

# 有关 LHC (大型强子对撞机) 的进展和启动计划的介绍

- 加速器、探测器和TeV物理

钱思进

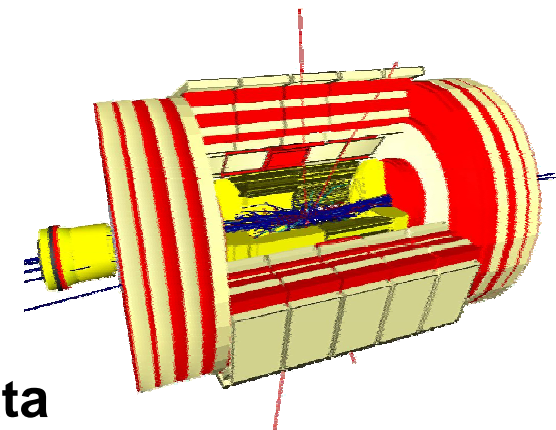


Physics School, Peking University

Beijing

2006.3.2

- **Introduction**
  - CERN and LHC (Large Hadron Collider)
- **Now: Status of the**
  - LHC machine
  - Detectors
  - Peking University's contribution to CMS
- **Pretty soon:**  
**Commissioning and start-up scenarios of the**
  - LHC machine
  - Detectors
- **Soon**
  - Pilot and first Physics run
- **Further aspects**
  - Learn as much as possible from the data
  - Some comments, LHC upgrade scenarios
- **Peking University's plan for CMS physics analysis**



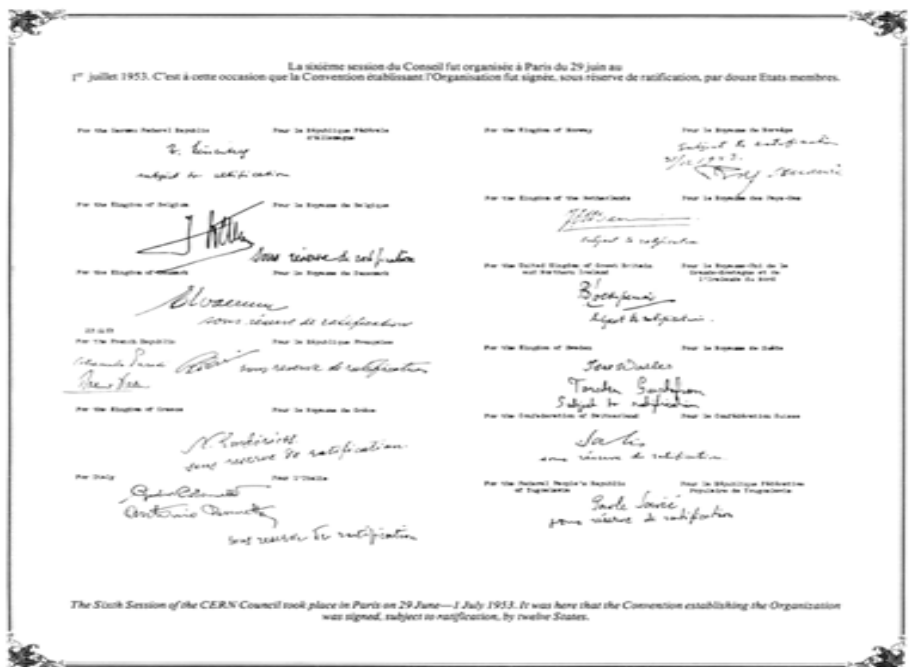
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# CERN (European Organization for Nuclear Research)



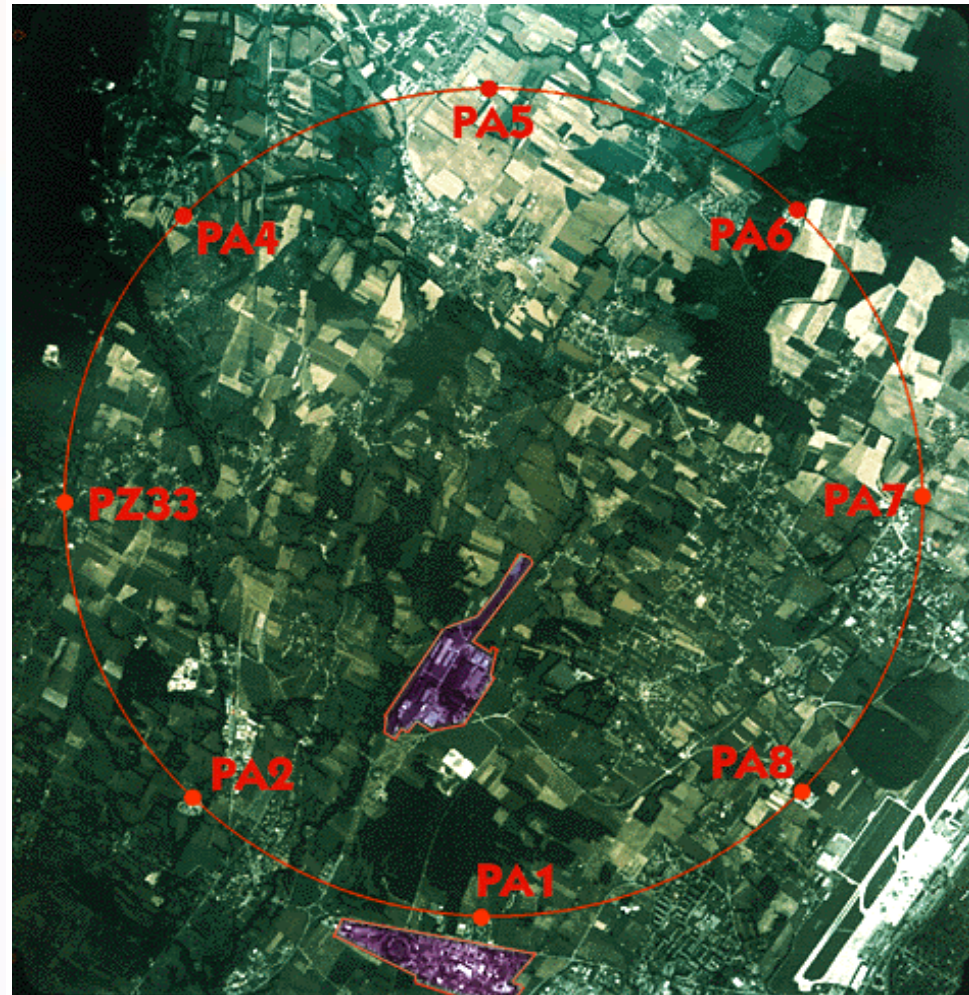
- Founded in 1954 by 12 countries
- Today: 20 member states
- More than 7000 users from all over the world
- ~1300 MCHF / Year budget



1954: Convention establishing the Organization - original signatures



2004: The 20 member states



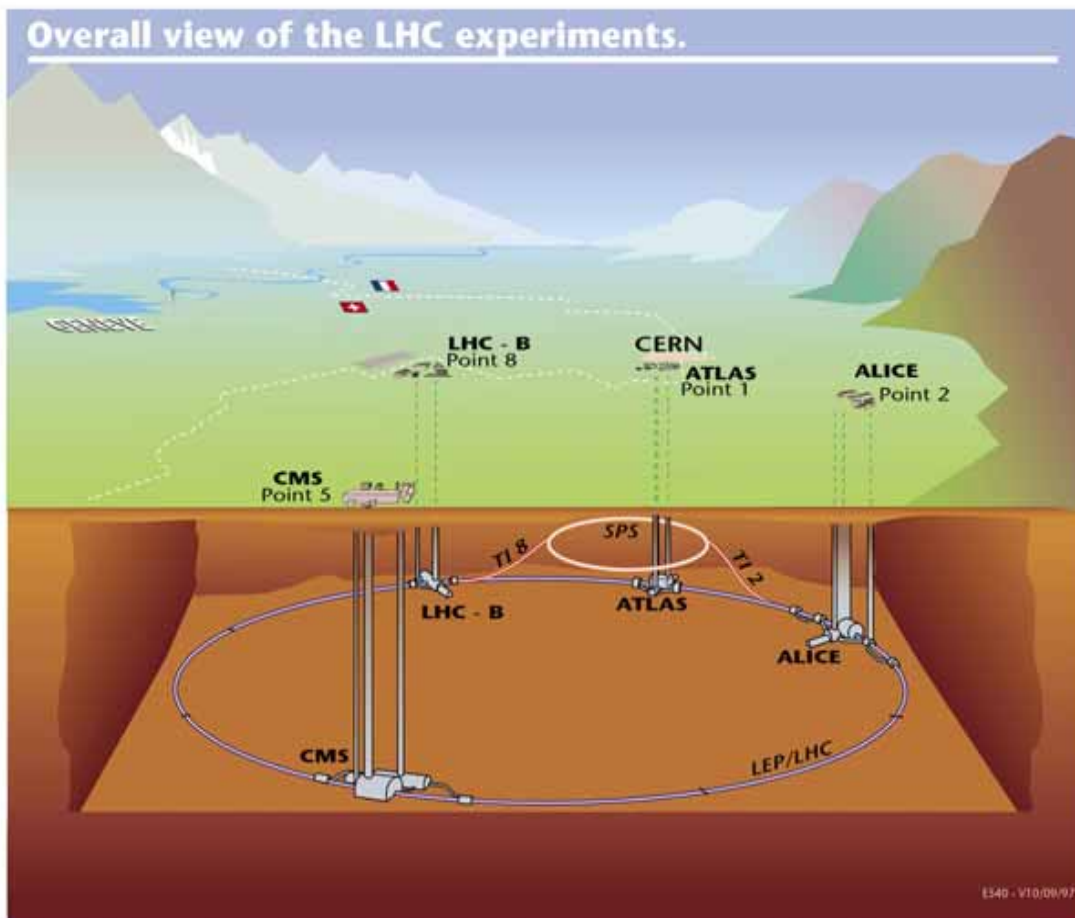


# Another View of CERN & LHC





The Large Hadron Collider (LHC) will be the most powerful instrument ever built to investigate particles properties.



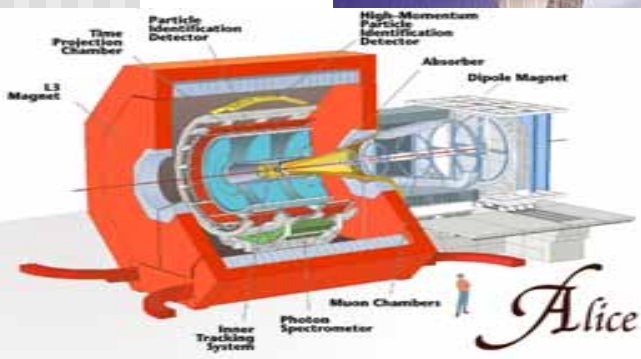
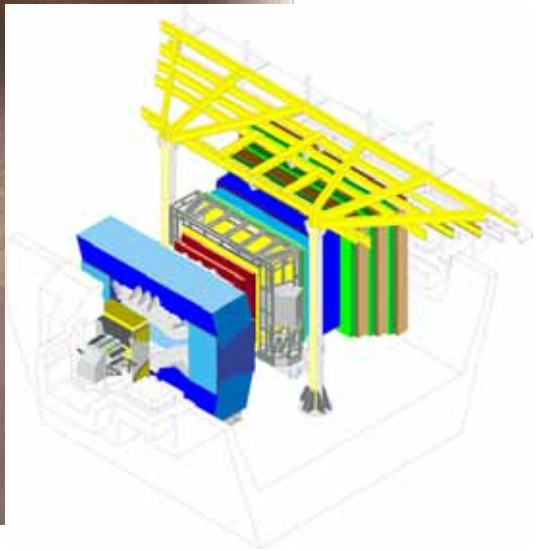
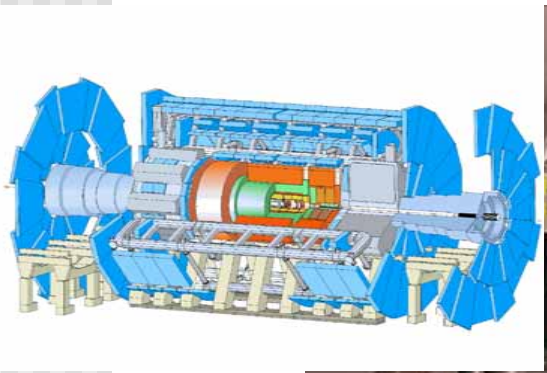
- Four **gigantic underground caverns** to host the huge detectors
- The **highest energy** of any accelerator in the world
- The **most intense beams** of colliding particles
- It will operate at a temperature **colder than outer space**



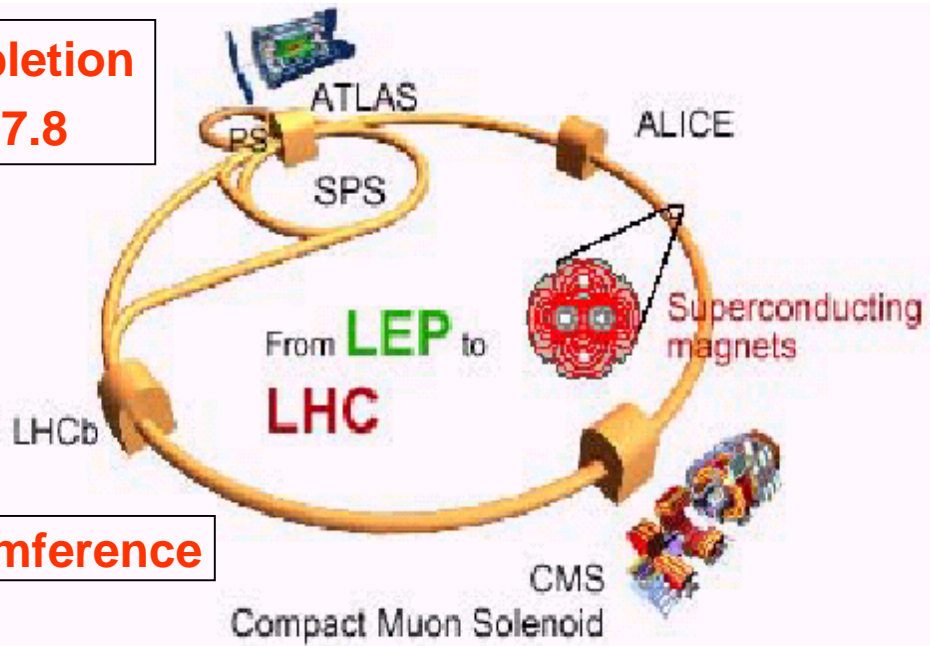
# The LHC: What it will be looked like



The LHC will start operation in 2007. It will certainly change our view of the Universe



**LHC completion date: 2007.8**



**27 km circumference**

**Cost:**

- LHC:** ~ 2.3 Billion SFr
- CMS, ATLAS:** ~ 500 Million SFr / each
- ALICE, LHCb:** ~ 100 Million SFr / each

	Beams	Energy GeV	Luminosity
<b>LEP</b>	e+ e-	200	$10^{32} \text{ cm}^{-2} \text{ s}^{-1}$
<b>LHC</b>	p p	<b>14000</b>	<b><math>10^{34}</math></b>
	Pb Pb	1,312,000	$10^{27}$

