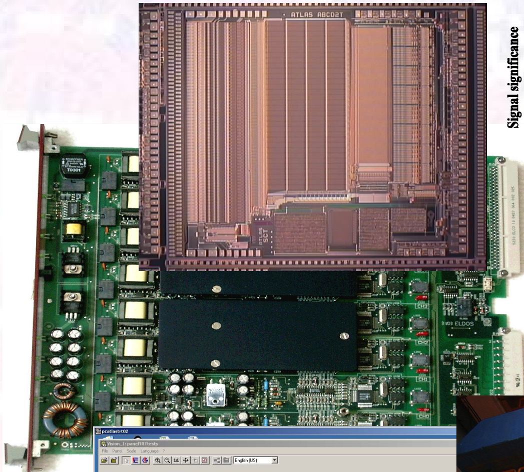


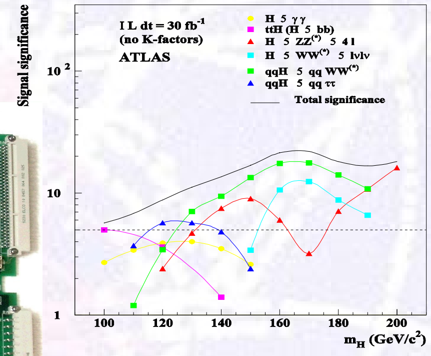
LHC experiments - ATLAS

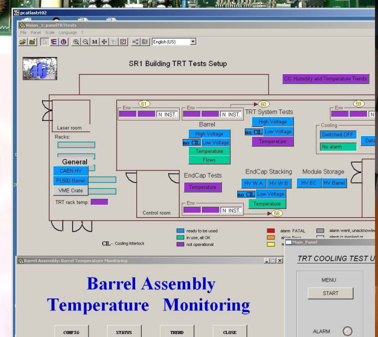
Polish contribution

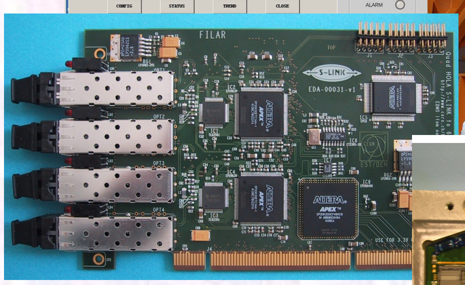
IFJ PAN, Cracow, AGH-UST Cracow

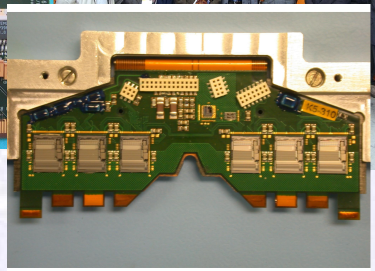
- physics case studies (Higgs WG, supersymetry, B physics, b-jet tagging, heavy ions)
- development of SCT ASIC readout (ABCD3T) and detector bias power supplies; hybrid testing
- development of TRT gas gain stabilisation system, power supply system and detector control
- development of DAQ data S-link; simulation and modelling of high level filter
- mechanical engineering and cooling
- industrial production (heavy support structures, ~5000 ch. power supplies)



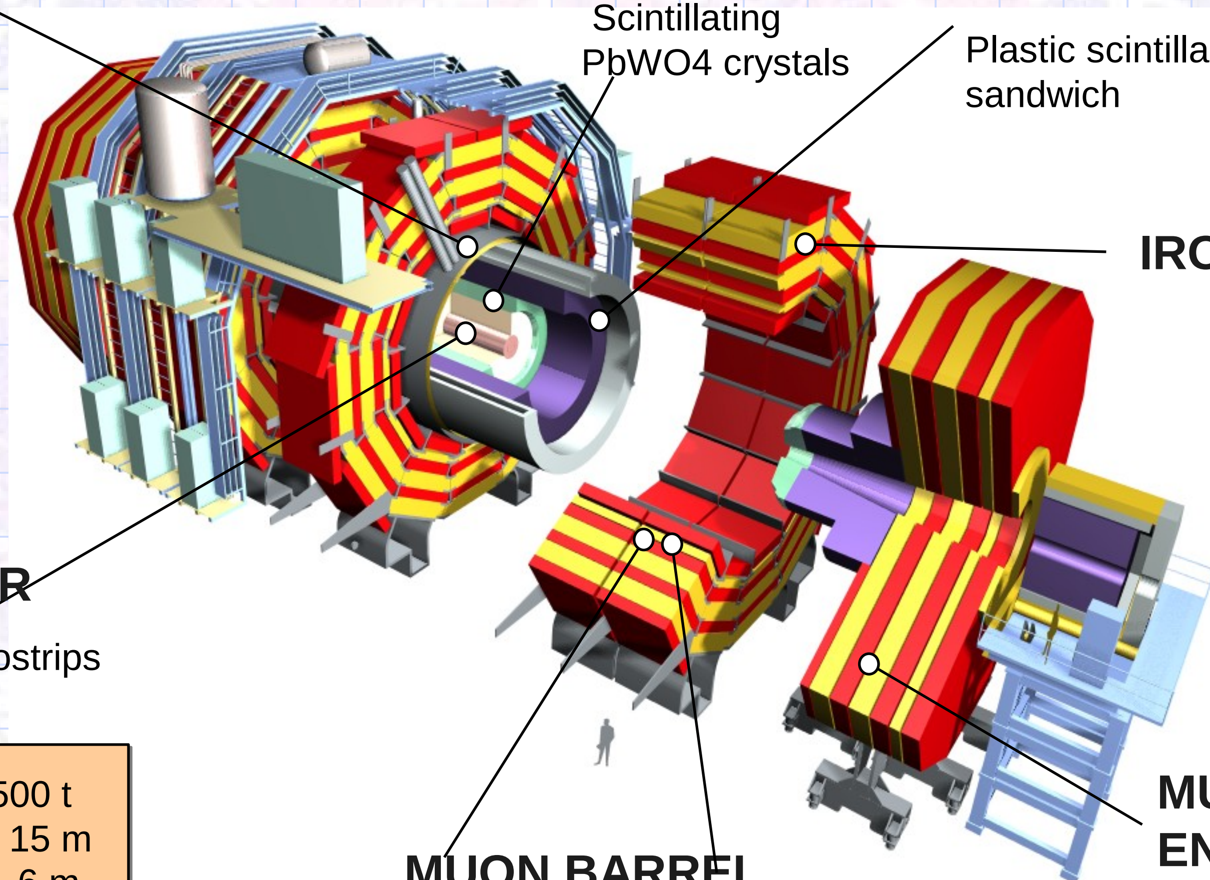








Compact Muon Solenoid



Total weight : 12,500 t
Overall diameter : 15 m
Overall length : 21.6 m
Magnetic field : 4 Tesla

LHC experiments - CMS

Main challenges

- silicon tracker (210 m²!)
- EM crystal calorimeter (Pb_3WO_4)
- large SC magnet

Status and schedule

- SC coil mass completed
- insertion of dummy solenoid tested
- most of muon chambers produced, la
  fraction installed,
- on critical path:
  - crystals (delivery, cost)
  - Si tracker hybrids and integrati
- cosmic challenge (Q1, 2006): slice te
  of CMS during the Magnet Test

- initial CMS detector will be ready and closed for beam on 30 June 2007

CERN bulletin 13 February 2006

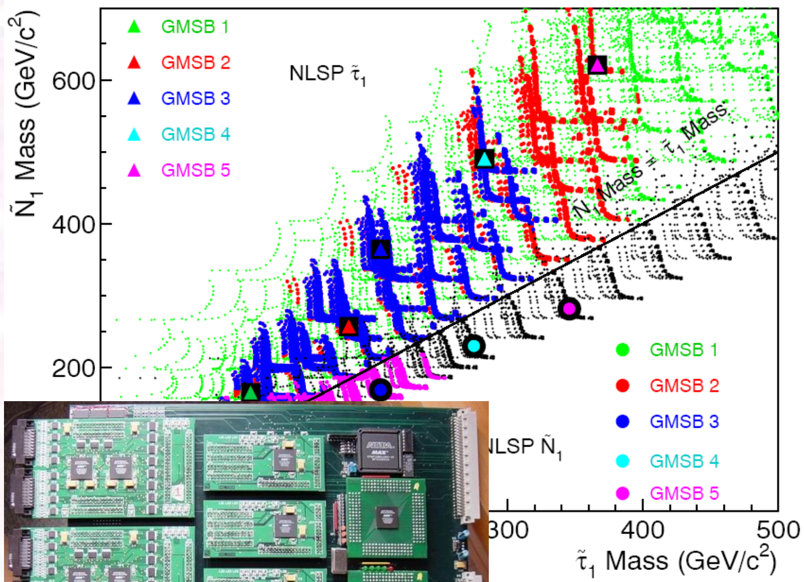
More than 50% of the crystals produced

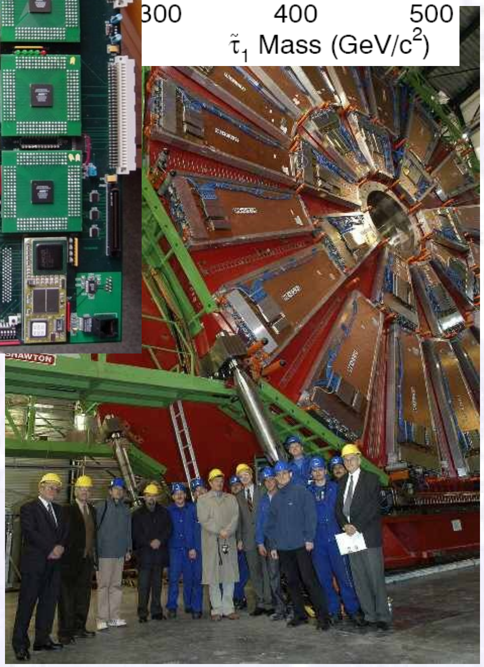
LHC experiments - CMS

Polish contribution

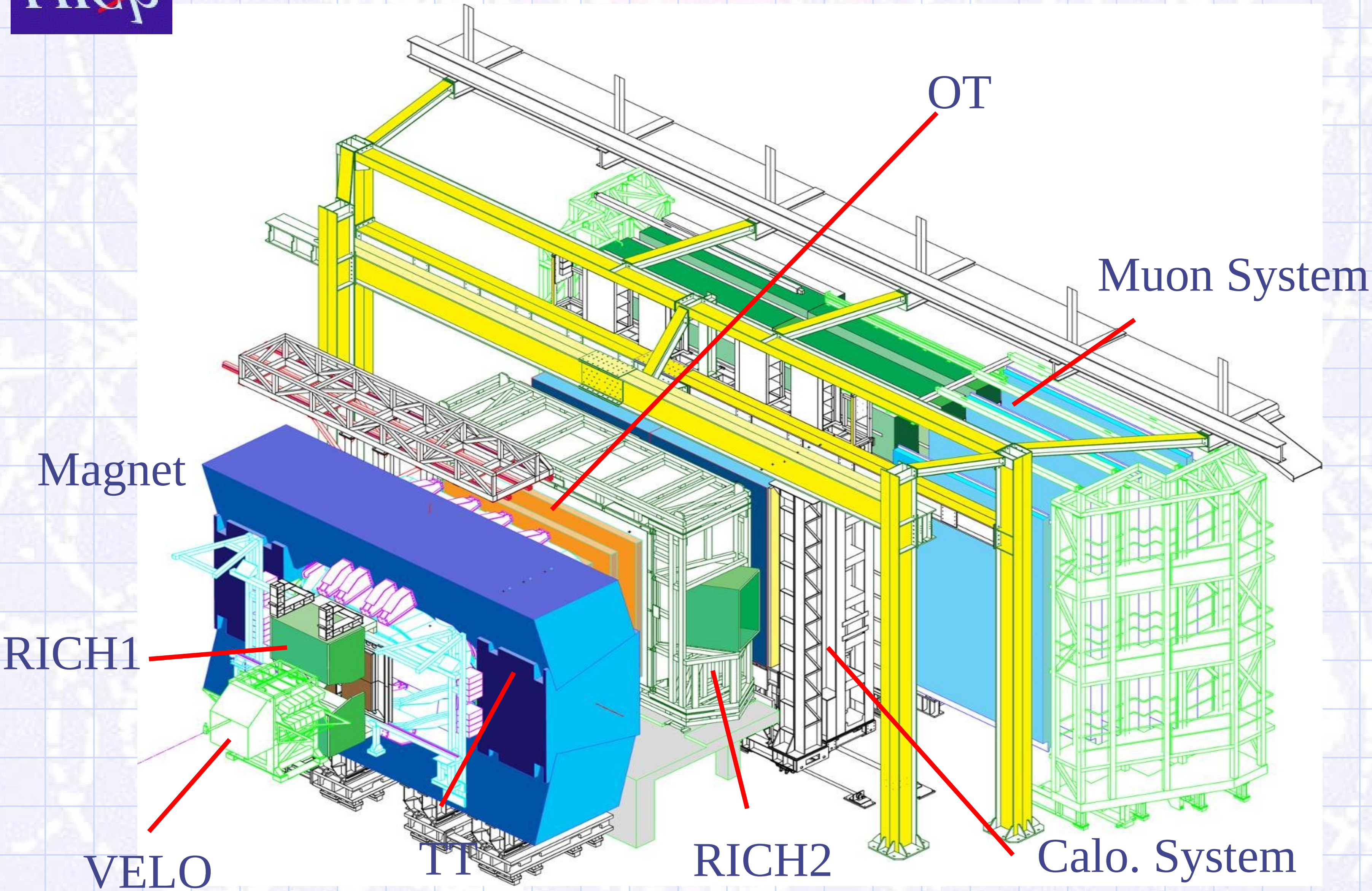
INS Warsaw and IEP UW Warsaw

- **physics case studies:**
  - exotic signatures: long lived stau,
  - nonpointing g from neutralino decays
  - excited gravitons in extra dimensions
- **reconstruction software:**
  TeV m, isolation in tracker, pixels
- **LV1 Muon Trigger based on RPC**
  90% simulation, design, proto & tests,
  50% production
  - 200 000 channels, 700 optical links
  - 1700 Link Boards (synchronization, compression, optical output)
  - 108 Trigger+DAQ boards (hit pattern recognition, m p_T measurement)
- **R&D for Resistive Plate Chambers**
- **ZEC Wroclaw – was awarded contracts for the installation of gas & water pipes on the CMS detector**





LHCb Spectrometer



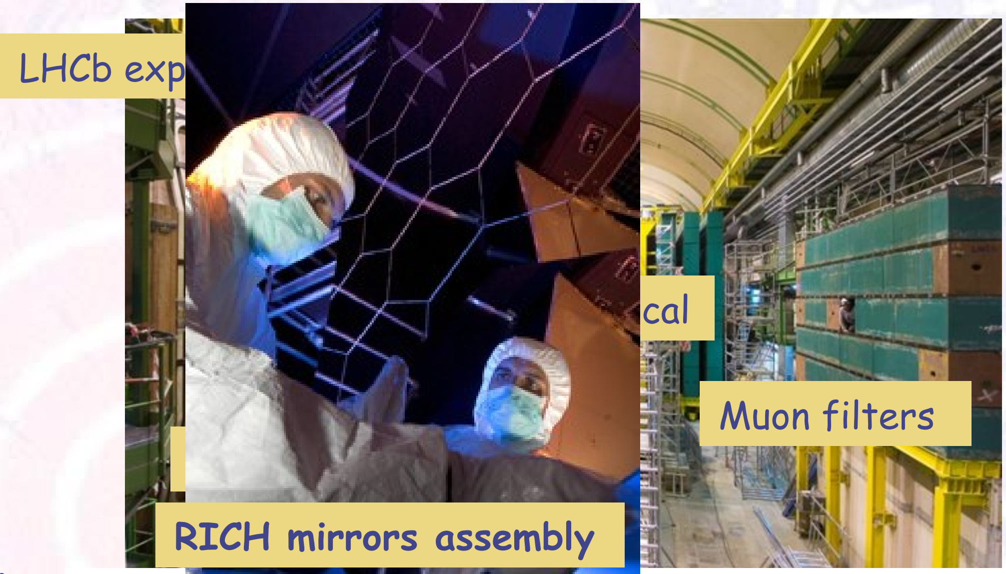
LHC experiments - LHCb

Main challenges

- preselection of B events (trigger)
- particle identification (RICH counters)

Status and schedule

- good progress in construction of all components
- trigger (level 1 – VELO) ‘under control’ (well understood)
- Pilot Run → commission run for calibration & alignment (J/Psi ….x-sections…)

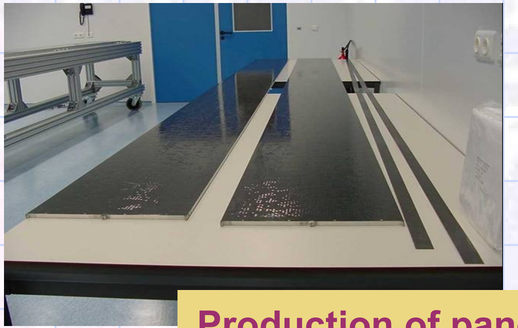


LHC experiments - LHCb

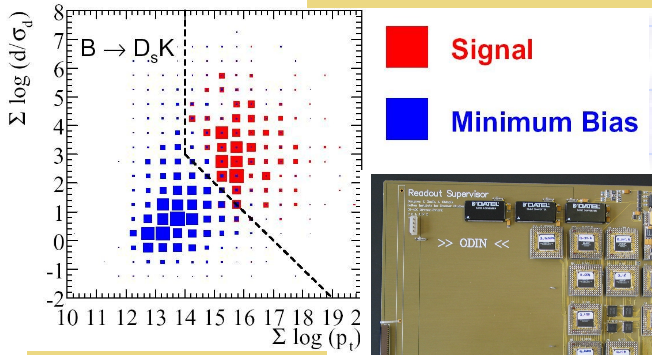
Polish contribution

Soltan Institute for Nuclear Studies, Warsaw
Institute of Nuclear Physics PAN, Cracow
AGH University of Science and Technology, Cracow

- **Hardware contributions:**
  - **Outer Tracker prototyping and production**
    - Panels for all modules
    - Production of 130 (~ 1/3 of all) modules of straw drift chambers
    - Contributions to readout electronics, mechanical design and alignment system
  - **TFC (Timing and Fast Control) electronics** – Readout Supervisor card
- **Software contributions:**
  - **Detector re-optimization – MC studies**
  - **Development of trigger algorithms**
  - **Tools to control systematic effects**
  - **Physics analyses of CP violation (MC)**



Production of panels



T1 simulations

Readout Supervisor

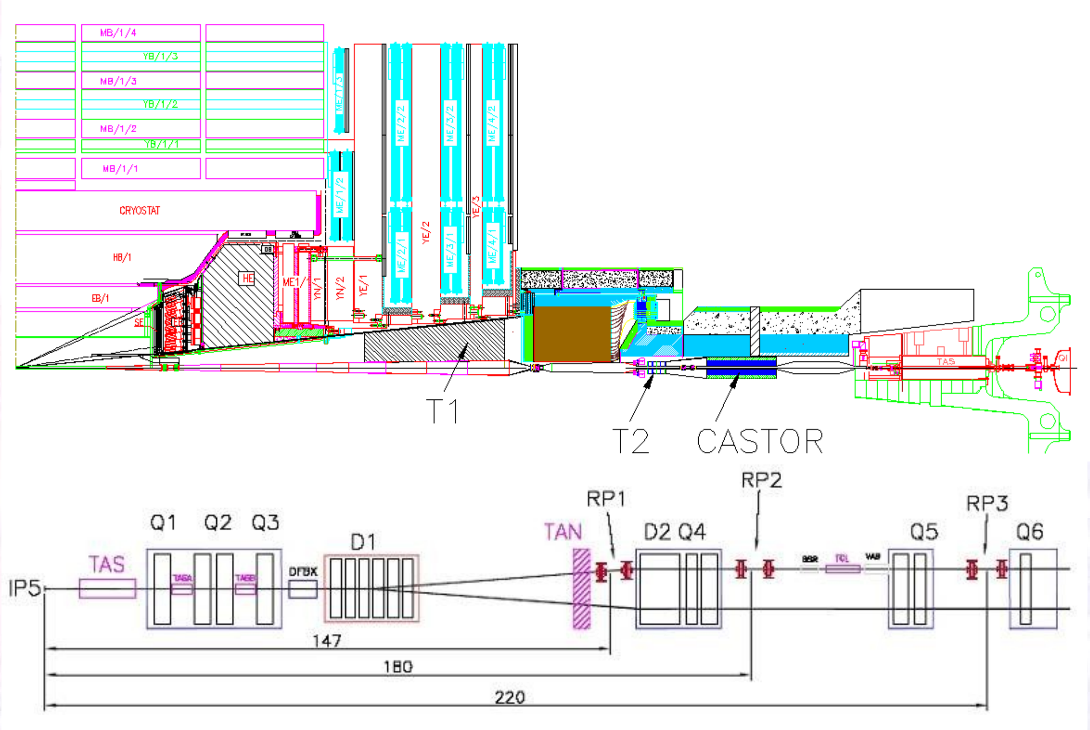
Production of modules

LHC experiments - TOTEM

- **beta* = 1540 m, 43 bunches, low emittance**
- **plus large t elastic scattering at 18 m**
  - 3 x 1-day runs at 1540 plus 2 short runs at 18 m
- **Roman Pots at 10 σ, high beam stability, low BGs**
  - Roman Pots at ~10σ imply:

    - collimators must be set to 6/7 s;

    - e* ~ 1 mm, ~ 4 times smaller, than nominal collimator gaps ≤ 1 mm



Requires special machine conditions– similar to polarization at LEP.
The difficulty and challenge of TOTEM operation is coming from the requested precision for both optics & beams.