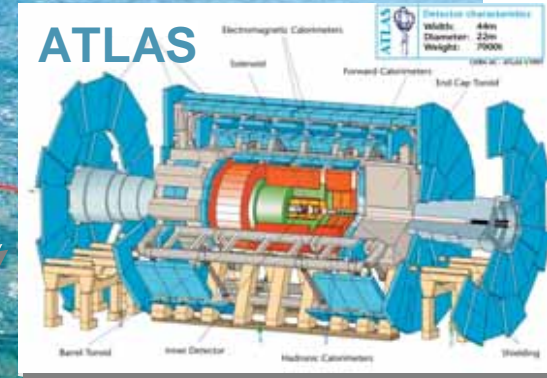
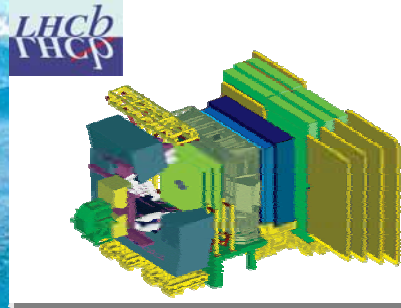
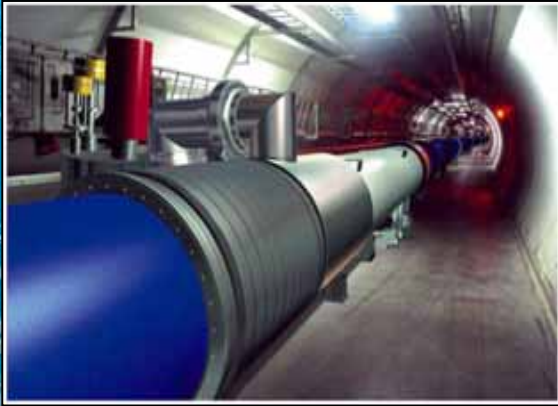
# Our future play ground

**Introduction**

- Status of
- Machine
- Detectors
- Startup of
- Machine
- Detectors
- First Physics
- Comments

pp, B-Physics,  
CP Violation

LHC : 27 km long  
100m underground



General Purpose,  
pp, heavy ions



Heavy ions, pp



# What will be (not) covered here:



## Introduction

Status of

Machine

Detectors

Startup of

Machine

Detectors

First Physics

Comments

- **I will talk about**
  - A brief overview of CERN and the **hardware preparations** of
    - the LHC machine
    - ATLAS and CMS
  - Explain the **startup**
    - Why is the LHC startup planned in this particular way?
    - What are the initial challenges for the detectors
  - **Pilot run** and first year
    - What can we do with pilot run data?
    - The first year's data
  - Some **comments** about
    - Use of data to constrain backgrounds, MCs
    - Use of MCs
- **I will not talk about**
  - LHCb and ALICE (sorry for that...)
  - All the wonderful physics we can do (from NNMSSM to Black Holes)
  - All the details of Higgs and SUSY searches
  - Data challenges, Data flow, ATLAS Blind test
  - For these, please see **A. De Roeck's talk at the 1st LHC-Olympics workshop (7/2005)!**
    - A few slides I will show again, nevertheless :-)



Introduction

**Status of**

Machine

Detectors

Startup of

Machine

Detectors

First Physics

Comments

# Now : Status of the LHC and the Detectors

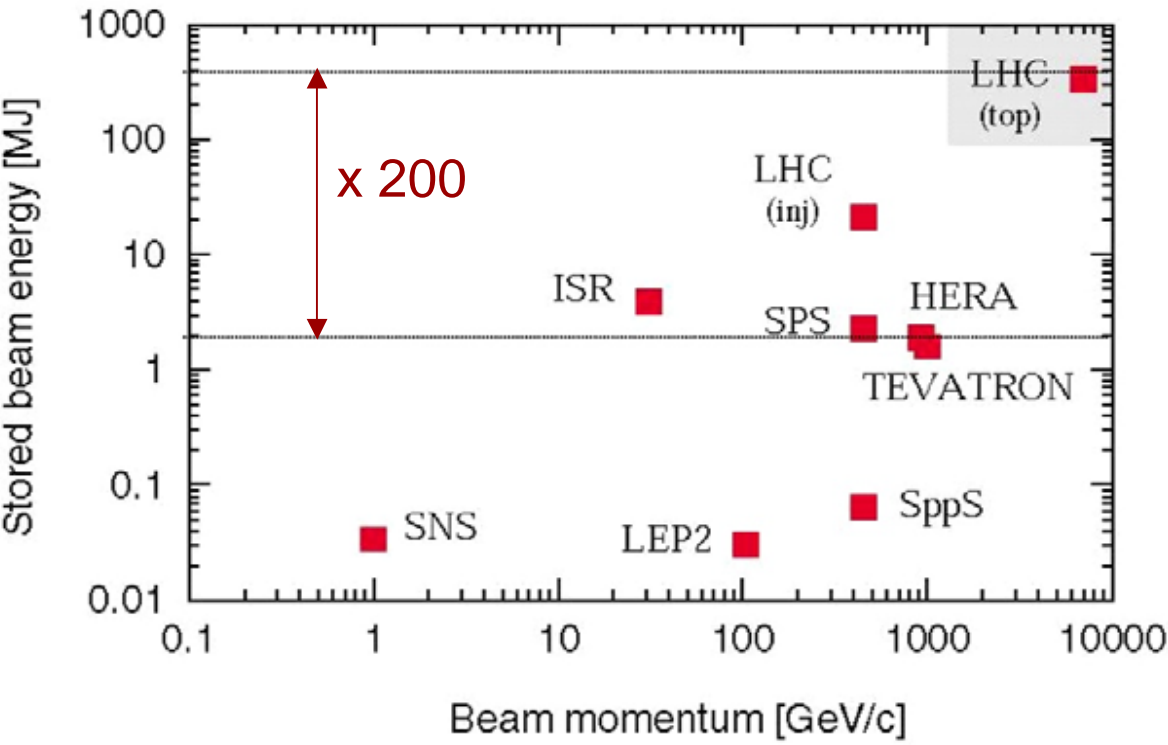
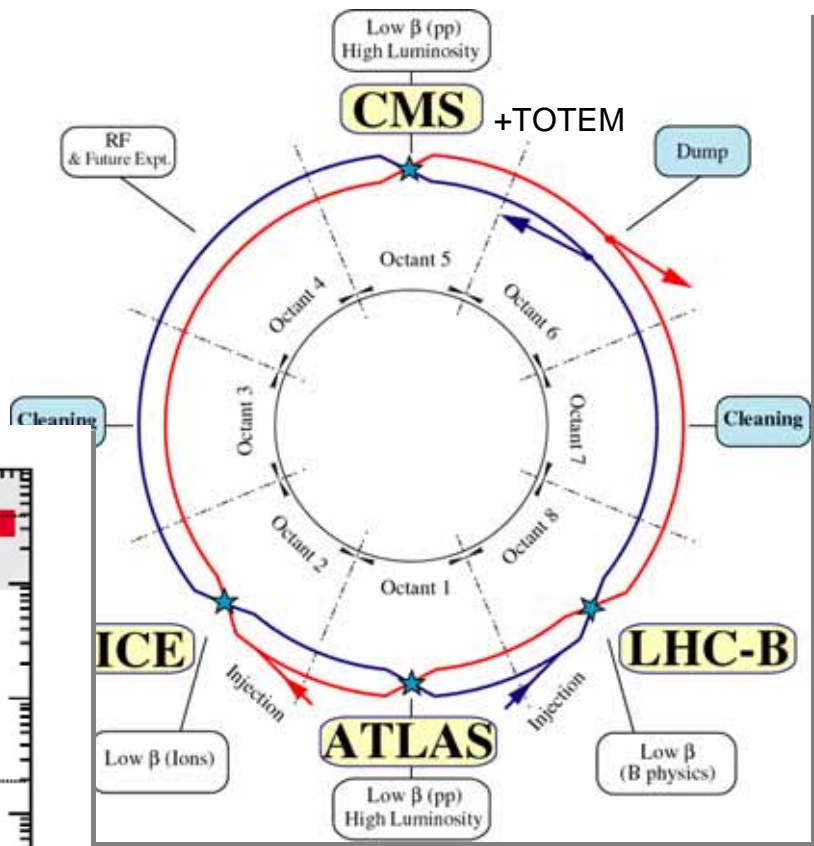
*“The greater the obstacle, the more glory in overcoming it.” (Moliere)*



# The LHC : Basic parameters



- Introduction
- Status of **Machine**
- Detectors
- Startup of Machine
- Detectors
- First Physics



8 independent sectors

- Challenge for control, powering 10 GJ stored in magnets
- Warm insertion regions for beam dump, cleaning, acceleration



# The LHC : Status report (1)



- Introduction
- Status of
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Lowering of the first dipole into the tunnel (March 2005).

By now there are **> 250 dipoles**

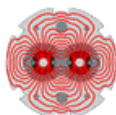
Now : installation rate of ~20 per week  
Needed to maintain schedule : 25 / week  
Schedule review in Spring 2006.



Cryogenic services line : Major previous problems solved in 2005.  
inter-connections



# The LHC : Status report (2)

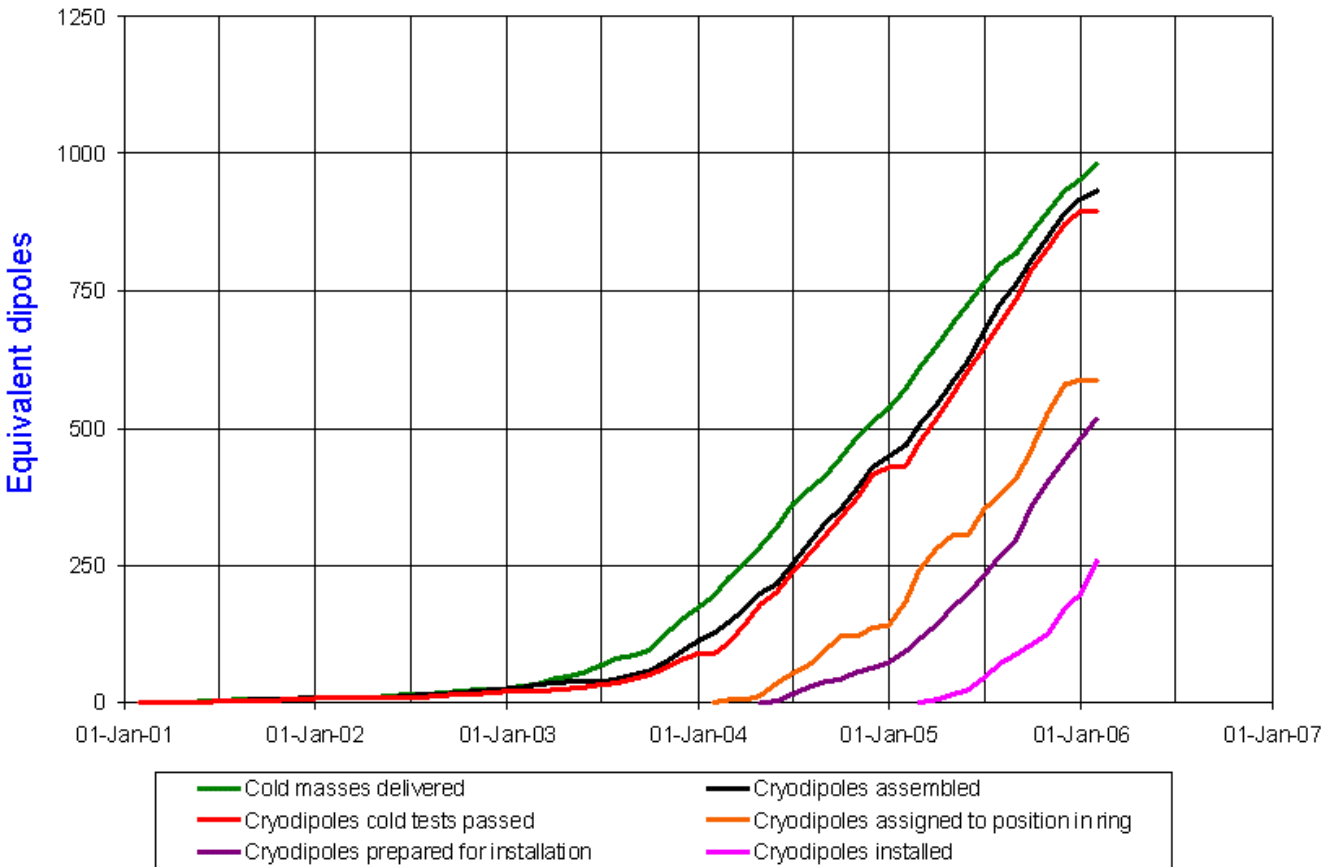


LHC Progress Dashboard

Accelerator Technology Department

- Introduction
- Status of
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### Cryodipole overview



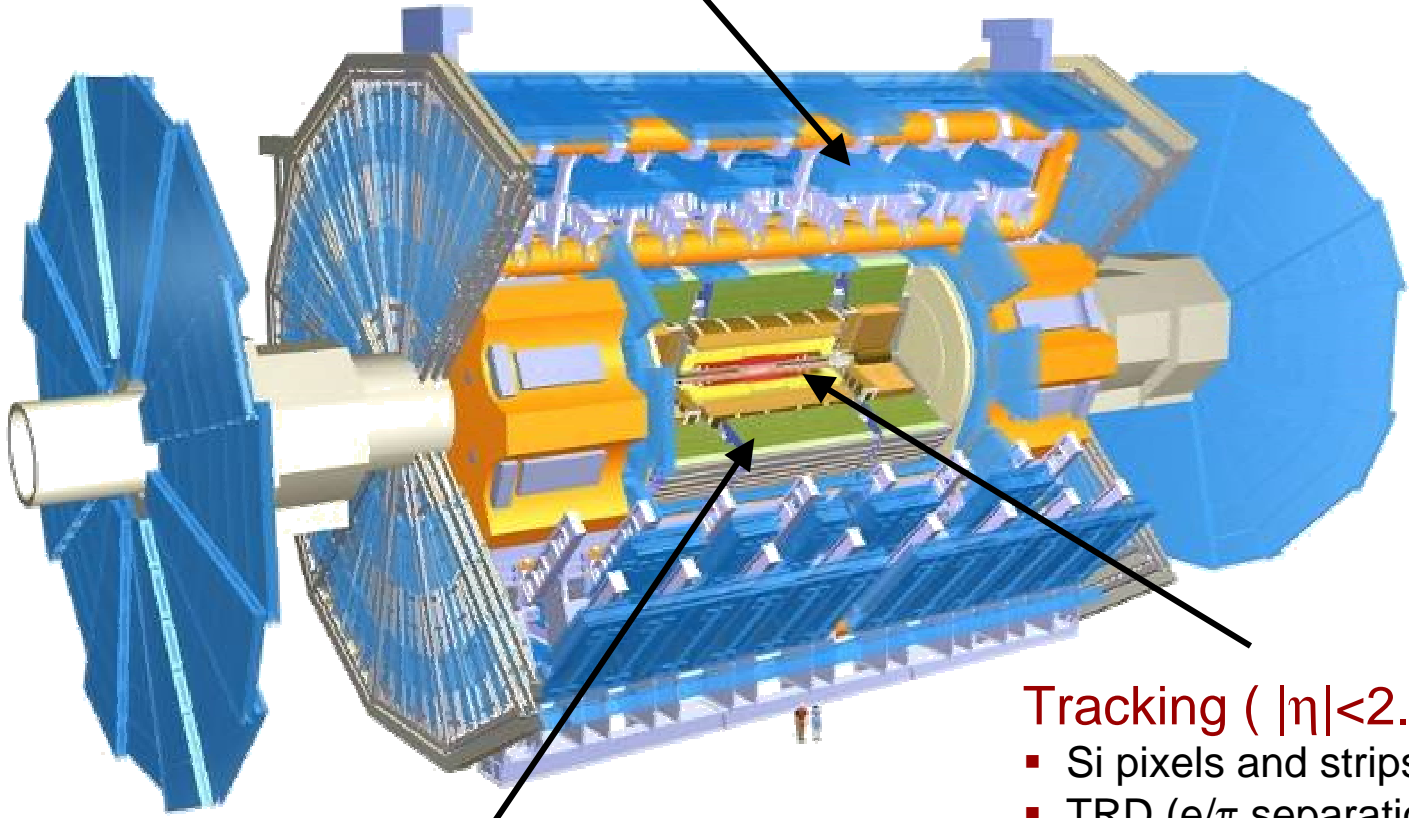
Updated 31 Jan 2006

Data provided by D. Tommasini AT-MAS, L. Bottura AT-MTM

See : <http://lhc-new-homepage.web.cern.ch/lhc-new-homepage/DashBoard/index.asp>

## Muon Spectrometer ( $|\eta| < 2.7$ )

- air-core toroids with muon chambers



## Tracking ( $|\eta| < 2.5, B=2T$ )

- Si pixels and strips
- TRD (e/ $\pi$  separation)