Komputing dla LHC

LHC experiments and data rate

Data preselection in real time

- many different physics processes
- several levels of filtering
- high efficiency for events of interest
- total reduction factor of about 10^7

Data rates

	Rate [Hz]	RAW [MB]	ESD Reco [MB]	AOD	M…	…o % of real
ALICE HI	[illegible]			250	300	
ALI…	[illegible]		0.04	4		
	200	1.6	0.5			20
CMS	150			50	2	100
LHCb			0.025		0.5	20

…ing in 2007
…seconds/year pp from 2008 on → ~10^9 events/experiment
10^6 seconds/year heavy ion

For LHC computing, 100M SpecInt2000 or 100K of 3GHz Pentium 4 is needed!

For data storage, 20 Peta Bytes or 100K of disks/ tapes per year is needed!

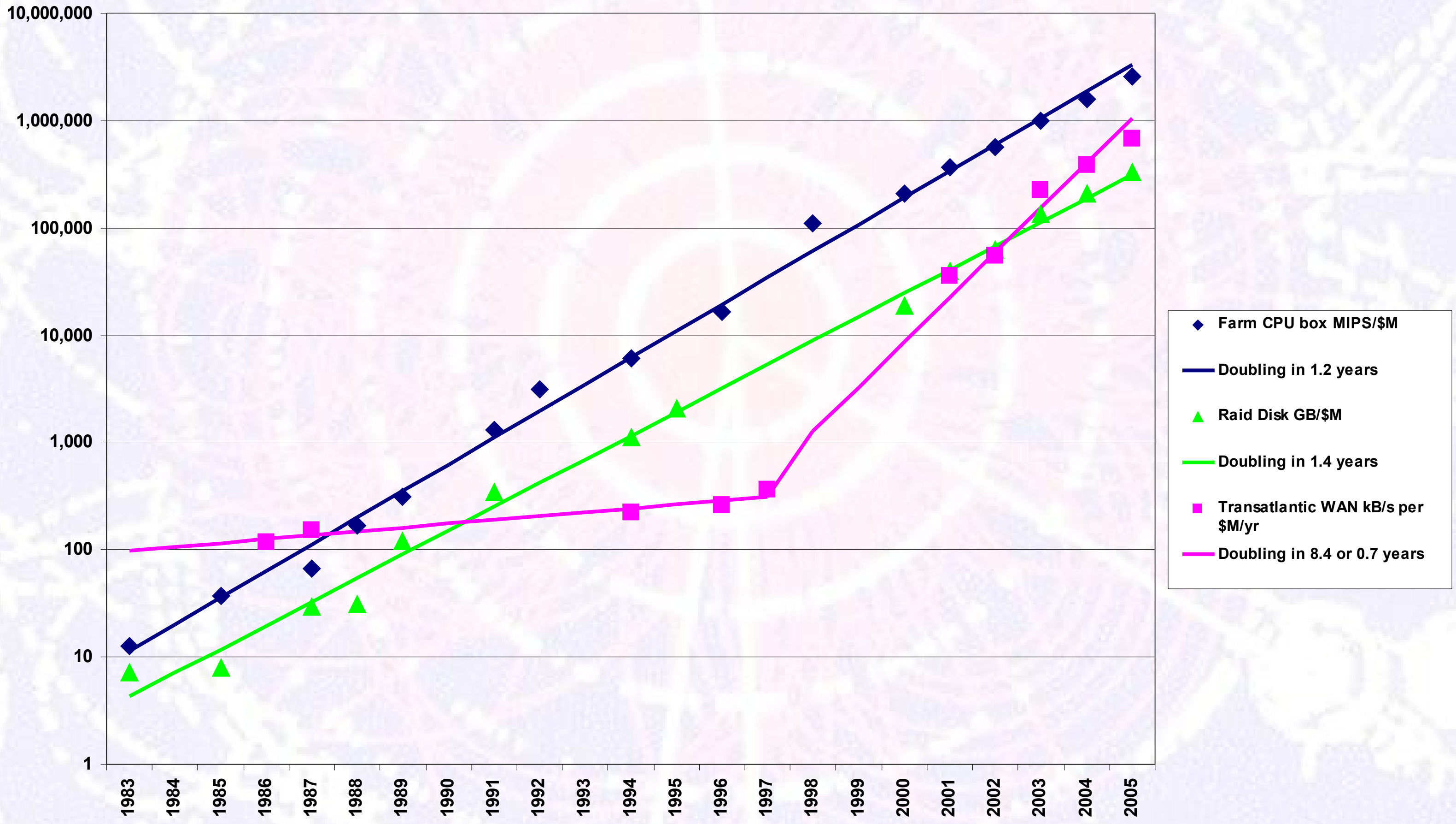
ICFA Network Task Force (1998): required network bandwidth (Mbps)

	1998	2000	2005
BW Utilized Per Physicist (and Peak BW Used)	0.05 - 0.25 (0.5 - 2)	0.2 – 2 (2-10)	0.8 – 10 (10 – 100)
BW Utilized by a University Group	0.25 - 10	1.5 - 45	34 - 622
BW to a Home Laboratory Or Regional Center	1.5 - 45	34 - 155	622 - 5000
BW to a Central Laboratory Housing Major Experiments	34 - 155	155 - 622	2500 - 10000
BW on a Transoceanic Link	1.5 - 20	34 - 155	622 - 5000

100–1000 X Bandwidth Increase Foreseen for 1998-2005
See the ICFA-NTF Requirements Report:
http://l3www.cern.ch/~newman/icfareq98.html

Progress on IT technology

Performance per unit cost in function of time



from R. Mount

Development of Grid projects

Computing Grid – definition (-s)

„When the network is as fast as the computers internal links, the machine disintegrates across the net into a set of special purpose appliances."

(G. Gilder)

„The Grid is a service for sharing computer power and data storage capacity over the Internet. The Grid goes well beyond simple communication between computers, and aims ultimately to turn the global network of computers into one vast computational resource."

(Internet Cafe)

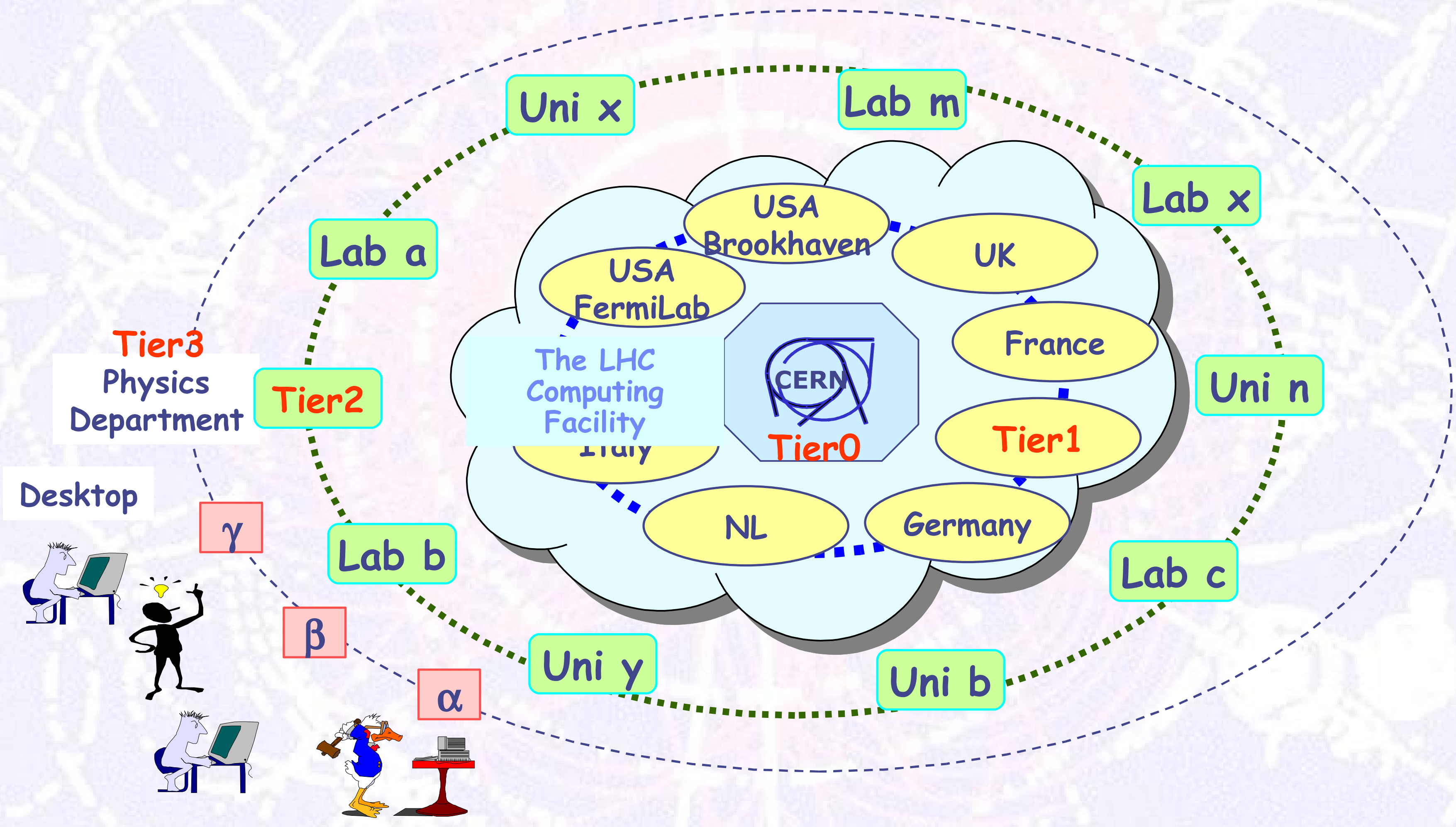
„A computational grid is a hardware and software infrastructure that provides dependable, consistent, pervasive, and inexpensive access to high-end computational capabilities"…………… Grid computing is concerned with "coordinated resource sharing and problem solving in dynamic, multi-institutional virtual organizations".