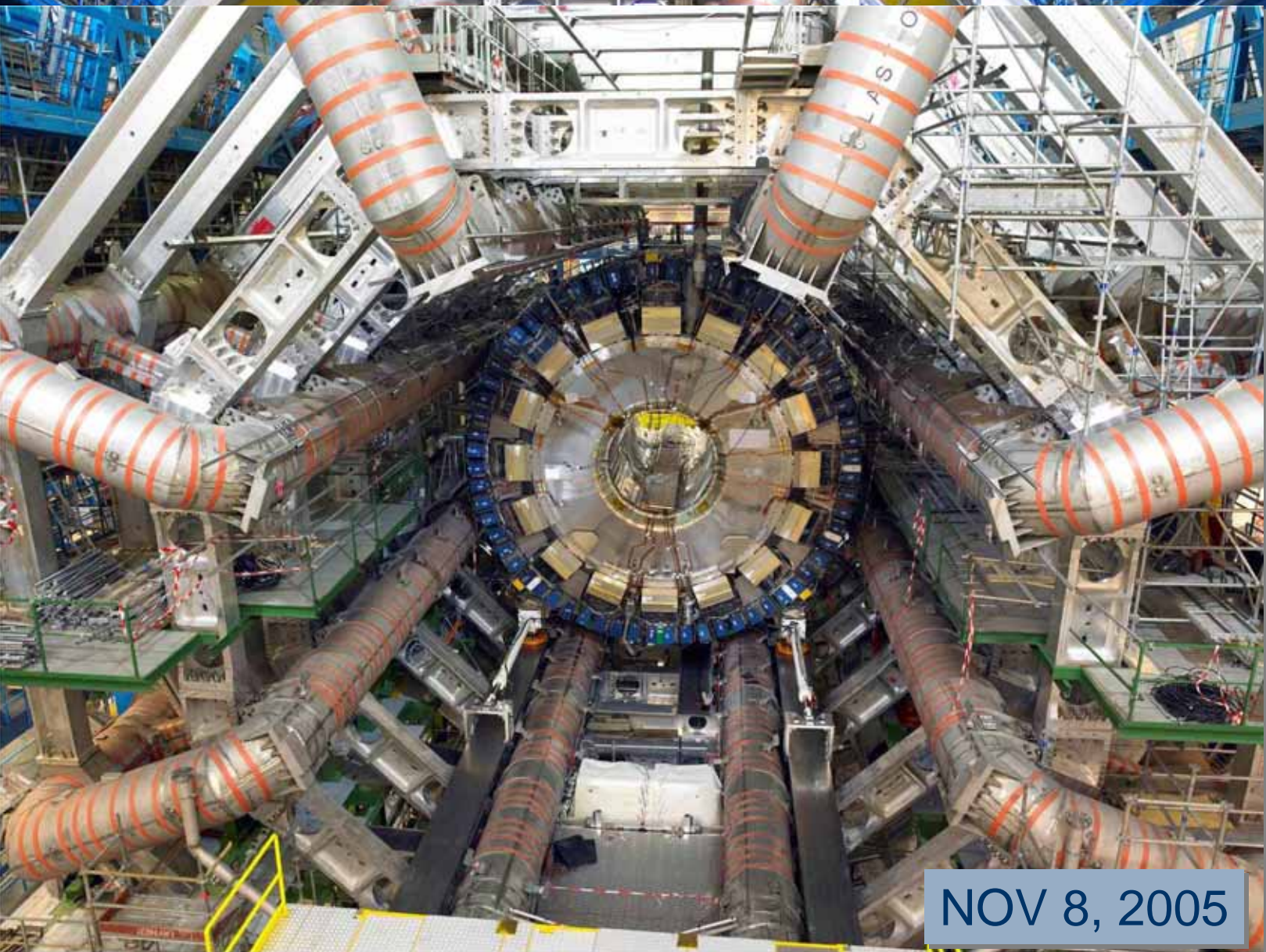
## Calorimetry ( $|\eta| < 5$ )

- EM : Pb-LAr
- HAD : Fe/scintillator (central), Cu/W-LAr (fwd)

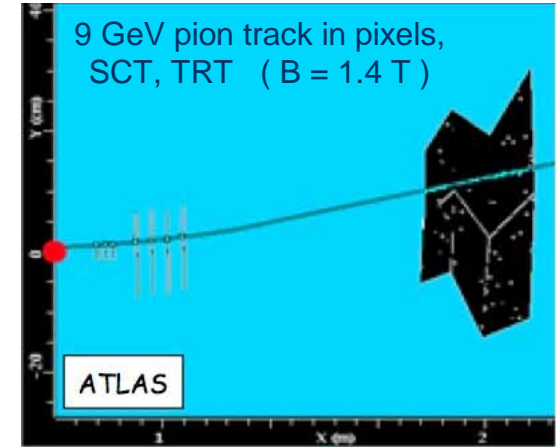
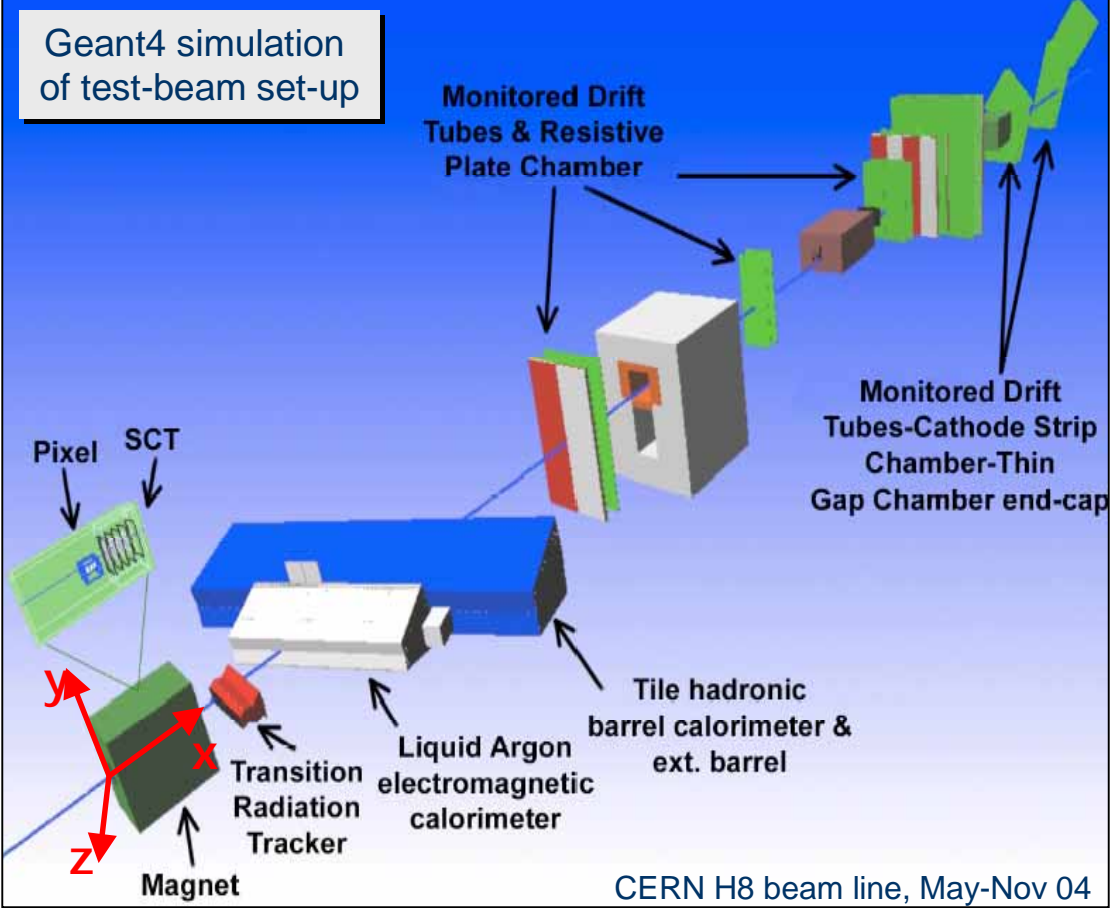
Diameter	25 m
Barrel toroid length	26 m
End-cap end-wall chamber span	46 m
Overall weight	7000 tons

# ATLAS : Status report

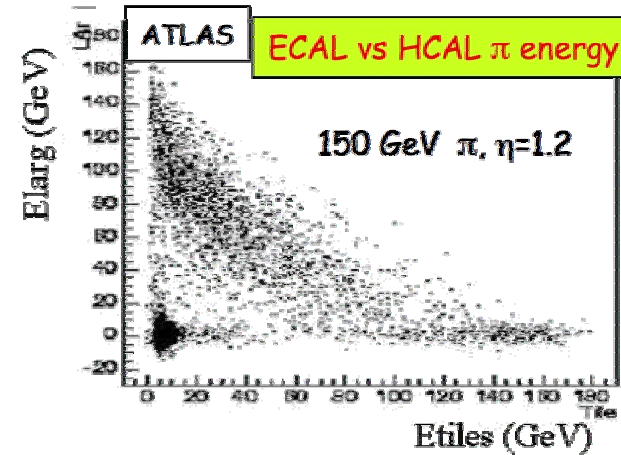
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M  
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Sta  
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Co



NOV 8, 2005



Preliminary results



For the first time, all ATLAS sub-detectors integrated and run together with common DAQ, “final” electronics, DCS, etc.

Gained lot of global operation experience during ~ 6 month run. Common ATLAS software used to analyze the data (4.5 TB).

- Introduction
- Status of Machine
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**Superconducting Coil, 4 Tesla**

**CALORIMETERS**

**ECAL**

76k scintillating PbWO4 crystals

**HCAL**

Plastic scintillator/brass sandwich

**IRON YOKE**

**TRACKER**

Pixels  
Silicon Microstrips  
210 m<sup>2</sup> of silicon  
9.6M channels

**MUON BARREL**

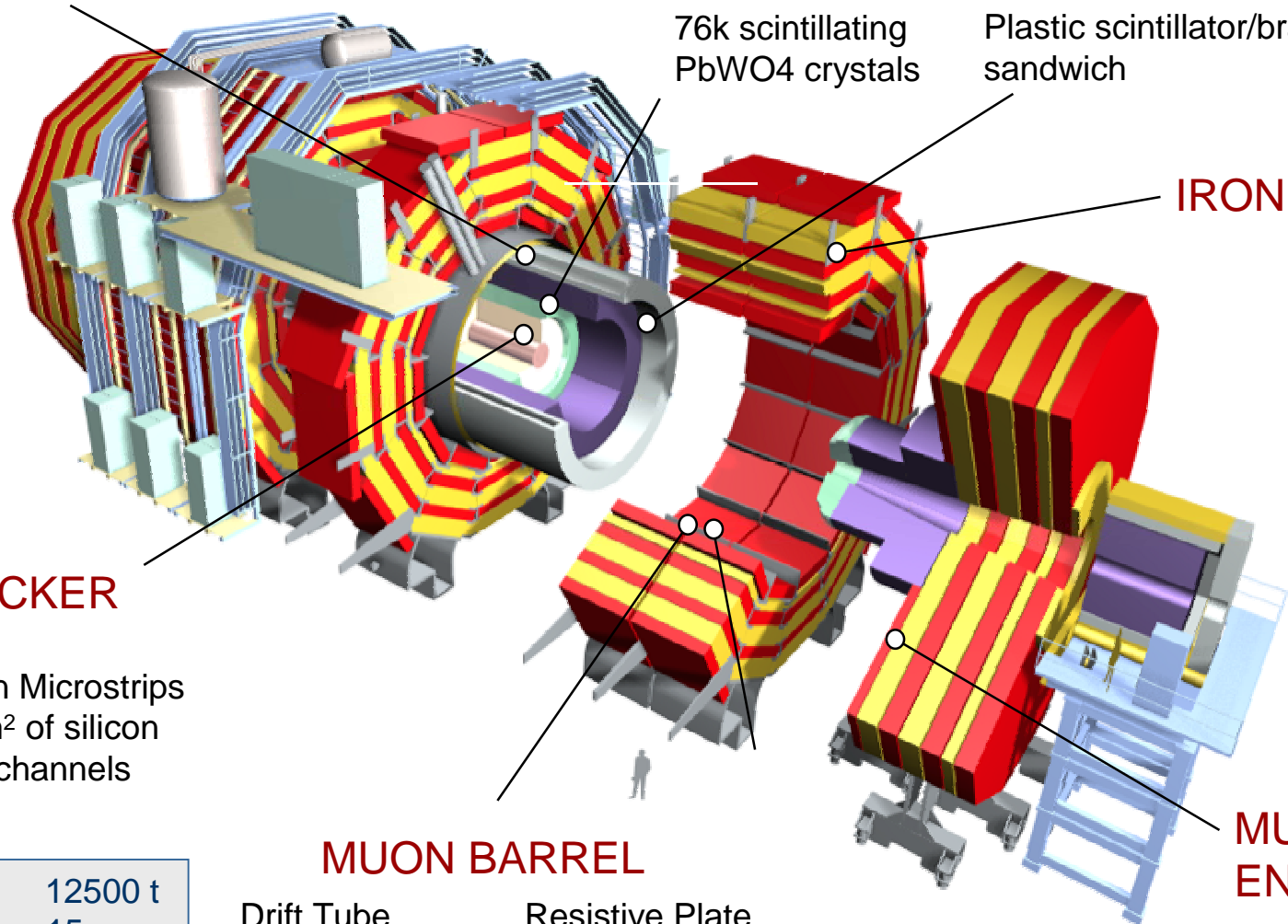
Drift Tube Chambers (**DT**)

Resistive Plate Chambers (**RPC**)

**MUON ENDCAPS**

Cathode Strip Chambers (**CSC**)  
Resistive Plate Chambers (**RPC**)

Total weight	12500 t
Overall diameter	15 m
Overall length	21.6 m





# CMS : Status report



Magnet Swivelling:  
Aug 05

- Introduction
- Status of Machine
- Detectors**
- Startup of Machine
- Detectors
- First Physics
- Comments



QuickTime and a TIFF (Uncompressed) decompressor are needed to see this picture.