(I. Foster, C. Kasselman, S. Tuecke)

GRID = Globalisation de Ressources Informatiques et Donnees

(M. Cosnard)

Computing model („cloud”)



Computing model („cloud”)

- **Tier-0 at CERN**
  - Record RAW data (1.25 GB/s ALICE)
  - Distribute second copy to Tier-1s
  - Calibrate and do first-pass reconstruction
- **Tier-1 centers (11 defined)**
  - Manage permanent storage – RAW, simulated, processed
  - Capacity for reprocessing, bulk analysis
- **Tier-2 centers (> 100 identified)**
  - Monte Carlo event simulation
  - End-user analysis
- **Tier-3**
  - Facilities at universities and laboratories
  - Access to data and processing in Tier-2s, Tier-1s

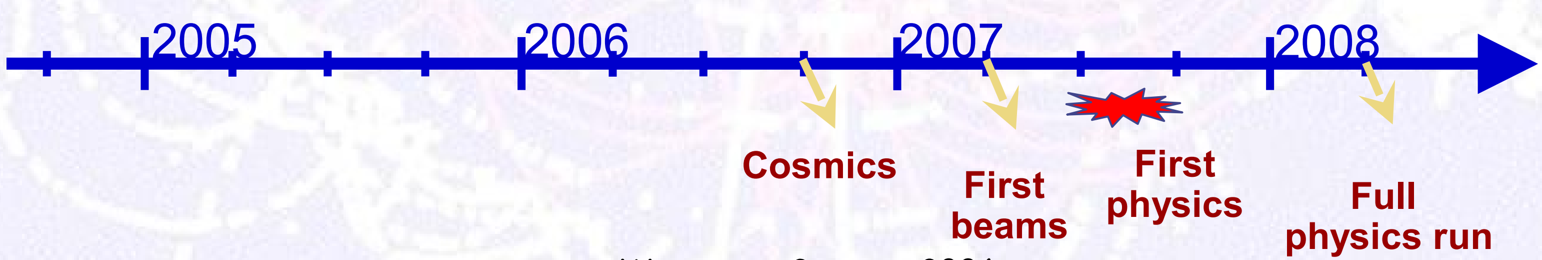
LHC Computing Grid project - LCG

Objectives

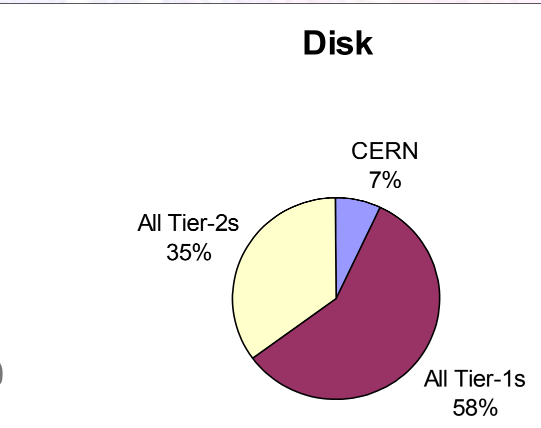
- design, prototyping and implementation of the computing environment for LHC experiments (Monte Carlo simulation, reconstruction and data analysis):
  - infrastructure (for HEP it is effective to use PC farms)
  - middleware (based on EDG, VDT, gLite….)
  - operations (experiment VOs, operation and support centres)

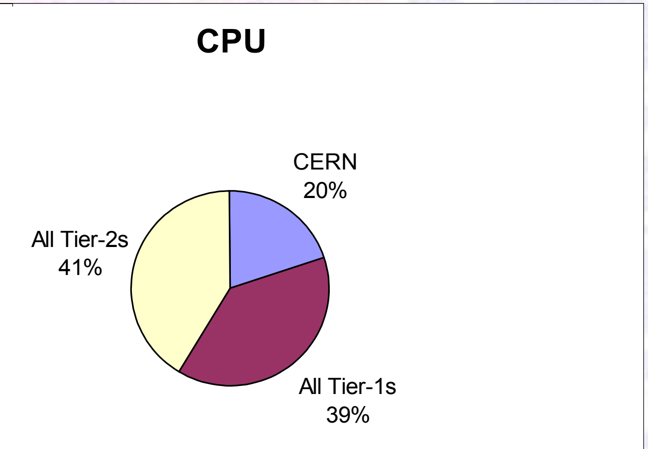
Schedule

- phase 1 (2002 – 2005; ~50 MCHF); R&D and prototyping (up to 30% of the final size)
- phase 2 (2006 – 2008); preparation of a Technical Design Report, Memoranda of Understanding, deployment (2007)



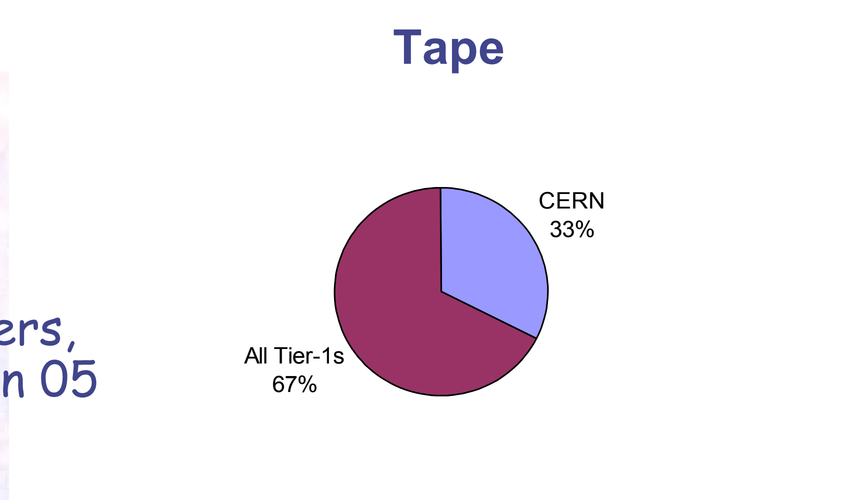
Planned sharing of capacity between CERN and Regional Centres in 2008



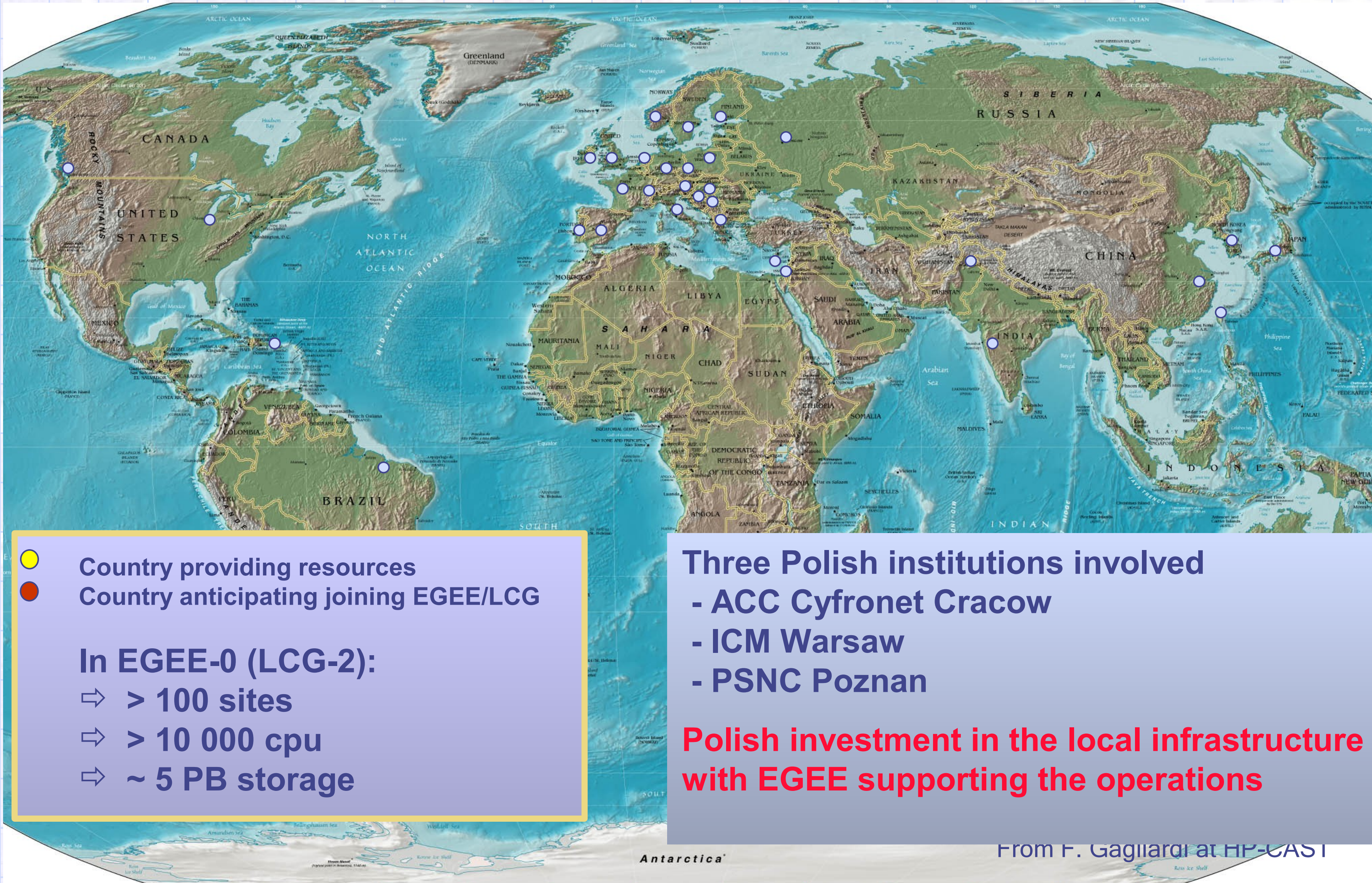


Preliminary planning data

Requirements from December 2004 Computing model papers, reviewed by LHCC Jan 05



Cooperation with the EU EGEE project Computing Resources – April. 2005



- Country providing resources
- Country anticipating joining EGEE/LCG

In EGEE-0 (LCG-2):

- ⇨ > 100 sites
- ⇨ > 10 000 cpu
- ⇨ ~ 5 PB storage

Three Polish institutions involved

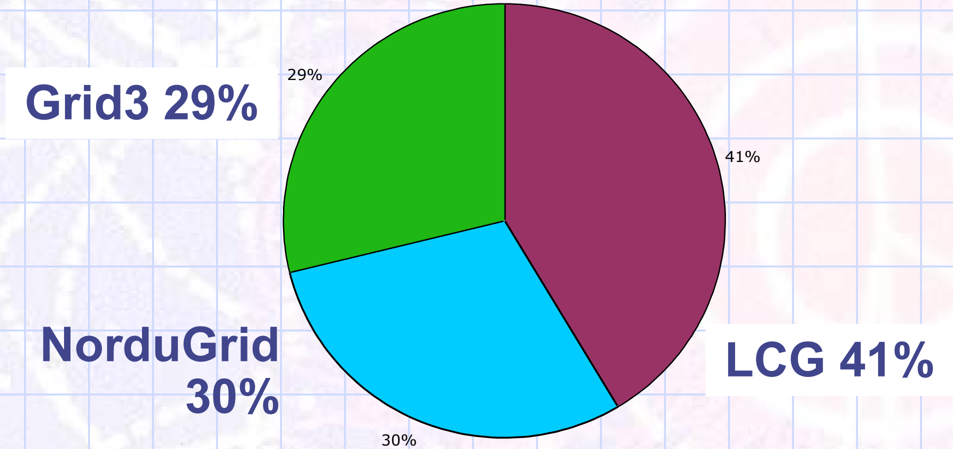
- ACC Cyfronet Cracow
- ICM Warsaw
- PSNC Poznan

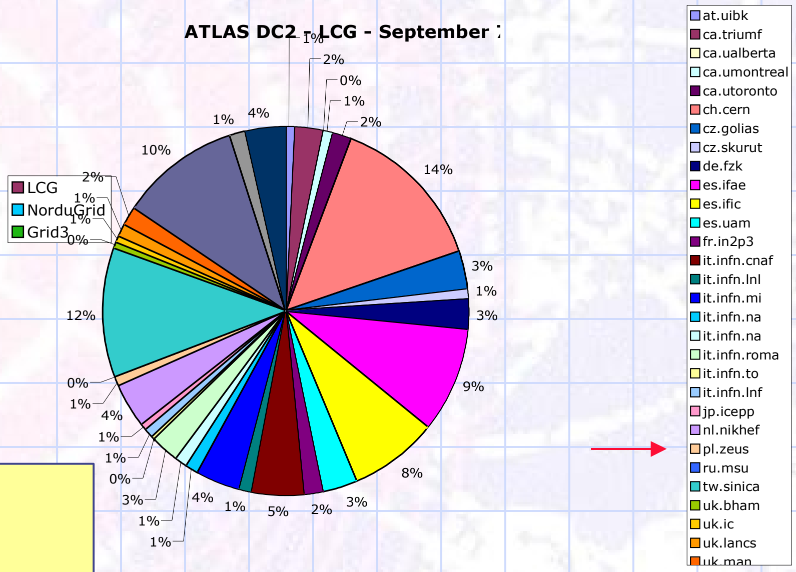
Polish investment in the local infrastructure with EGEE supporting the operations

From F. Gagliardi at HP-CAST

ATLAS Data Challenges Status

- DC2 Phase I started in July, finished in October 2004
- 3 Grids were used
  - LCG (~70 sites, up to 7600 CPUs)
  - NorduGrid (22 sites, ~3280 CPUs (800), ~14TB)
  - Grid3 (28 sites, ~2000 CPUs)





~ 1350 kSI2k.months
~ 120,000 jobs
~ 10 Million events fully simulated (Geant4)
~ 27 TB

from L. Robertson
at C-RRB 2004

All 3 Grids have been proven to be usable for a real production

about 1% of the events have been generated in Cracow

LCG Data Recording Challenge – SC2

Data distribution from CERN to Tier-1 sites

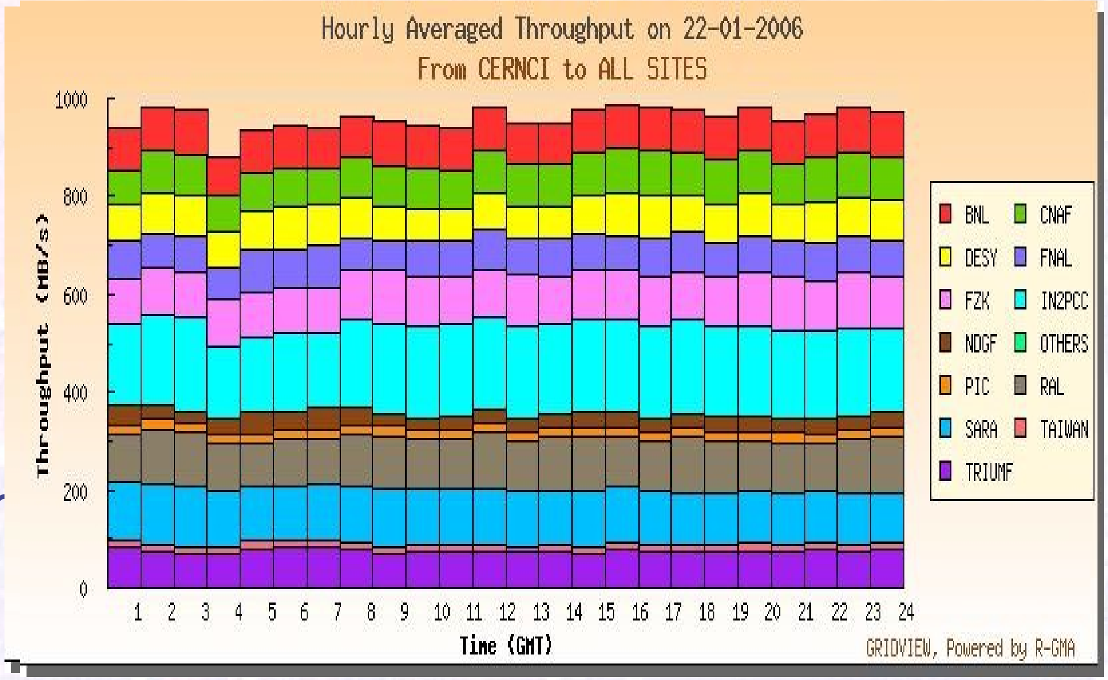
Original target – sustain daily average of 500 MByte/sec from CERN to at least 5 Tier-1 sites for one week by the end of April 2005

Target raised to include 7 sites and run for 10 days

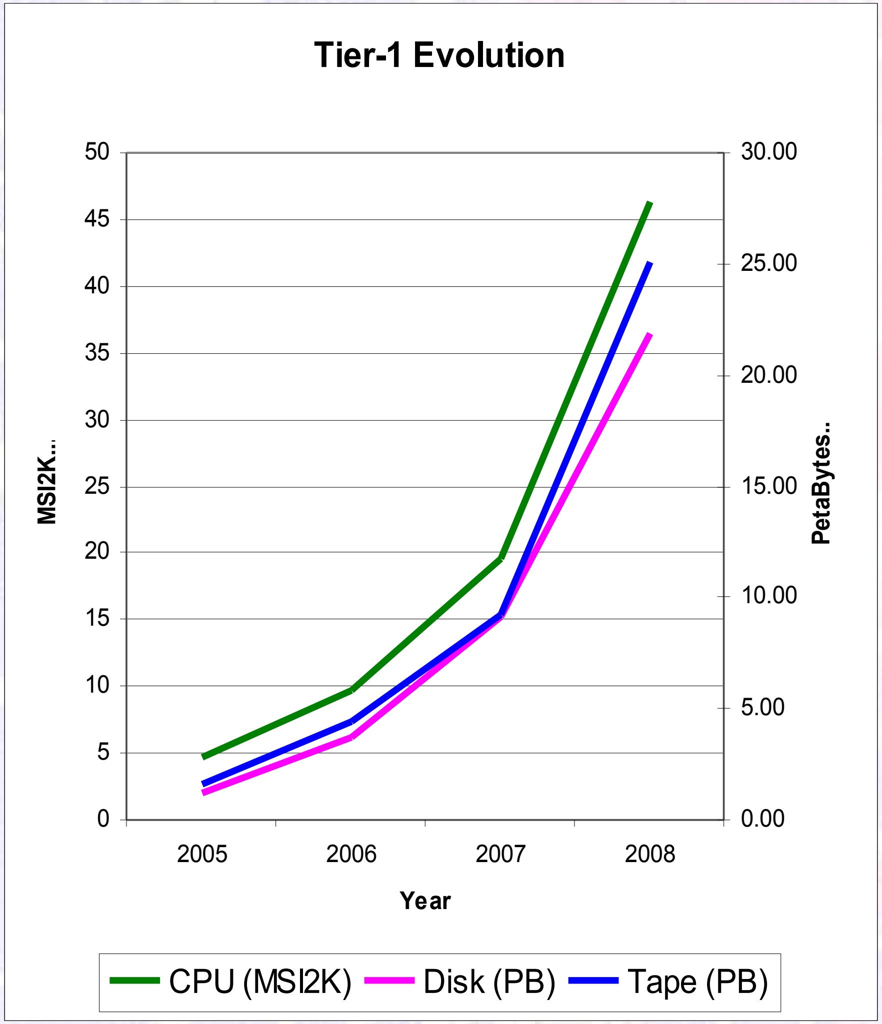
BNL, CCIN2P3, CNAF, FNAL, GridKa, RAL, NIKHEF/SARA

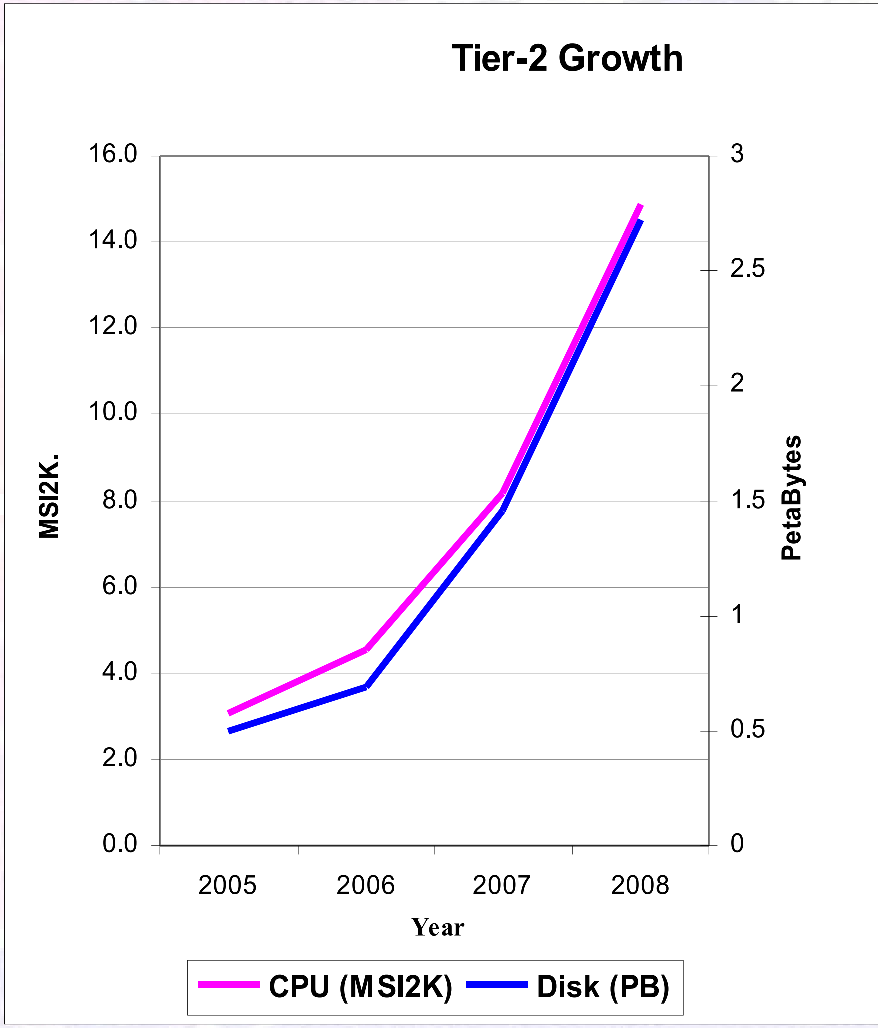
Achieved on 2 April –
-- average 600 MB/sec
-- peak 820 MB/sec