All 5 coil modules delivered, connected and leak-tested.

- Cool down : [now...](#)
- Important Milestone : Magnet Test and Cosmic Challenge, Spring 2006

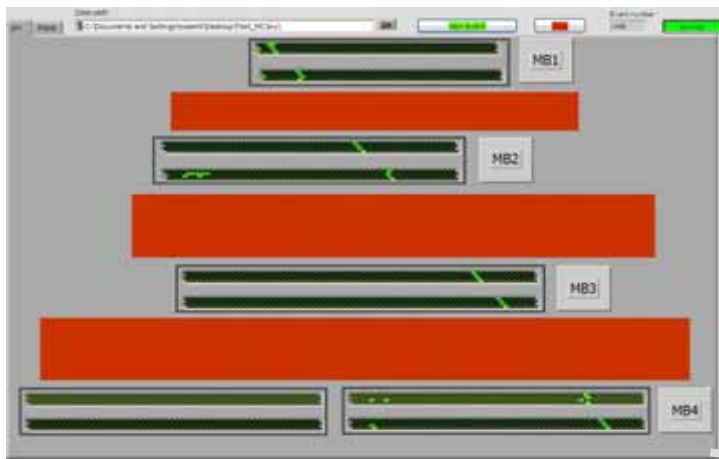
S. Qian

LHC Status and Near Future Plan

- Introduction
- Status of Machine
- Detectors**
- Startup of Machine
- Detectors
- First Physics
- Comments



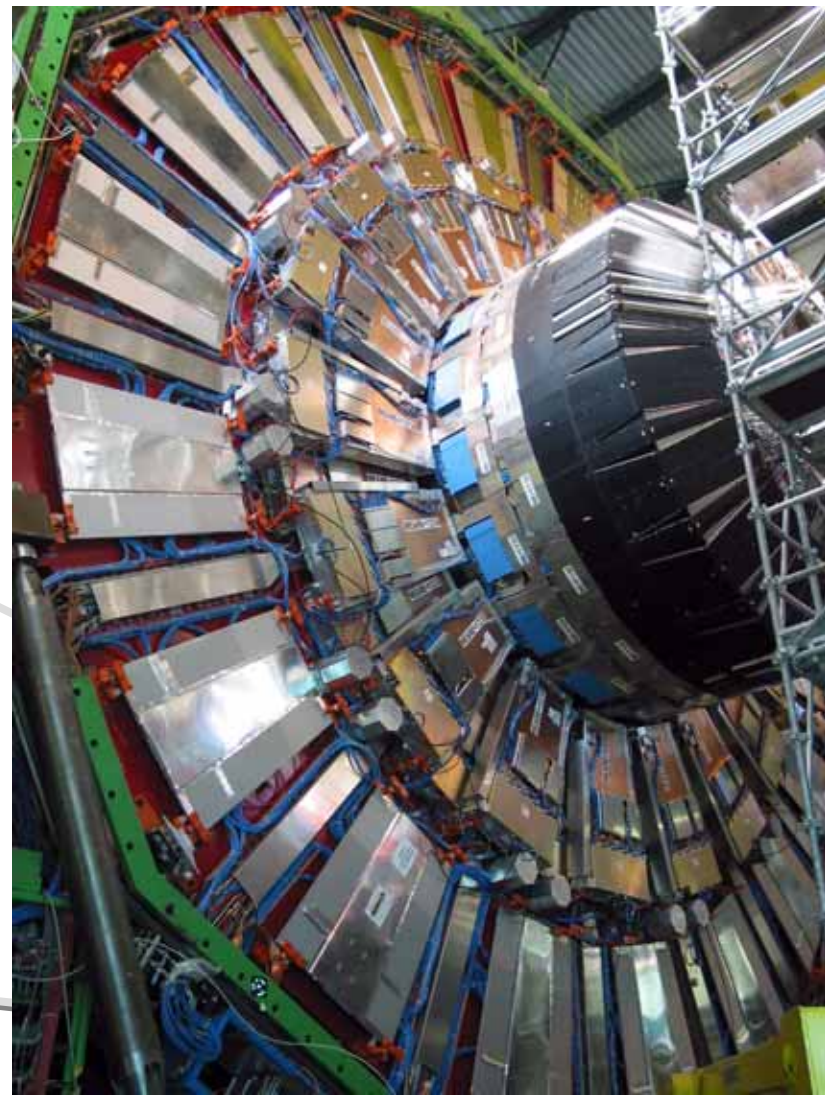
**Barrel Muon System**



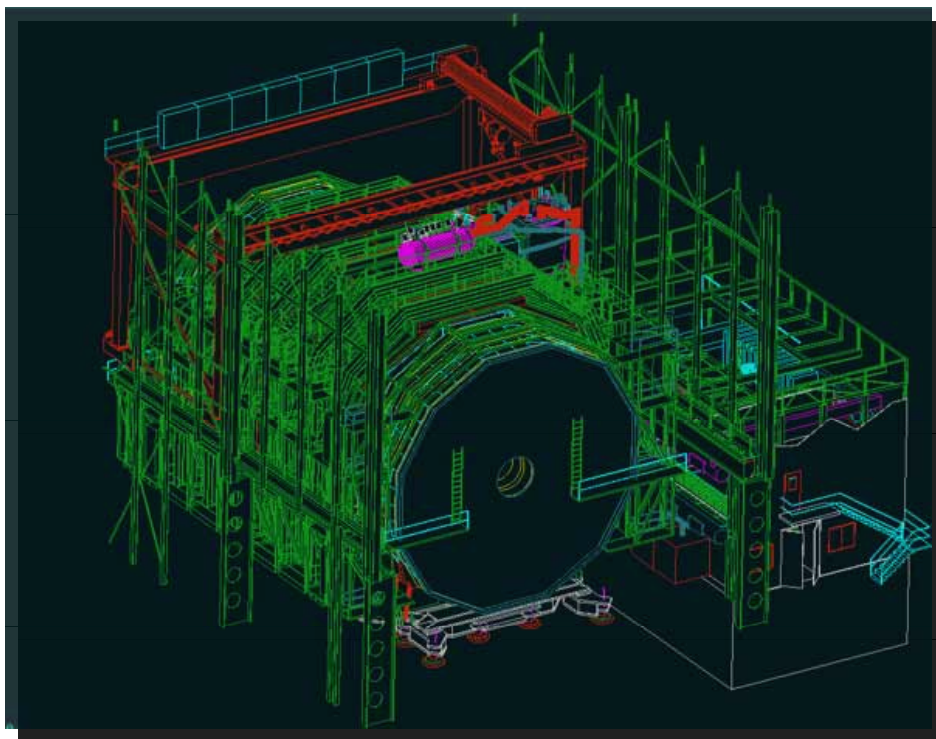
**real cosmic muons measured at P5**  
**See also:**

[http://iguana.web.cern.ch/iguana/live\\_events/](http://iguana.web.cern.ch/iguana/live_events/)

**Endcap Disk**

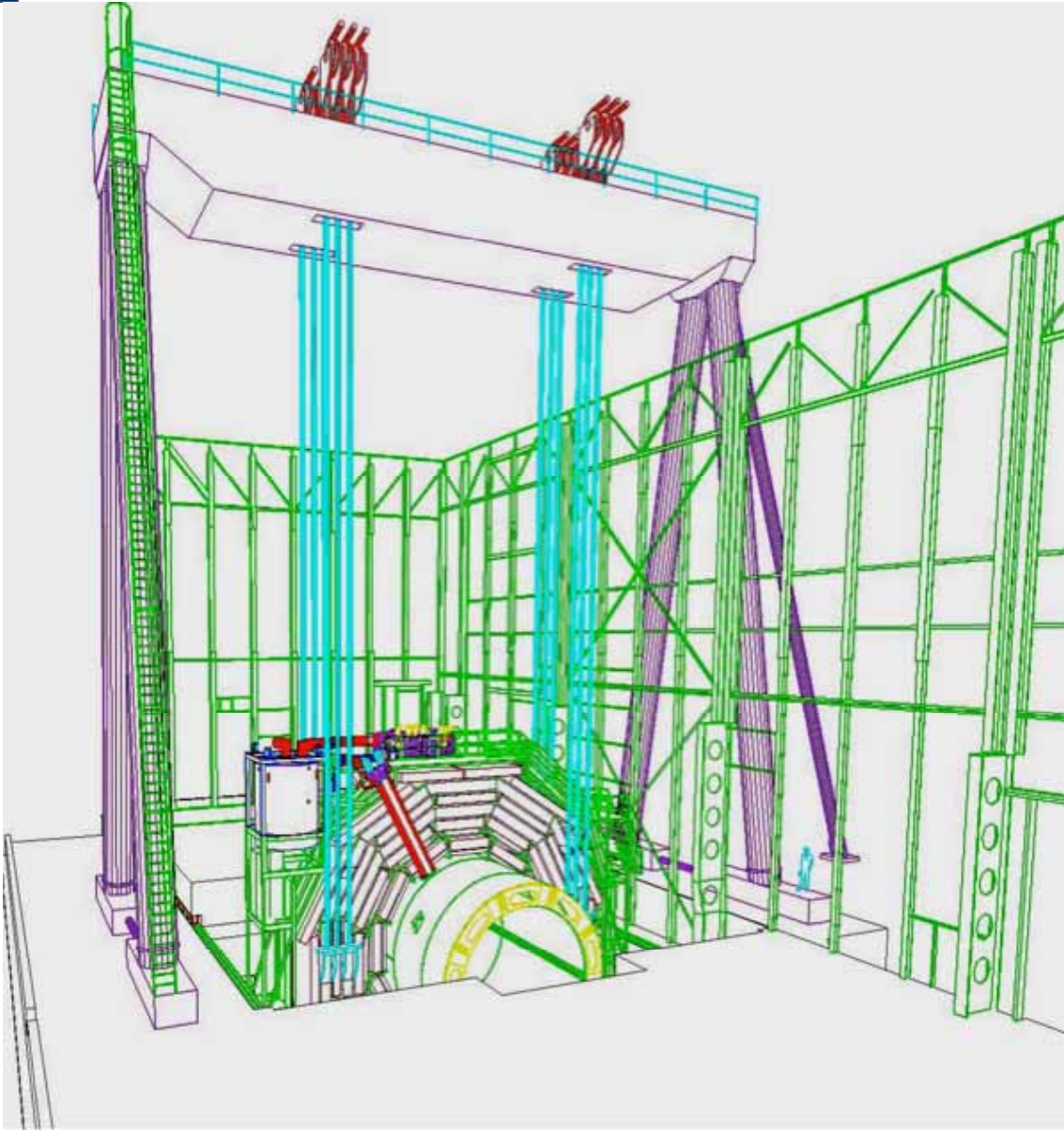


## CMS closed for Magnet test in the SX5 surface building (April/May 2006)



- Check functionality of all magnet systems
- Map the magnetic field
- Check installation & cabling of
  - ECAL/HCAL/Tracker inside coil
- Test combined sub-detectors in 20 degree slice(s) of CMS with Magnet. Try out operation procedures for CMS (24/7 running)

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- Status of Machine
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**15 heavy lifts in 2006, 1 week duration each.  
Heaviest piece: 2k tons**



# 北京大学承担的CMS的硬件责任



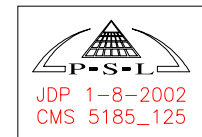
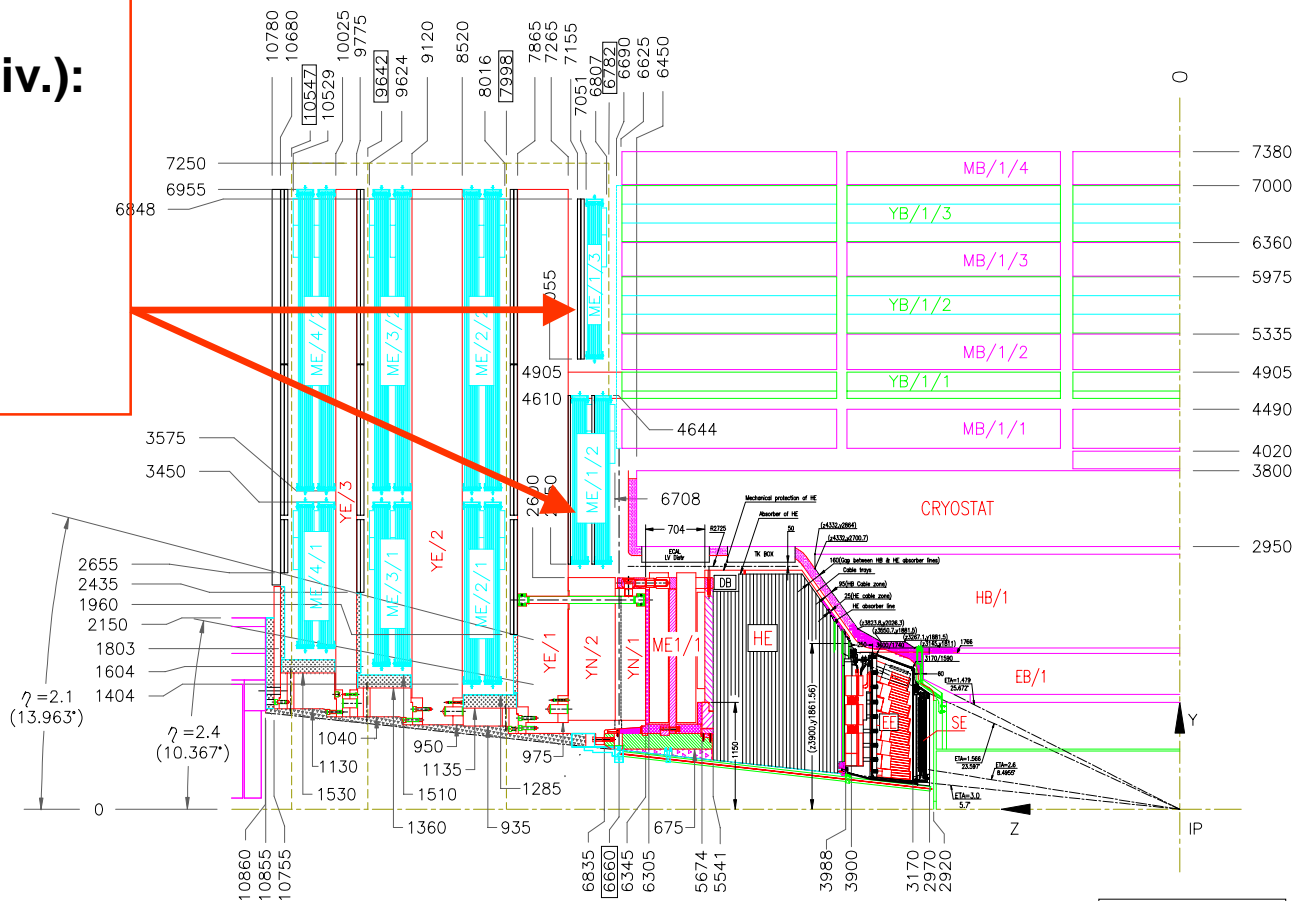
Responsibility of China (Peking Univ.):