500 MB/sec is 30% of the data distribution throughput required for LHC



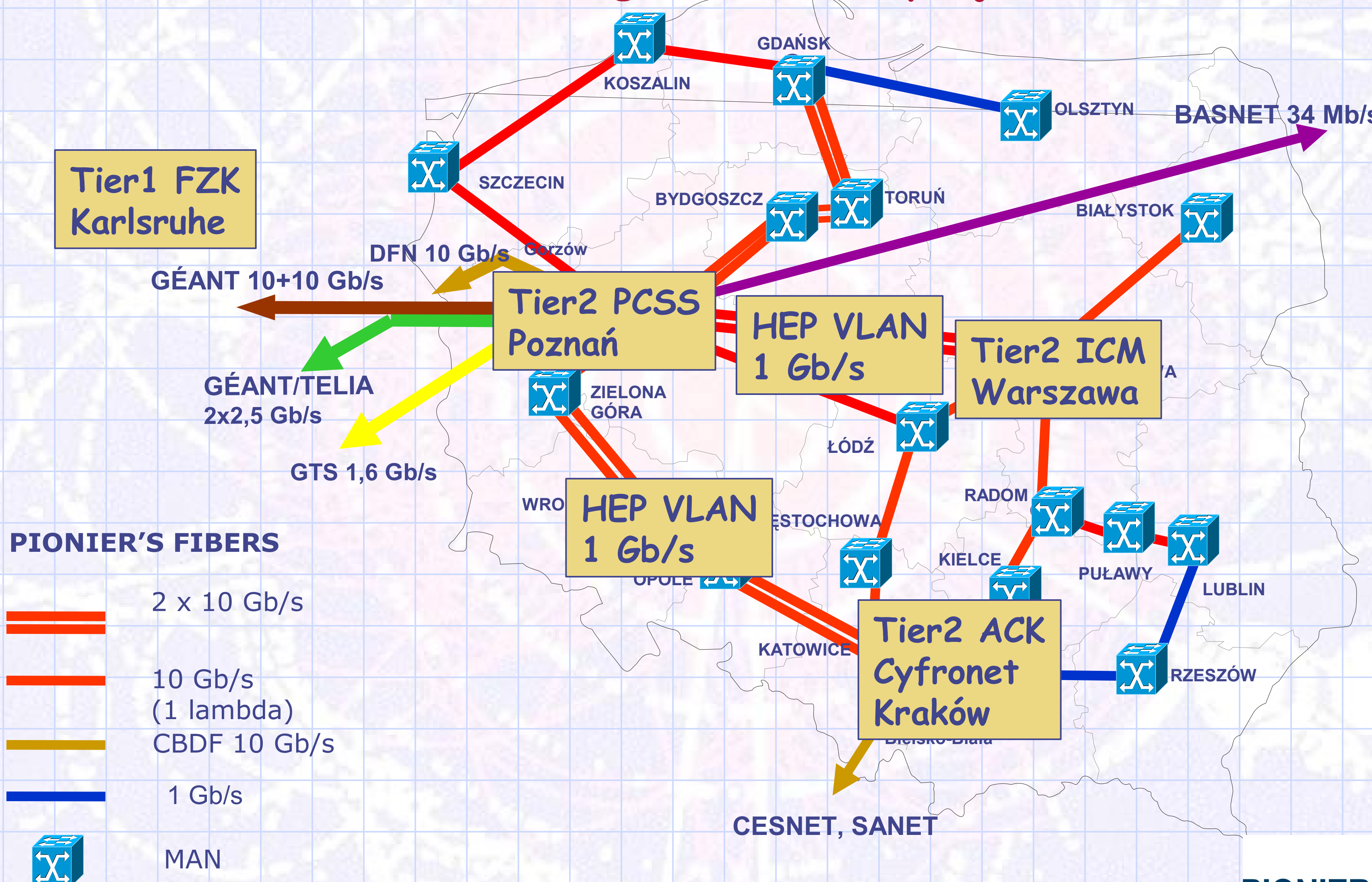
Rumping-up World LCG Services





Polish Grid infrastructure

Networking – PIONIER project



Polish Grid infrastructure

Tier2: ACC Cyfronet – ICM – PSNC

Three computing centres contribute to the Polish Tier2 (as part of EGEE/ LCG ROC)

- ACC Cyfronet Cracow
  - ~300 (450) Pentium 32 bit processors
  - connected to PSNC via 1 Gbs HEP VLAN
- ICM Warsaw
  - ~180 (340) AMD-64 Opteron processors
  - connected to PSNC via 1 Gbs HEP VLAN
- PSNC Poznan
  - ~240 Itanium IA-64 processors
  - connected to GEANT and DFN – 10 Gbs

In the hierarchy of WLCG the Polish Tier2 is connected to Tier1 at FZK Karlsruhe

Building Tier3 at IFJ Cracow and IPJ Warsaw

Attempt to create (and finance) scientific network POLTIER

Fizyka LHC

LHC Physics

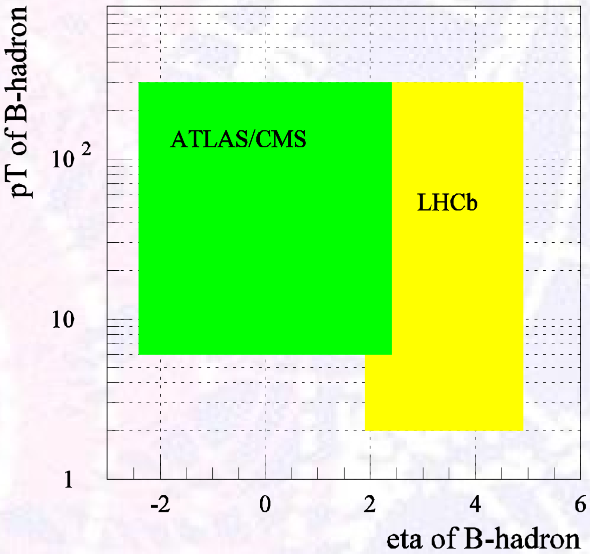
B- and top- physics

B-physics

- copious production of *b* hadrons (10^{12} bb-bar/y)
- CP violation studies
  - sin2β as a crosscheck; δ(sin2β) = 0.010 after 30 fb^{-1}
  - α angle: $B^0_d \to \pi\pi$, $B^0_d \to \pi+\pi-\pi^0$
  - γ anle: $B_s \to D_sK$, $B \to \pi+\pi-$, K+K-
  - $\Delta\Gamma_s$, Γ_s, Φ_s : $B^0_s \to J/\psi\Phi$, $B^0_s \to J/\psi\eta$
- B_d and B_s oscillations
  - $B^0_s \to D_s\pi$, $B^0_s \to D_sa_1$ with $D_s \to \Phi\pi$

    Δm_s reach in one year : 29.5 ps^{-1} for ATLAS, CMS (30 fb^{-1}) and 68 ps^{-1} for LHCb
- exclusive rare decays (new physics!)
  - $B^0_s \to \mu+\mu-$ (Br SM~$4\cdot10^{-9}$), $B^0_d \to \mu+\mu-$ ($1\cdot10^{-10}$)

    (Tevatron experimental limit <10^{-6})
  - $B^0_d \to K^{0*}$ μ+μ-, $B^0_d \to \rho^0$μ+μ-, $B^0_s \to \varphi^0$ μ+μ-



Complementarity of ATLAS, CMS, LHCb detectors

Top-physics

- production of ~10^7 tt-bar pairs per experiment at 10 fb^{-1}
- top quark mass (essential channel tt->bWbW->bblνqq)
- W polarisation in top decays, spin correlation in tt production

LHC Physics

SM and Higgs

- Electroweak physics
  - study of $WW\gamma$ couplings
  - study of $ZZ\gamma$ and $Z\gamma\gamma$ couplings
  - precision measurements of W and top mass
  - Drell-Yan production of lepton pairs

Expected 95% C.L. constraints in ATLAS

Coupling	14 TeV 100 fb^{-1}	14 TeV 1000 fb^{-1}	28 TeV 100 fb^{-1}	28 TeV 1000 fb^{-1}	LC 500 fb^{-1}, 500 GeV	from LEP
λ_γ	0.0014	0.0006	0.0008	0.0002	0.0014	0.040
λ_Z	0.0028	0.0018	0.0023	0.009	0.0013	…
$\Delta\kappa_\gamma$	0.034	0.020	0.027	0.013	0.0010	0.090
$\Delta\kappa_Z$	0.040	0.034	0.036	0.013	0.0016	….
g_1^Z	0.0038	0.0024	0.0023	0.0007	0.0050	0.040

- QCD + jet physics
  - measurement of α_s

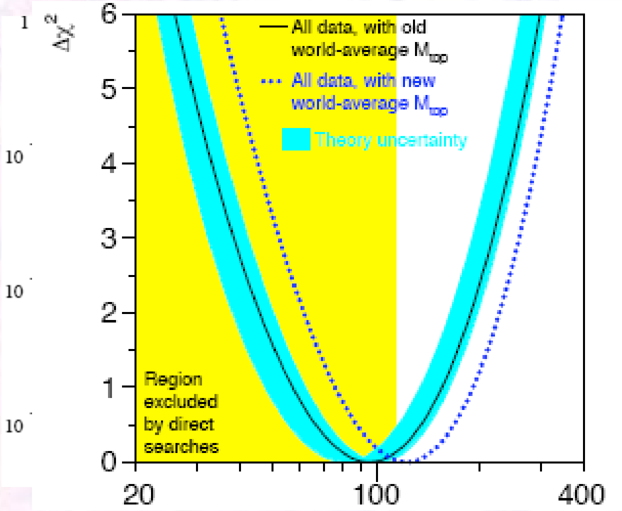
- Study of parton distribution functions of *c*, *b* and *s* quarks