In Endcap RPC system

RE1/2 and RE1/3

144 chambers

Counted for a contribution (to CMS) of 350 K SFr among the total Chinese contribution of 4,765 K SFr



2  
0  
0  
2



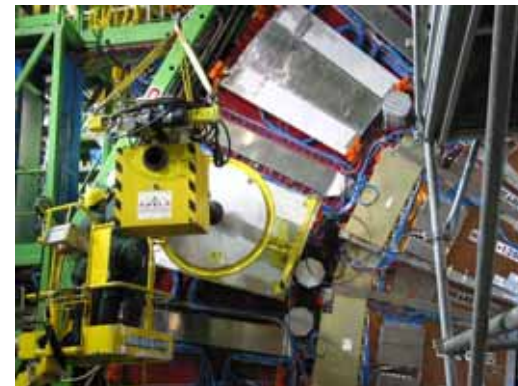
Before installing RE1/3

2  
0  
0  
5

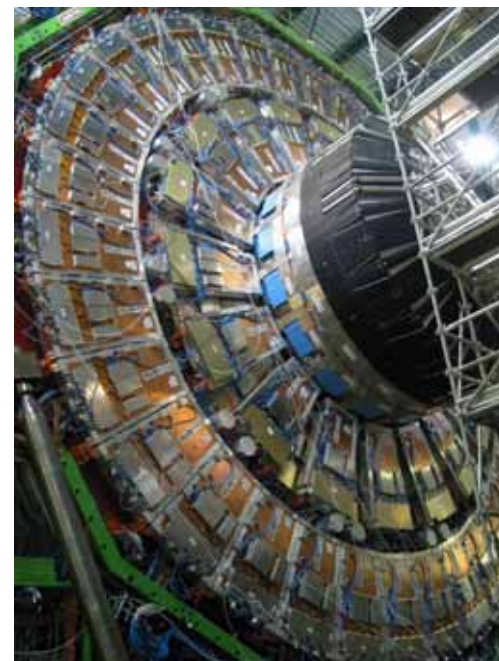
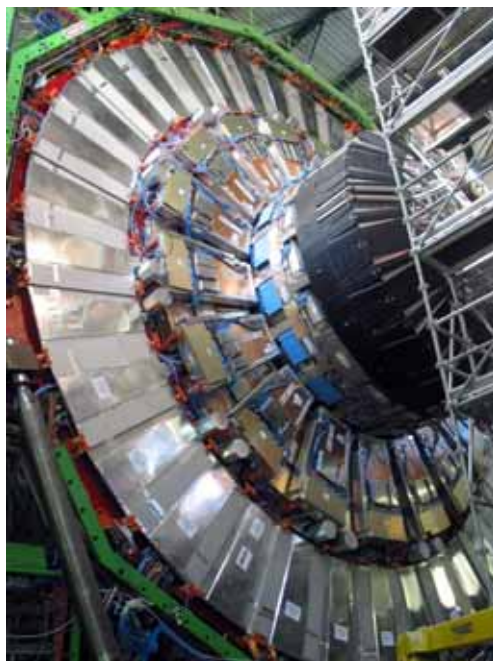
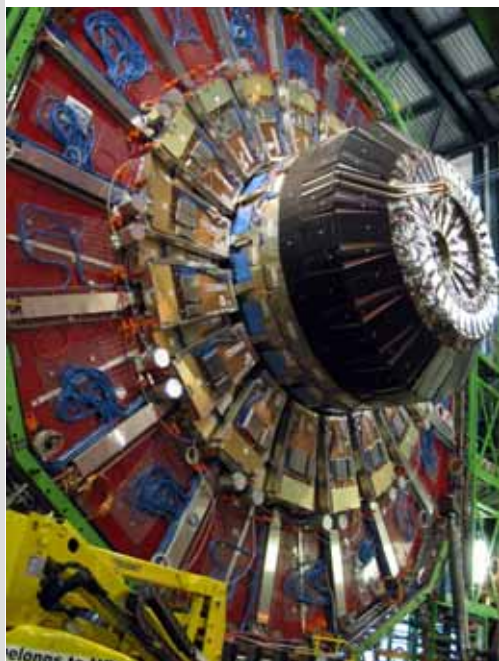


After installing RE1/3

2  
0  
0  
6



After installing CSC





Introduction  
Status of  
Machine  
Detectors  
**Startup of**  
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Detectors  
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# Pretty soon: Commissioning and start-up scenarios

*“If we wait for the moment when everything, absolutely everything, is ready,  
we shall never begin.” (Ivan Turgenev)*



# LHC : Performance Limitations (1)



- Introduction
- Status of Machine
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- Startup of Machine
- Detectors
- First Physics
- Comments

**Legend:**

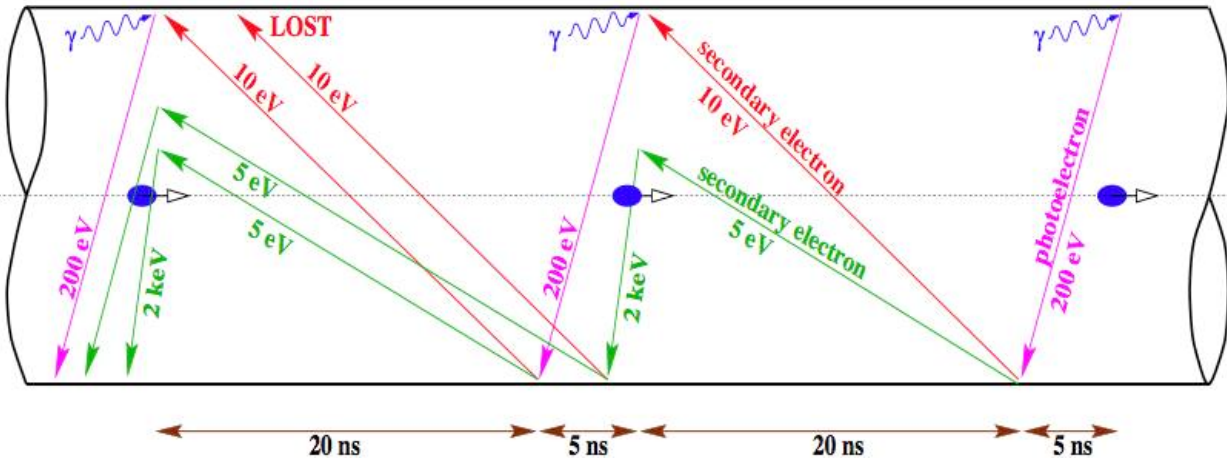
**N** : particles/bunch  
**n** : nr. of bunches  
**I** : current / beam  
 $\epsilon_n = \epsilon\gamma$ ,  $\epsilon$  : emittance  
 $\beta^*$  :  $\beta$  at IP  
 Beam size  $\sigma^2 = \beta\epsilon$   
**Q** : tune (number of trans. oscil./turn)  
 Tune spread  
 $\Delta Q \propto N / \epsilon_n$

Parameter/Effects	Limitations
<b>Beam energy</b> limited by maximum dipole field. Industrially available technology.	7 TeV
<b>Bunch and total beam intensity</b> beam-beam effect (tune spread), small allowed space in Q-space, collimators (impedance, collective instabilities), electron cloud, radiation	$N < 1.7 \cdot 10^{11}$ $N_{nom} = 1.15 \cdot 10^{11}$ $I < 0.85 \text{ A}$
<b>Normalized emittance</b> Basically given by injector chain and limited by main dipole aperture	$\epsilon_n < 3.75 \mu\text{m}$
<b>Beam size at IP (<math>\beta^*</math>)</b> Limited by (triplet) quadrupole aperture	$\beta^* > 0.55 \text{ m}$ $\sigma \sim 16 \mu\text{m}$
<b>Number of bunches</b> Limited by stored beam energy, electron cloud eff.	2808
<b>Operation efficiency and <math>L_{int}</math></b> minimize quenches and beam aborts, collimators and cleaning important: $N_{lost} < 7 \cdot 10^8 / m = 2.2 \cdot 10^{-6} N$	Total beam intensity

$$\mathcal{L} = \frac{N^2 n f_{rev}}{4\pi \epsilon_n \beta^*}$$

Introduction  
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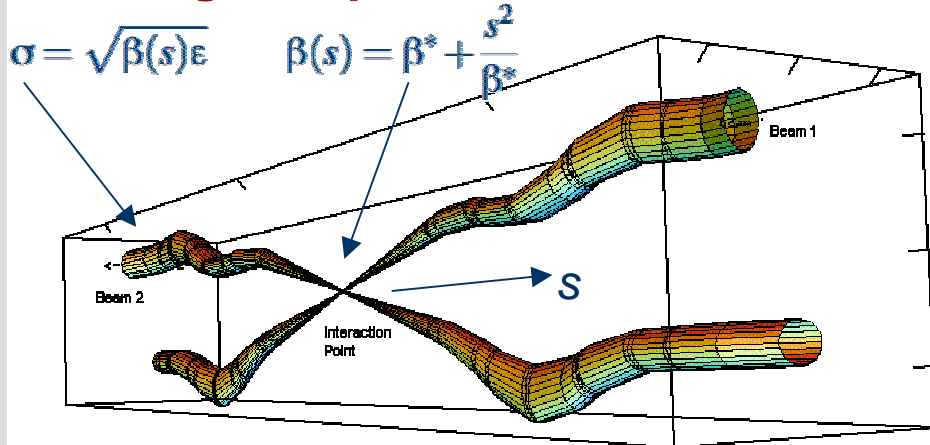
- **Electron cloud** : heat load on the beam screen, larger for smaller bunch spacing



**25 ns ok** for well conditioned surfaces  
 (→ 2808 bunches)

**12.5 ns : at the limit!**  
 Final conclusion only after LHC startup

- **Magnet aperture, beam-beam, collimators**



$\sigma^* = 16.6 \mu\text{m} \xrightarrow{\sim 23\text{m}} \sigma(\text{triplet}) = 1.54 \text{ mm}$

**Badly conducting collimators : large wake fields : instability**

Phase 1 : graphite (robust),  $I < 0.3 \text{ A}$   
 Phase 2 : Cu (good conduct.)  $I < 0.85 \text{ A}$



# LHC : Start-up scenario (1)



M. Lamont

Introduction  
Status of  
Machine  
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Comments

ID	Task Name	Start	Finish	Duration	May 2007				Jun 2007				Jul 2007				Aug 2007			
					5/6	5/13	5/20	5/27	6/3	6/10	6/17	6/24	7/1	7/8	7/15	7/22	7/29	8/5	8/12	8/19
1	<b>HARDWARE COMMISSIONING</b>	1/1/2007	6/29/2007	26w																
2	<b>SYSTEM TESTS</b>	1/1/2007	7/31/2007	30.4w																
3	MACHINE PROTECTION	4/2/2007	6/29/2007	13w																
4	RF CONDITIONING/COMMISSIONING	1/1/2007	6/29/2007	26w																
5	ACCESS/INB	7/23/2007	7/31/2007	1.4w																
6	<b>MACHINE CHECKOUT</b>	6/14/2007	7/31/2007	6.8w																
7	<b>TI8</b>	7/2/2007	7/30/2007	4.2w																
8	<b>CHECKOUT</b>	7/2/2007	7/13/2007	2w																
9	<b>WITH BEAM</b>	7/23/2007	7/30/2007	1.2w																
10	<b>T12</b>	7/16/2007	8/2/2007	2.8w																
11	CHECKOUT	7/16/2007	7/26/2007	1.8w																
12	WITH BEAM	7/26/2007	8/2/2007	1.2w																
13																				
14	<b>LHC COMMISSIONING WITH BEAM</b>	8/1/2007	10/30/2007	13w																
15																				



- **Objective** : establish colliding beams as quickly as possible, safely, without compromising further progress
- Take two moderate intensity multi-bunch beams to high energy and collide them : minimize problems due to electron cloud, event pile-up, equipment restrictions, use phase 1 collimators.



# LHC : Start-up scenario (2)



Introduction  
 Status of  
 Machine  
 Detectors  
 Startup of  
**Machine**  
 Detectors  
 First Physics  
 Comments