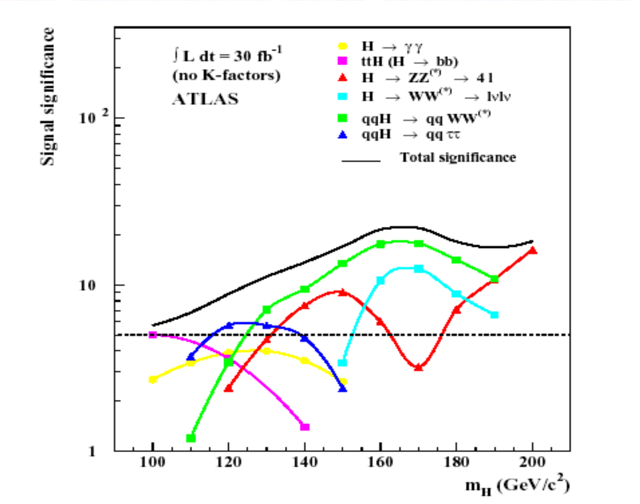
LHC Physics

from M. Grazzini talk, 2004

SM and Higgs

- **Forward physics**
  - Cross-sections
  - Small x-physics
  - Higgs + forward jets (Pomeron exchange)
  - Experiment: CMS + TOTEM
- **Higgs**
  - **dominant processes**
    - gluon-gluon fusion
    - heavy quark loops
    - W, Z production
    - …..
  - **at lower masses**
    - dominant process H -> bb-bar
    - in addition H -> γγ and H -> ττ

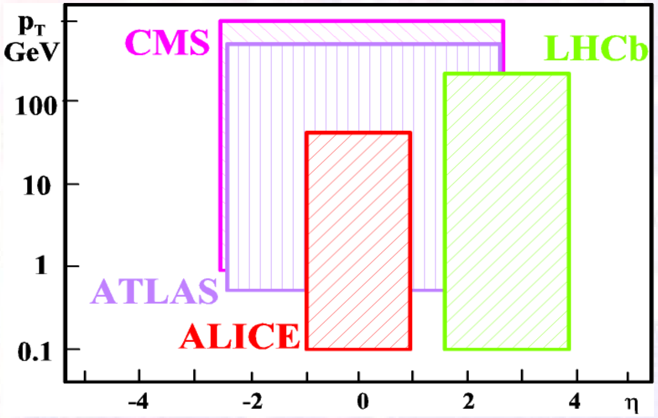




LHC Physics

Heavy ions

- **Large jump in energy (at LHC $\sqrt{s_{NN}}$ = 5500 GeV)**
  - copious production of high p_T particles
  - large cross section for J/ψ and ϒ family production
  - weakly interacting probes Z^0, W^{+-}
- **Heavy ions**
  - global observables (on event-by-event basis)
  - jet physics (quenching) – detailed studies of medium effects on jets
  - heavy quarkonia (suppression in dense matter)
- **Experiments – their complementarity**
  - dedicated ALICE
  - general purpose CMS
  - recently also ATLAS



p_T - η acceptance for LHC Experiments

LHC Physics

New Physics

- **SUSY**
  - new particles at TeV scale stabilize m_H
  - MSSM Higgs bosons: h, H, A, H^{+-}
- **Extra dimensions**
  - additional dimensions $m_{gravity} \sim m_{EW}$
- **Little Higgs**
  - SM embedded in larger gauge group
  - new particles at TeV scale, stable m_H
- **Technicolour**
  - new strong interactions break EW symmetry
  - Higgs (elementary scalar) removed - new particles at TeV scale

LHC Physics

What can be done at the beginning

The first LHC data : from Summer 2007...

$1\ fb^{-1}$ ($10\ fb^{-1}$) ≡ 6 months at 10^{32} (10^{33}) $cm^{-2}s^{-1}$ at 50% efficiency → may collect several fb^{-1} per experiment by end 2008

Channels (examples ...)	Events to tape for $1\ fb^{-1}$ (per expt: ATLAS, CMS)	Total statistics from previous Colliders
$W \to \mu\nu$	7×10^6	~ 10^4 LEP, ~ 10^6 Tevatron
$Z \to \mu\mu$	~ 10^6	~ 10^6 LEP, ~ 10^5 Tevatron
$t\bar{t} \to WbWb \to \mu\nu + X$	~ 10^5	~ 10^4 Tevatron
$\tilde{g}\tilde{g}$ m = 1 TeV	10^2 - 10^3	———

With these data:

- Understand and calibrate detectors in situ using well-known physics samples

  e.g. - $Z \to ee, \mu\mu$ tracker, ECAL, Muon chambers calibration and alignment, etc.

  - $t\bar{t} \to bl\nu\ bjj$ jet scale from $W \to jj$, b-tag performance, etc.

- Measure SM physics at $\sqrt{s}$ = 14 TeV : W, Z, $t\bar{t}$, QCD jets ... (omnipresent backgrounds to New Physics)

→ prepare the road to discovery .... it will take a lot of time ...

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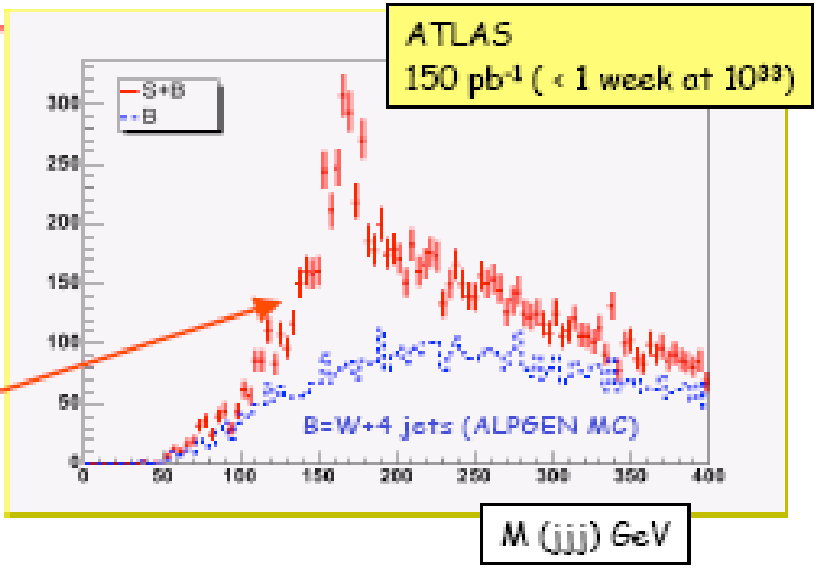
LHC Physics

Example of initial SM measurement : top signal and top mass
(relevant to New Physics .....)

Bentvelsen et al.

- Use gold-plated $t\bar{t} \rightarrow bW\ bW \rightarrow bl\nu\ bjj$ decay
- Very simple selection:
  - -- isolated lepton (e, μ) $p_T > 20$ GeV
  - -- exactly 4 jets $p_T > 40$ GeV
  - -- no kinematic fit
  - -- no b-tagging required (pessimistic, assumes trackers not yet understood)
- Plot invariant mass of 3 jets with highest p_T



Time	Events at 10^{33}	Stat. error δM_{top}(GeV)	Stat. error $\delta\sigma/\sigma$
1 year	3×10^5	0.1	0.2%
1 month	7×10^4	0.2	0.4%
1 week	2×10^3	0.4	2.5%

- top signal visible in few days also with simple selection and no b-tagging
- cross-section to ~ 20%
- top mass to ~7 GeV (assuming b-jet scale to 10%)
- get feedback on detector performance :
  m_{top} wrong → jet scale ?
  gold-plated sample to commission b-tagging
- $t\bar{t}$ is background to many searches

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LHC Physics

An "easy case" : $G \rightarrow e^+e^-$ resonance with m ~ 1 TeV

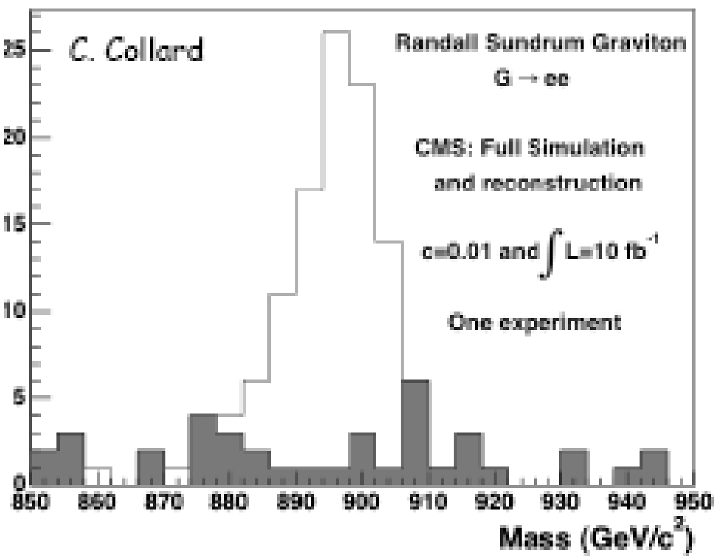
predicted in Randall-Sundrum Extra-dimensions

BR ($G \rightarrow ee$ = 2%), c = 0.01 (small/conservative coupling to SM particles)

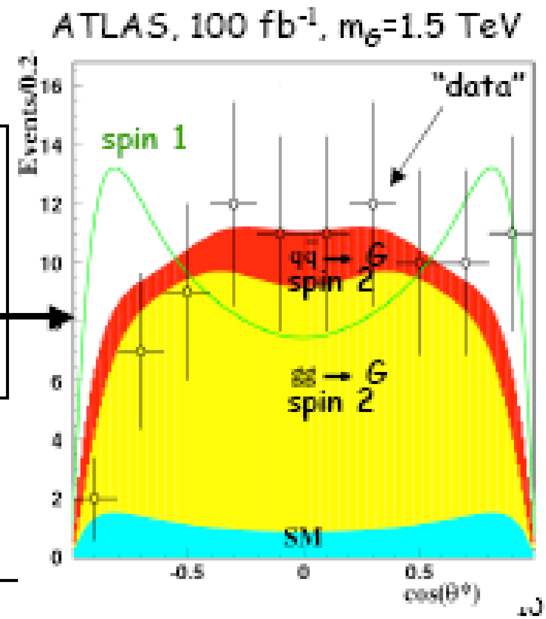
Mass (TeV)	Events for 10 fb^{-1} (after all cuts)	$\int L\,dt$ for discovery ($\geq$ 10 observed events)
0.9	~ 80	~ 1.2 fb^{-1}
1.1	~ 25	~ 4 fb^{-1}
1.25	~ 13	~ 8 fb^{-1}

CMS

- large enough signal for discovery with $\int L dt$ < 10 fb^{-1} for m < 1.3 TeV
- dominant Drell-Yan background small
- signal is <u>mass peak</u> above background