**Stage 1**  
 Initial commissioning  
 43x43 to 156x156,  $N=3 \times 10^{10}$   
 Zero to partial squeeze

$L=3 \times 10^{28} - 2 \times 10^{31}$

**Stage 2**  
 75 ns operation  
 936x936,  $N=3-4 \times 10^{10}$   
 partial squeeze

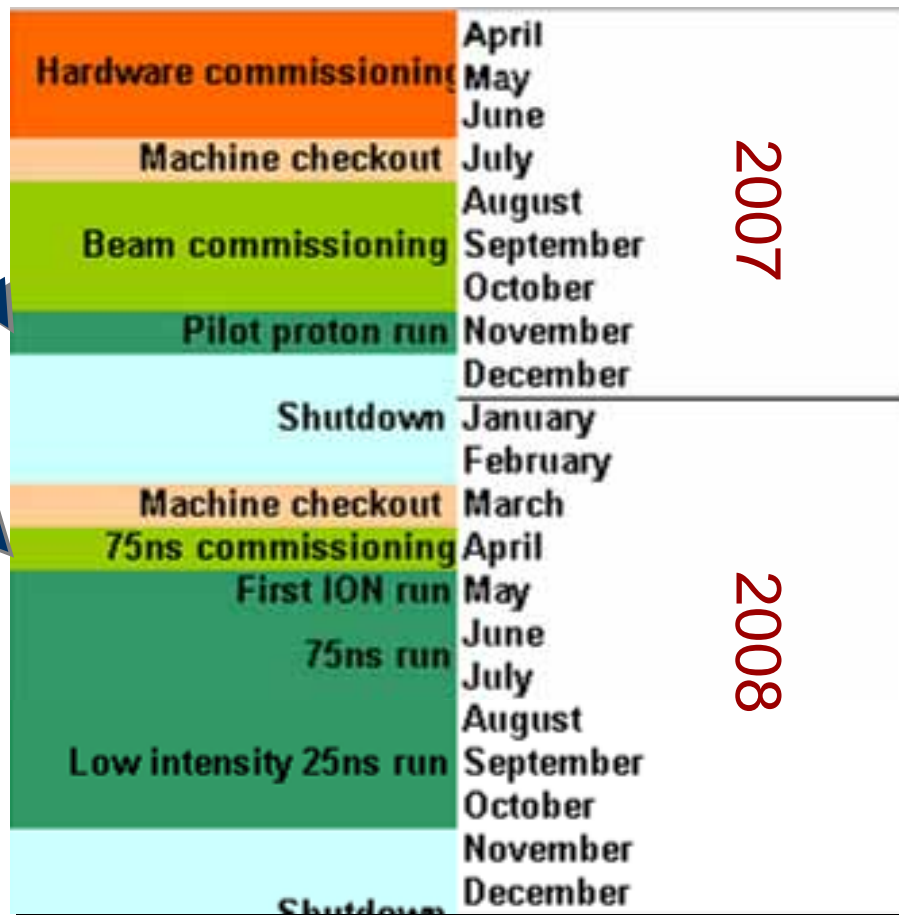
$L=10^{32} - 4 \times 10^{32}$

**Stage 3**  
 25 ns operation  
 2808x2808,  $N=3-5 \times 10^{10}$   
 partial to near full squeeze

$L=7 \times 10^{32} - 2 \times 10^{33}$

**Stage 4**  
 25 ns operation  
 Push to nominal per bunch  
 partial to full squeeze

$L=10^{34}$



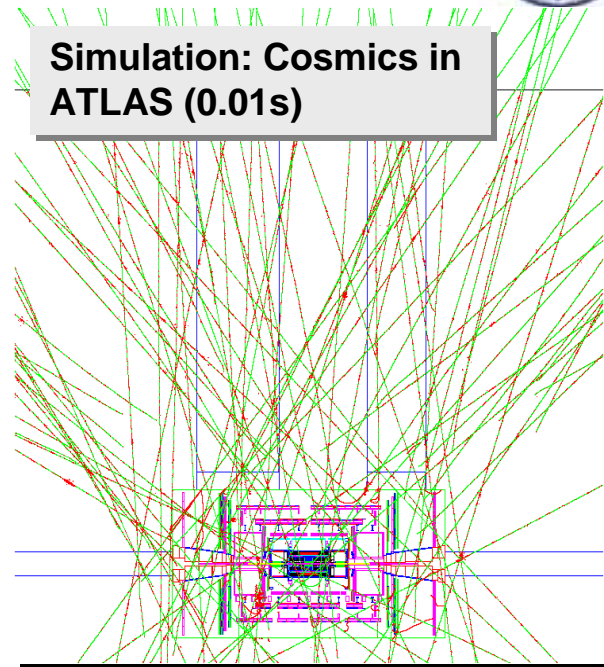


# Detector Commissioning (1)

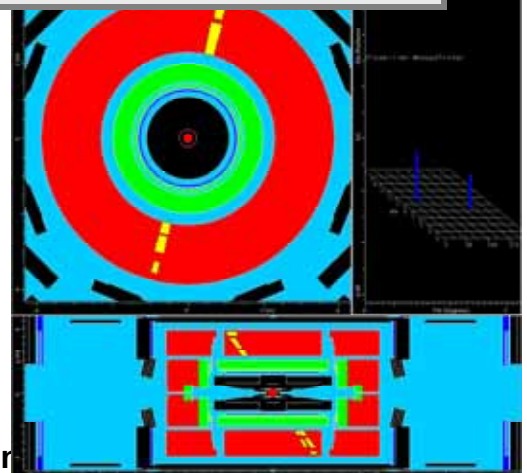


- Construction quality checks and beam tests of series detector modules show that the **detectors as built should give a good starting-point performance**
- However, a lot of data (**and time ...**) will be needed at the beginning to
  - Commission the detector and trigger **in situ**
  - Reach the performance needed to optimize the physics potential
  - Understand **“basic” physics at 14 TeV** and normalize (tune) the MC generators
  - Measure backgrounds to new physics and extract **“early” convincing signals**
- **Efficient/extensive/robust commissioning programme** with physics data is therefore crucial to reach quickly the **“discovery” mode**

- **No Beam :**
  - **Cosmic Muons**
  - **Initial alignment/detector calibration (barrel)**
  - **Debugging, dead-channels mapping**
  - **Rates :**
    - $E_{\text{surface}} > 10 \text{ GeV}$  :  $\sim 1 - 5 \text{ kHz}$
    - **useful for calibration** :  $\sim 0.5 \text{ Hz}$
  
- **One Beam :**
  - **Beam-Halo Muons**
    - **Alignment/calibration in end-caps**
    - **Rate for  $E > 100 \text{ GeV}$  :  $\sim 1 \text{ kHz}$**
  
  - **Beam-Gas events**
    - **resemble pp, with soft spectrum ( $p_T < 2 \text{ GeV}$ )**
    - **25 Hz of reco. Tracks with  $p_T > 1 \text{ GeV}$ ,  $|z| < 20 \text{ cm}$**
    - **eg. first alignment of inner trackers to about  $100 \mu\text{m}$  or better?**



First real cosmics seen in the ATLAS pit, June 05





Introduction

Status of

Machine

Detectors

Startup of

Machine

Detectors.

**First Physics**

Comments

# Soon : Pilot Run and First Physics

*“The only place you’ll find SUCCESS before WORK is in the dictionary” (May B. Smith)*



# Pilot run



- The first time that we will see proton-proton collisions at 14 TeV !
- Pilot run is short (max 30 days) and data taking will happen only for a small fraction of time
- Important to **use very efficiently** this time optimizing between competing tasks
  - Changing conditions to commission the detector (eg. synchronization)
  - Stable data taking for tracker alignment & measurement of minimum bias (can be done with coarse synchronization)

Introduction

Status of

Machine

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Detectors.

**First Physics**

Comments

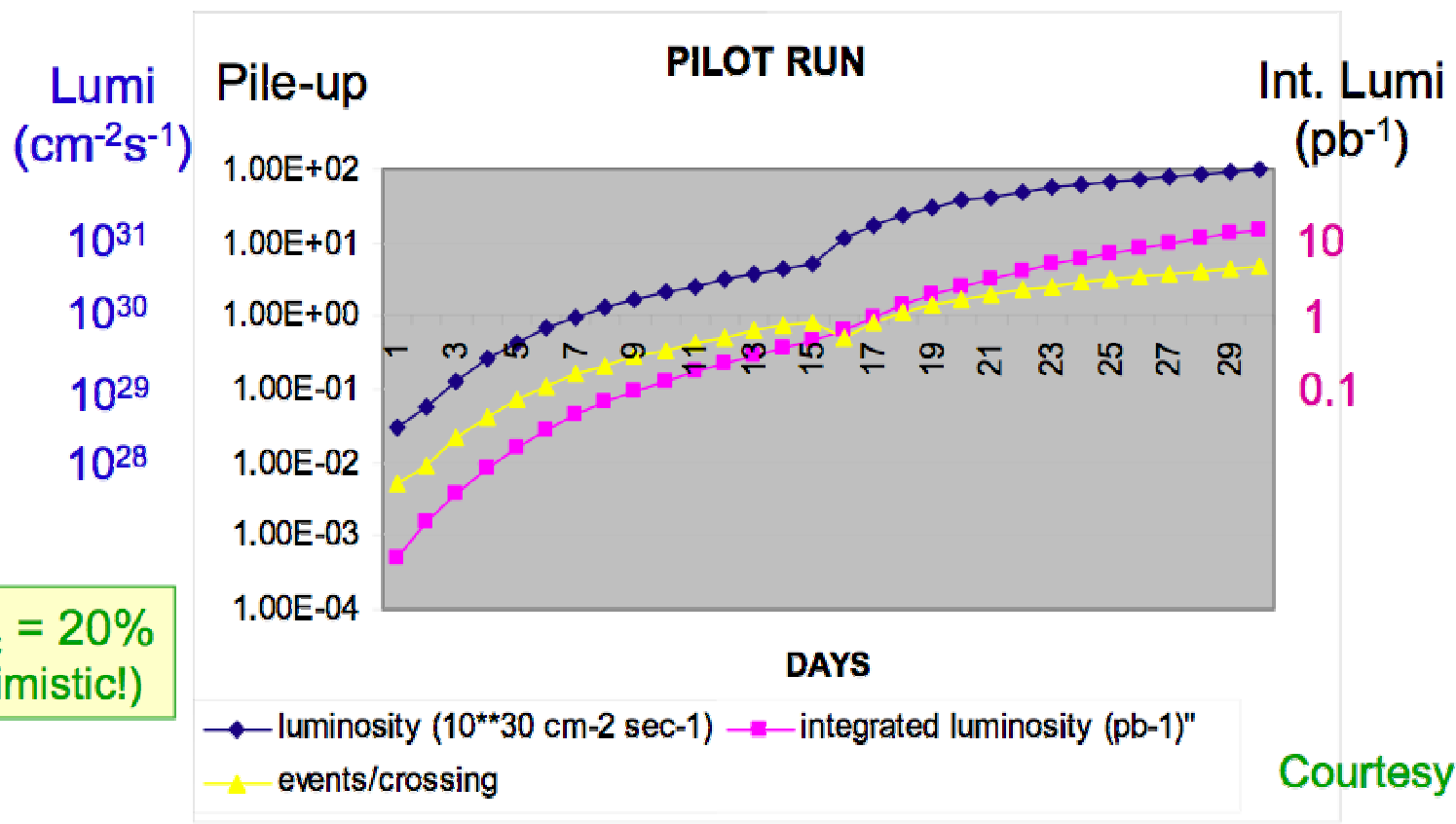


# Pilot run : Luminosity



Introduction  
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 Detectors.  
**First Physics**  
 Comments

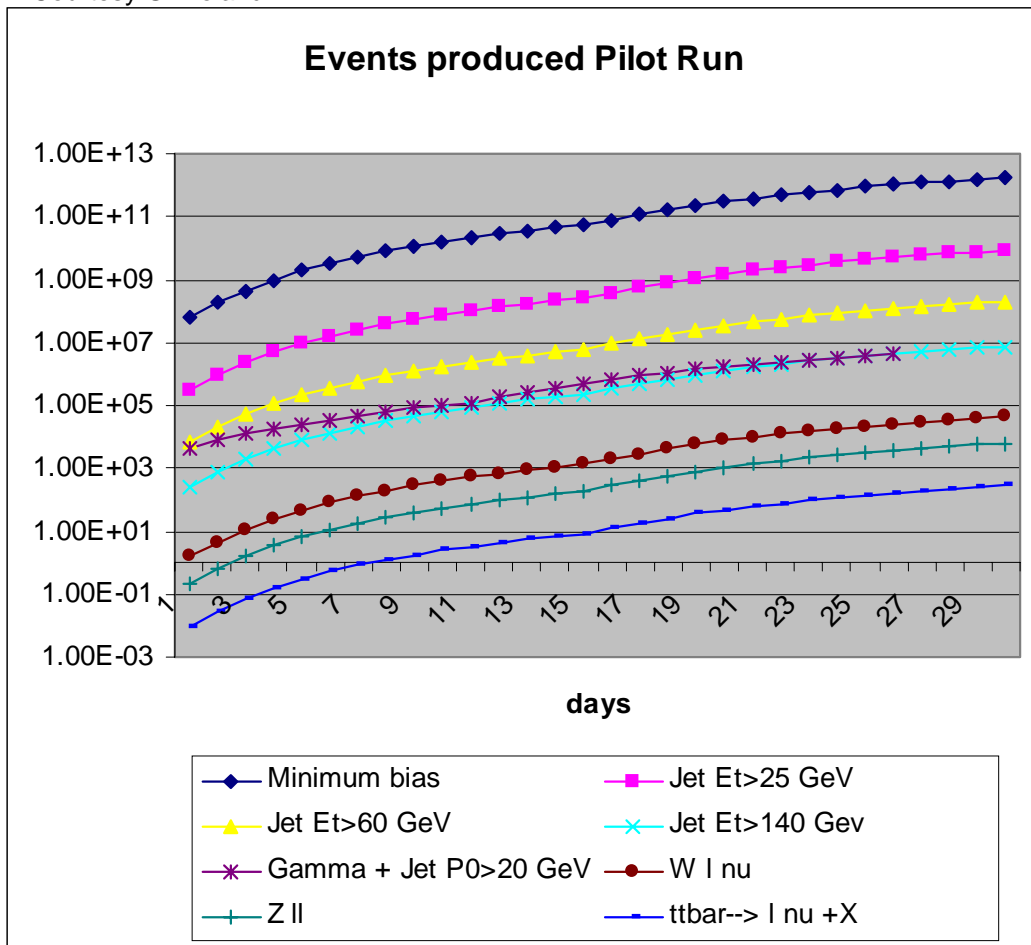
- 30 days maximum, probably less (?)
- 43x43 bunches, then 156x156 bunches



$\epsilon_{LHC} = 20\%$   
 (optimistic!)

Courtesy: Gigi

Courtesy G. Rolandi



Assumed efficiencies:

$$\epsilon(\text{jets}) = 100\%$$

$$\epsilon(W) = 20\%$$

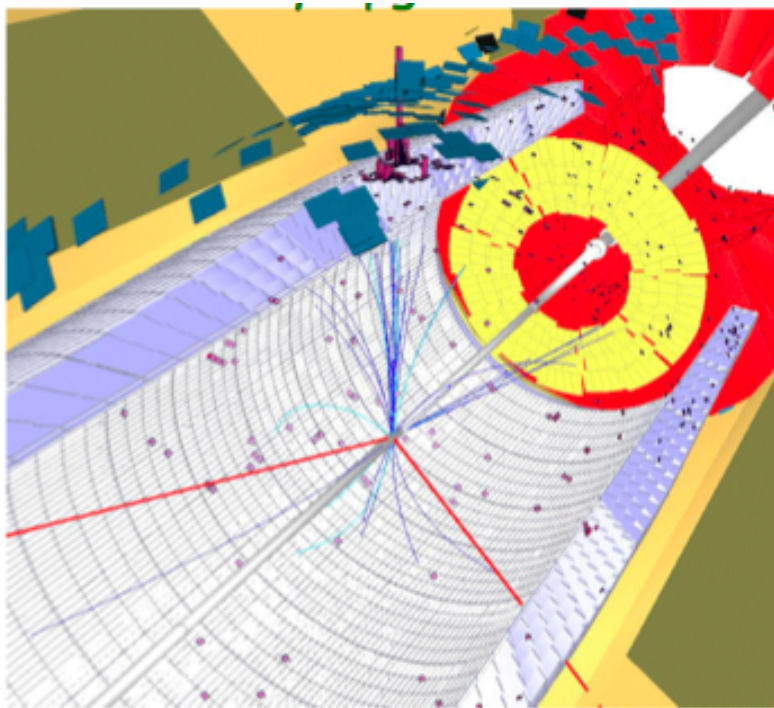
$$\epsilon(Z) = 20\%$$

$$\epsilon(\text{ttbar}) = 1.5\%$$

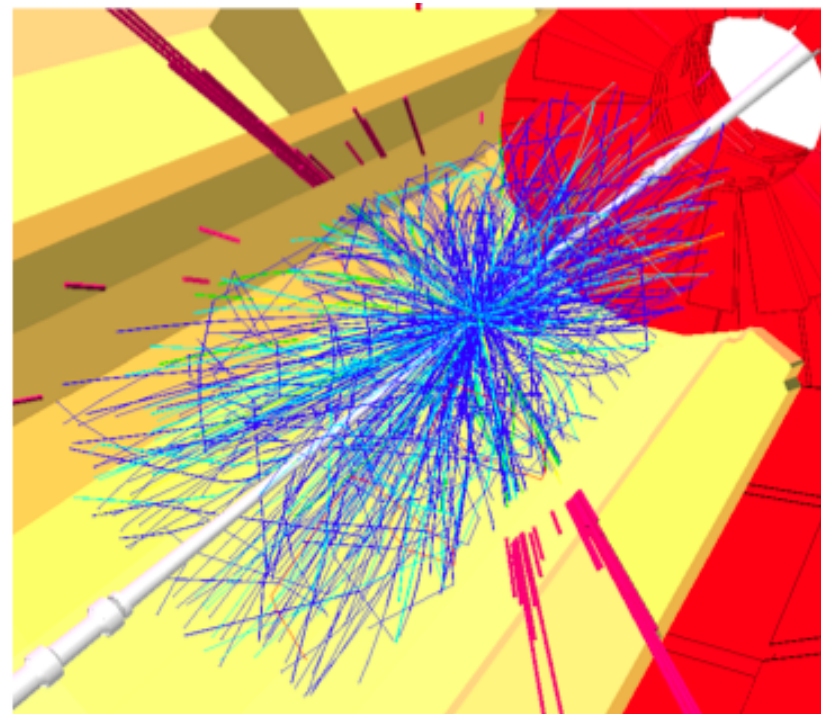
**Even within a few hours/days:**

- About 10 million minimum bias evts (almost possible to trigger randomly)
- A few million di-jet events with  $E_T > 15$  GeV
- Not much of anything else

- **Pile-up** : additional mostly soft-interactions per bunch crossing
- Start-up Lumi :  $2 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1} \Rightarrow 4 \text{ events}$  / bunch crossing
- High Lumi :  $10^{34} \text{ cm}^{-2}\text{s}^{-1} \Rightarrow 20 \text{ events}$  / bunch crossing



**LHC event - no pile-up**



**LHC event -  $10^{34} \text{ cm}^{-2}\text{s}^{-1}$**

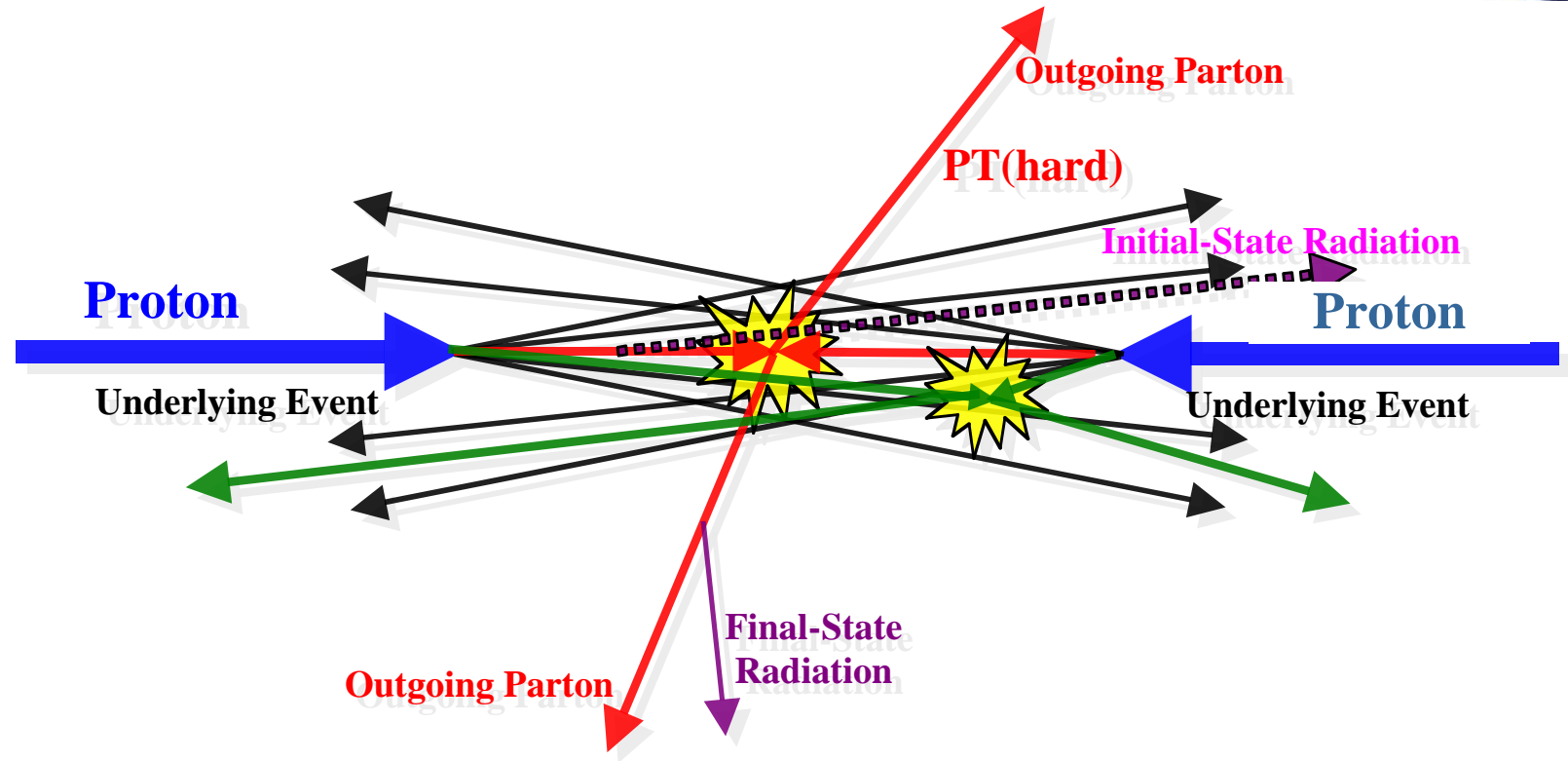
Courtesy A. De Roeck



# The Underlying Event (UE)



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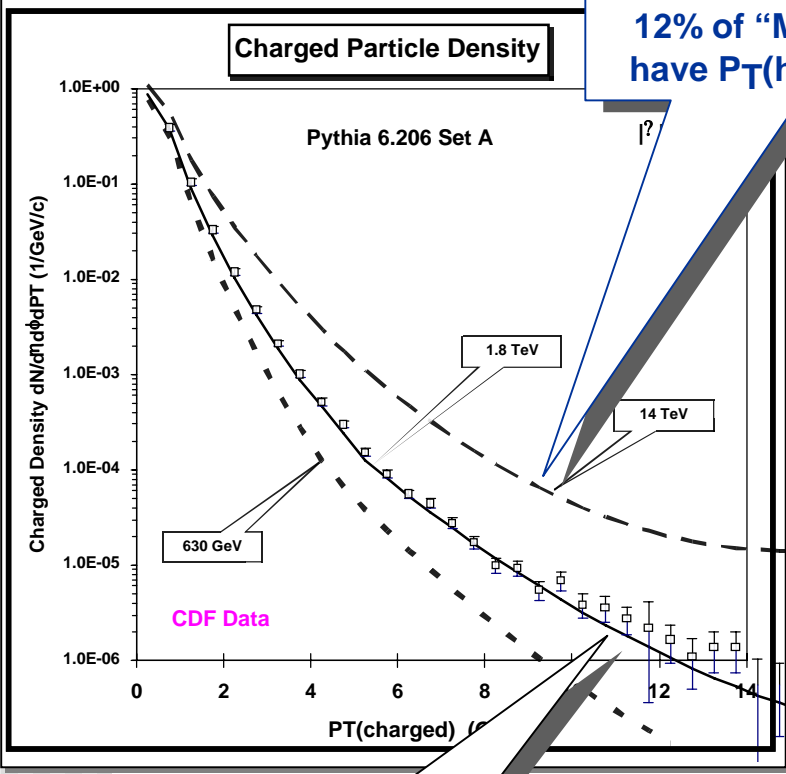
**The Underlying Event:**  
 beam-beam remnants  
 initial-state radiation  
 multiple-parton  
 interactions

## Issues:

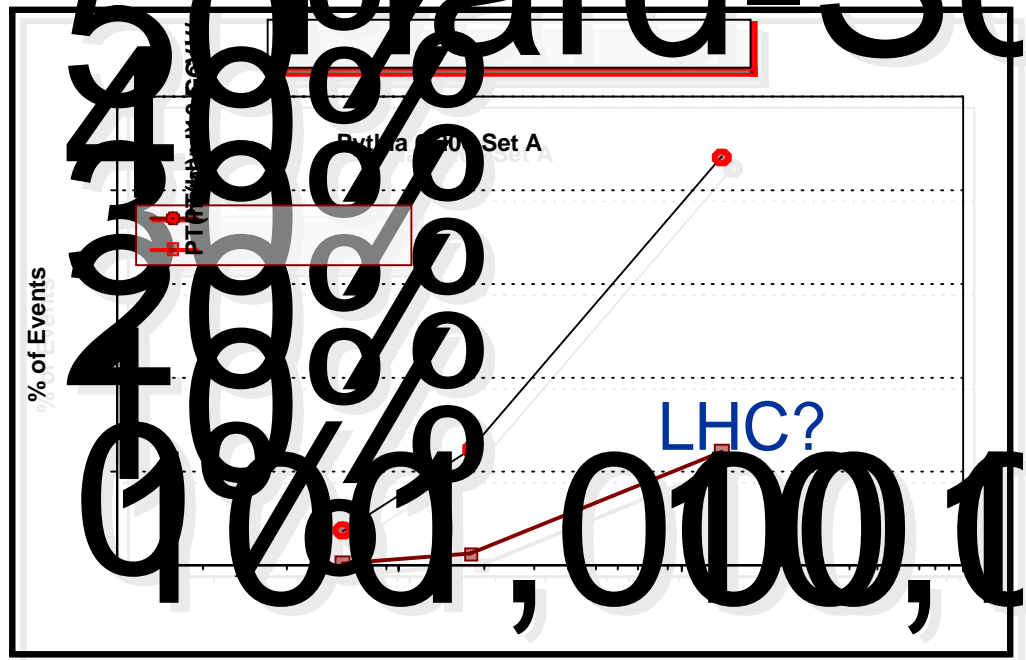
- modeling (learn from min. bias)
- extrapolation to LHC energies
- impact on selection efficiencies ?  
 - isolation, trigger strategy
- have to tune MCs (eg. Pythia) asap



# UE : Extrapolation to LHC (1)



by R. Field, see LHC MC WS

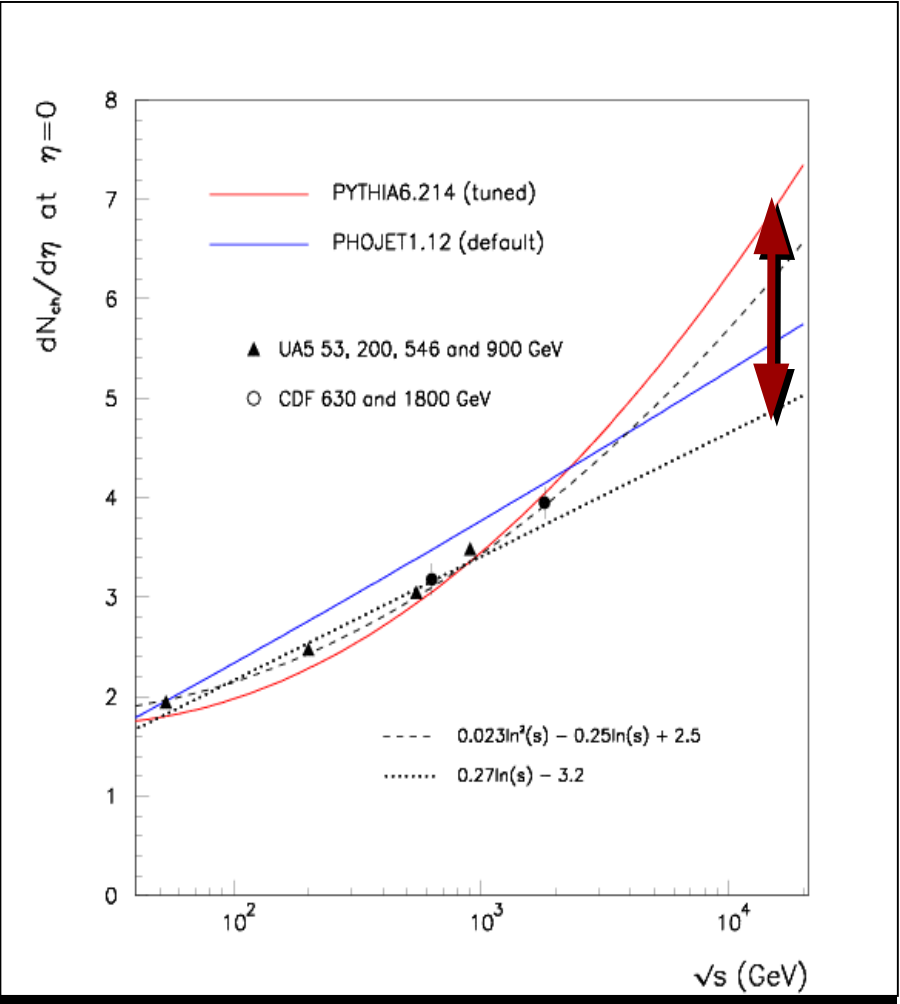
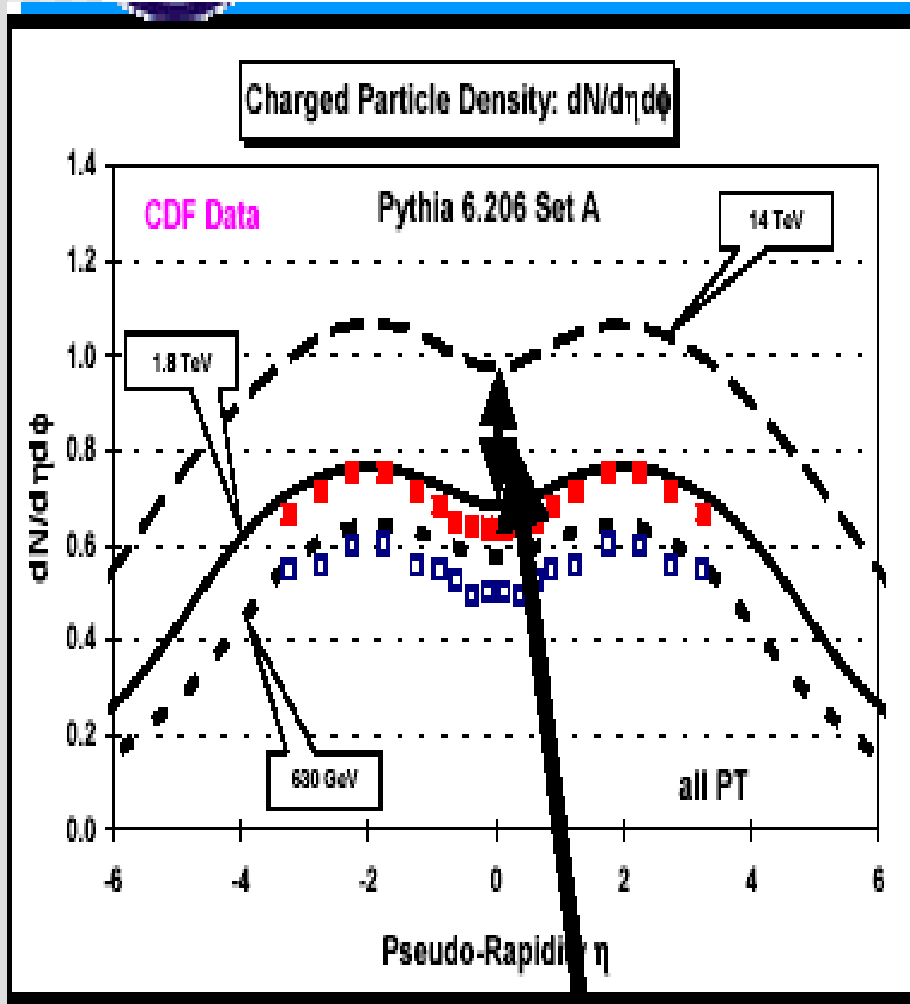


1% of "Min-Bias" events have  $P_T(\text{hard}) > 10$  GeV/c!