Graviton (s=2) or Z′ (s=1) ? → look at $e^\pm$ angular distributions



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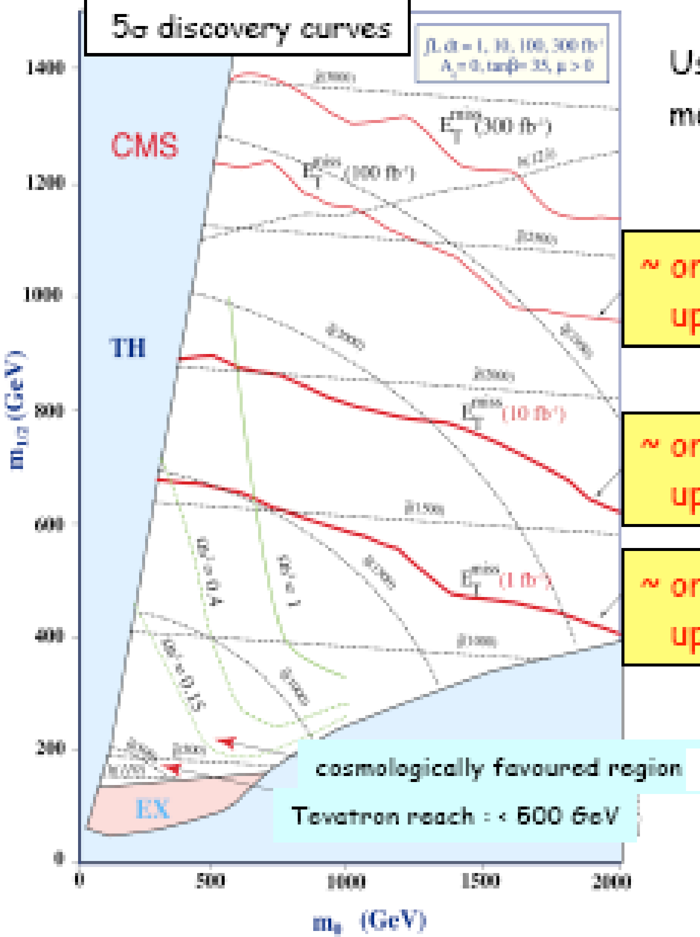
LHC Physics

An "intermediate case" : SUPERSYMMETRY

If SUSY stabilizes m_H → is at TeV scale → could be found quickly .... thanks to:

- large $\tilde{q}\tilde{q}, \tilde{q}\tilde{g}, \tilde{g}\tilde{g}$ cross-section → ≈ 100 events/day at 10^{33} for $m(\tilde{q},\tilde{g}) \sim 1$ TeV
- spectacular signatures

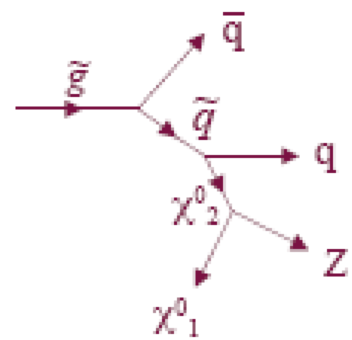


~ one year at 10^{34}: up to ~2.5 TeV

~ one year at 10^{33} : up to ~2 TeV

~ one month at 10^{33} : up to ~1.5 TeV

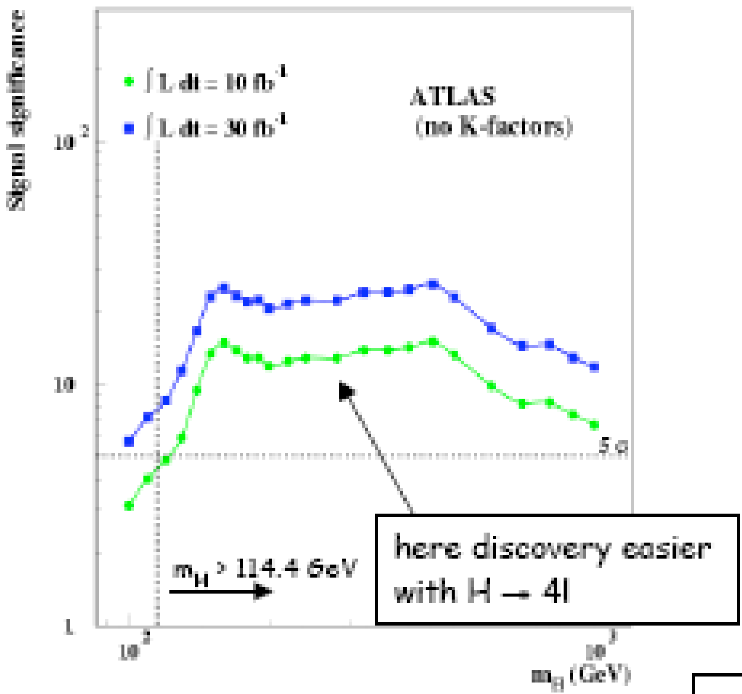
Using multijet + E_T^{miss} (most powerful and model-independent signature if R-parity conserved)

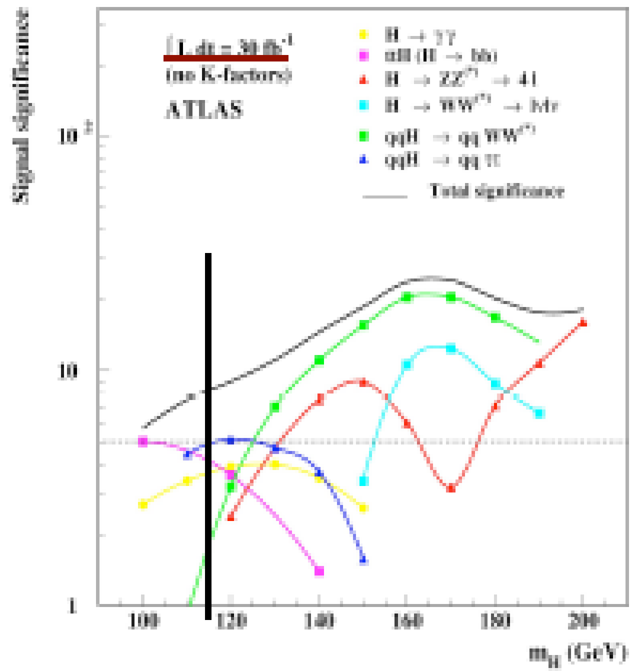


First/fast determination of SUSY (squark, gluino) mass scale from distribution of $E_T^{miss} + \Sigma p_T$(jets)

LHC Physics

A difficult case: a light Higgs (m_H ~ 115 GeV) ...





m_H ~ 115 GeV   10 fb^{-1}

ATLAS	$H \to \gamma\gamma$	$ttH \to ttbb$	$qqH \to qq\tau\tau$ (ll + l-had)
S B	130 4300	15 45	~ 10 ~ 10
S/ √B	2.0	2.2	~ 2.7

total $S/\sqrt{B} = 4^{+2.2}_{-1.3}$

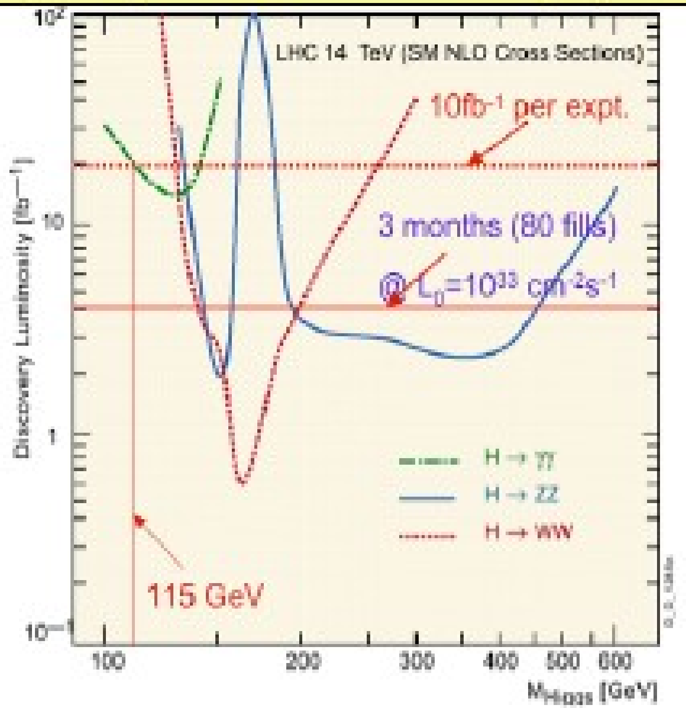
K-factors ≡ σ(NLO)/σ(LO) ≈ 2 not included

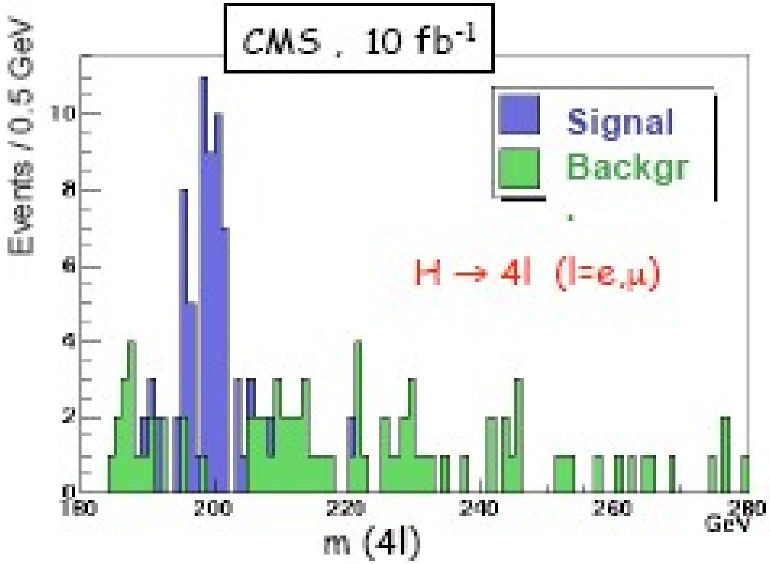
Full GEANT simulation, simple cut-based analyses

LHC Physics

If m_H > 180 GeV : early discovery may be easier with $H \rightarrow 4l$ channel

Luminosity needed for 5σ discovery (ATLAS+CMS)





- H → WW → lν lν : high rate (~ 100 evts/expt) but no mass peak
  → not ideal for early discovery …
- H → 4l : low-rate but very clean : narrow mass peak, small background

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LHC Physics

….. many years of hard but interesting and fruitful work…..

LHC Physics

To learn more, you are invited to come to Cracow in July 2006

Podsumowanie

Summary and outlook

We are approaching very exciting period in the history of accelerator particle physics – New Physics will be explored up to m ~ 5 TeV

Construction of LHC machine proceeds, in spite of some problems, with an objective to get first beams in summer 2007

LHC detectors become a reality and now the emphasis is on their installation, commissioning and pilot runs

The insurmountable problem of LHC computing seems to be solvable, due to rapid progress on IT technologies

LHC will have its limitations – some new phenomena can be measured only at future LCs

Acknowledgements

The material used for this presentations comes from many sources; I have used slides of LHC accelerator, LHC experimental teams and the LCG project, as well as of my LHC/LCG colleagues (in particular from talks of F. Gianotti and L. Rolandi at LP05, and L. Robertson at C-RRB meetings).

Dziękuję za uwagę