## Expected average $p_T = 0.7$ GeV

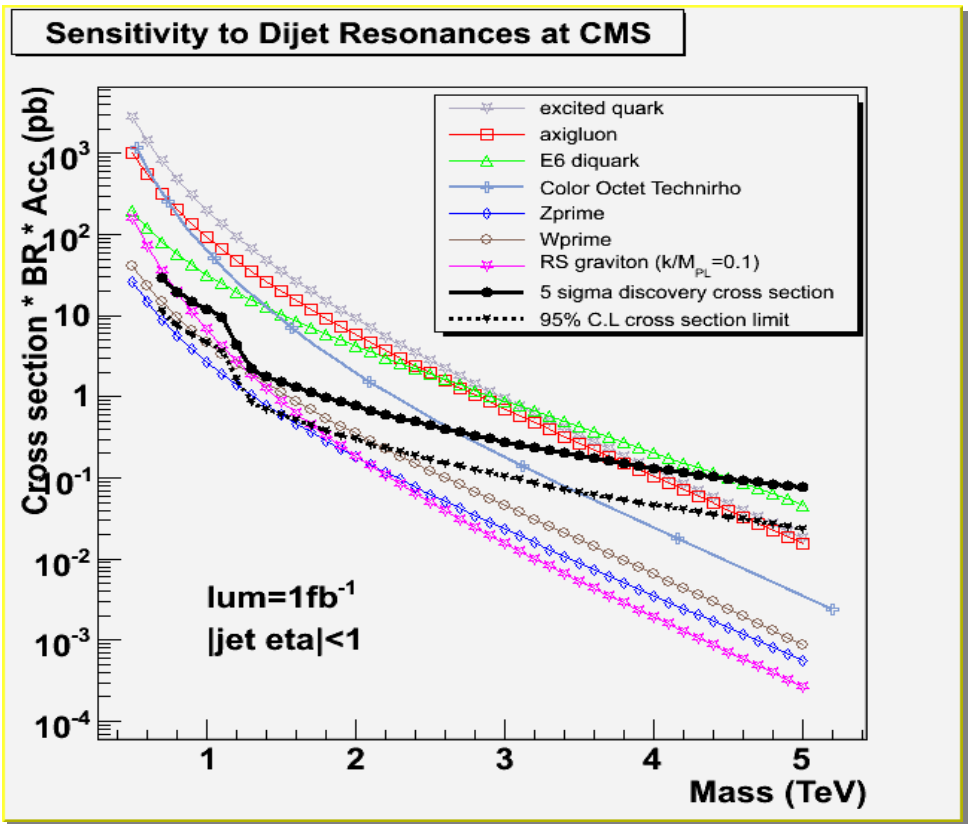


# UE : Extrapolation to LHC (2)



- ~12 particles/evt in the barrel (+12 forward)
- Half of them curl in the tracker, ~50% reach outermost tracker layer

- Produced at high rate
- Use for jet calibration by balancing jet transverse momentum
  - analyse (  $\Delta p_T / \text{di-jet } p_T$  ) . Works well for low  $p_T$ , but low stat. at high  $p_T$
- Physics interest in the high mass tail



- QCD cross section between 1.9 - 2.1 TeV is 3.5 pb
- Excited quarks : 8 pb !
- CDF/D0 limits in the range 0.4 - 1 TeV
- With 15 pb<sup>-1</sup> at 14 TeV we could extend this
- Crucial: energy resolution in measuring jet energy (narrow resonances)

But ... if we see a signal .. How can we be sure about the tails in the energy resolution?



# Example : CMS preparations for Pilot Run



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- **Simulate 10 million min. bias evts and 1 million di-jets with  $p_T^{\text{had}} > 10-15$  GeV, using pilot run geometry**
  - No pixel det., no ECAL endcaps
  
- **Reconstruct** these evts with latest reconstruction software
  
  
- “collect” the events
  - I.e. determine with which **rate** these events can be handled by the **initial DAQ** config.
  - Determine a **trigger strategy** to saturate it
    - Random, ECAL low energy photons, HCAL low thresholds, muons
  - Study trigger conditions as function of increasing luminosity

see CMS Physics TDR due this year !!



# First physics runs ( 2008... )



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- **After first “good” 10 pb<sup>-1</sup>**
  - ~20000 W, decaying to lepton + neutrinos
  - ~2500 Z, decaying into two leptons
  - ~200 semi-leptonic top-pair events
    - Measure rates, align and calibrate better
- **After first “good” 100 pb<sup>-1</sup>**
  - W(Z)+jets rates well measurable
    - Jet calibration, MET calibration (for SUSY)
  - Inclusive leptons, di-leptons, photons, di-photon triggers (for Higgs)
- **From 100 pb<sup>-1</sup> to 1 fb<sup>-1</sup>**
  - **Standard model candles**
    - Top pair prod., W/Z cross sections, PDF studies, QCD studies, b-jet production
    - Do extensive MC tuning
  - **Early Higgs boson search**
    - H→γγ, WW, ZZ
  - **Early SUSY-BSM searches**
    - MET + anything, di-jet, di-leptons, di-photon, resonances....

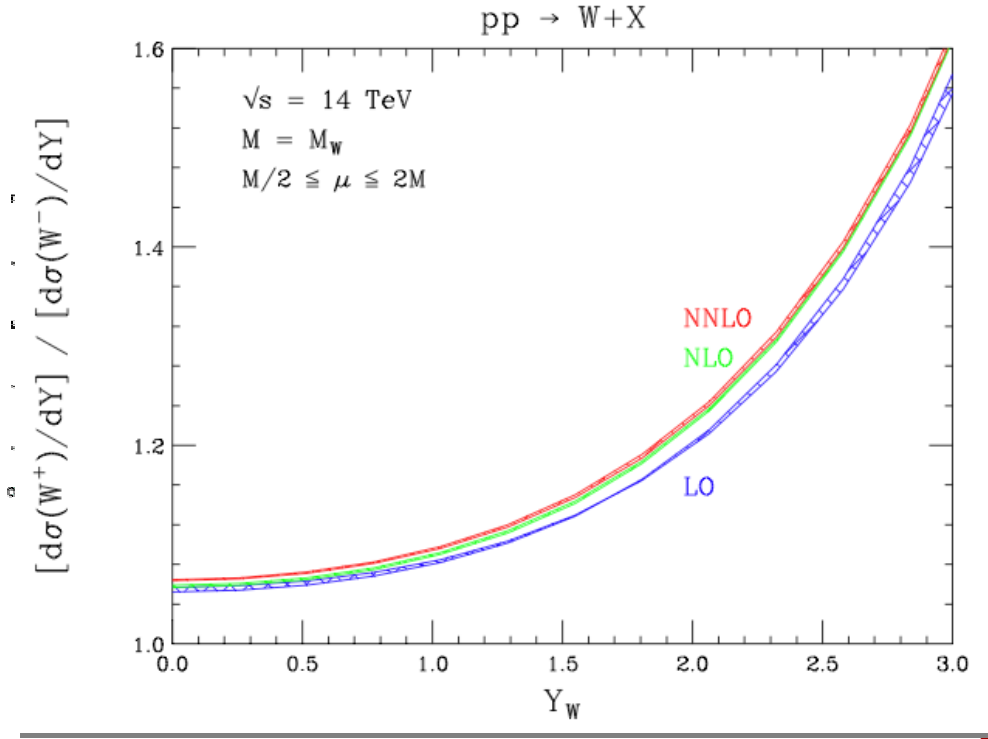


# Standard Model measurements



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 Phys. Reach

- **Drell-Yan (W, Z) production of lepton pairs**
  - best known cross section at LHC, at **NNLO : scale uncert. ~ 1% !**

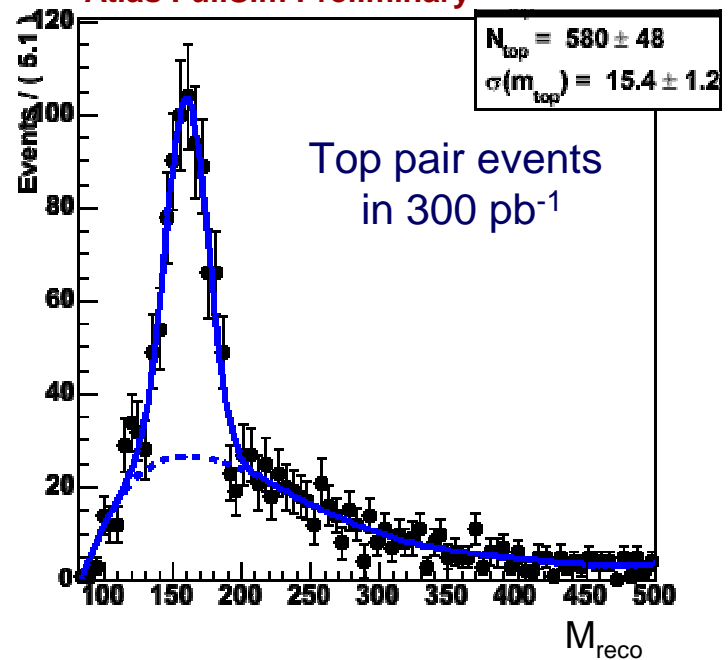


- Similarly for  $W^+/W^-$  (**ratios are good!!**)
- NNLO scale uncertainty 0.5 - 0.7 %
- **Constrain PDFs, determine Lumi.**

## ■ Top-Physics

- See the top immediately
- simple selection : Missing  $E_T$ , 1 lepton,  $\geq 4$  jets , **NO b-tag (!)**, cut on hadronic W mass

Atlas FullSim Preliminary



## Study the top quark properties

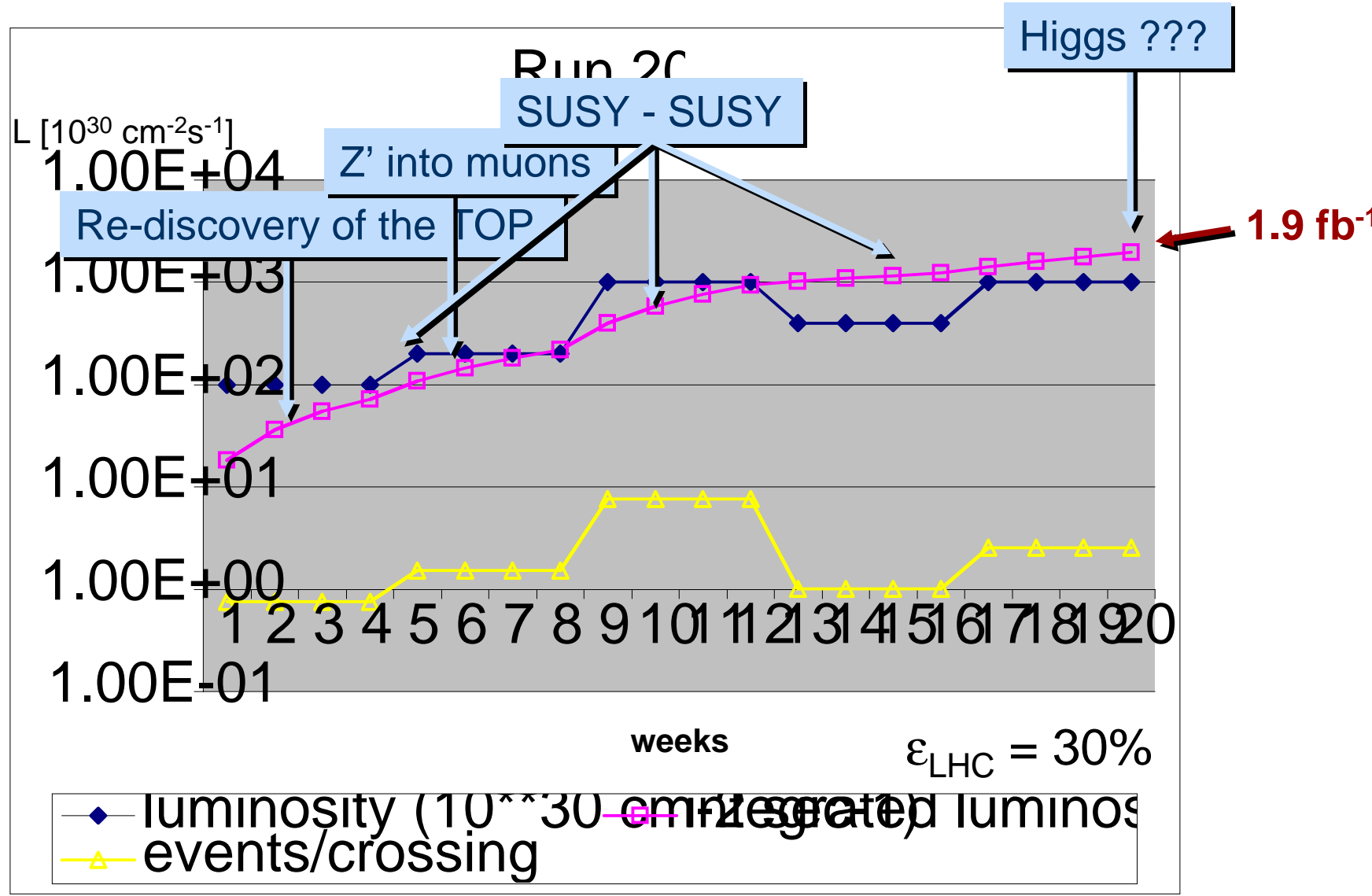
- mass, charge, spin, couplings, production and decay,  $\Delta M_{top} \sim 1$  GeV ?
- important background for searches
- **Jet energy scale** from  $W \rightarrow$  jet jet, commission b-tagging



# The path to discovery



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 Phys. Reach



Courtesy G. Rolandi



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# Some comments

*“Doing something ordinary is a waste of time”* (Madonna)

## Event production rates at $L=10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ and statistics to tape

Process	Events/s	Evts on tape, $10 \text{ fb}^{-1}$
$W \rightarrow e\nu$	15	$10^8$
$Z \rightarrow ee$	1	$10^7$
$t \bar{t}$	1	$10^6$
Minimum bias	$10^8$	$10^7$
QCD jets $p_T > 150 \text{ GeV}/c$	$10^2$	$10^7$
$b \bar{b} \rightarrow \mu X$	$10^3$	$10^7$
gluinos, $m=1 \text{ TeV}$	0.001	$10^3$
Higgs, $m=130 \text{ GeV}$	0.02	$10^4$

assuming 1% of trigger bandwidth

$10^7$  events to tape every 3 days, assuming 30% data taking efficiency, 1 PB/year/exp

- ⇒ statistical error negligible after few days (in most cases) !
- ⇒ **dominated by systematic errors** (detector understanding, luminosity, theory)



# Our Master Equation



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Stat vs syst errors, backgrounds from data or MC? Signal Significance

$$\sigma_{\text{meas}} = \frac{N_{\text{obs}} - N_{\text{bkg}}}{\epsilon L}$$

Understand isolation, jet veto;  $p_T$  distributions at NLO; need calculations for detectable acceptance.

$$\sigma_{\text{theo}} = PDF(x_1, x_2, Q^2) \otimes \hat{\sigma}_{\text{hard}}$$

constrain, define uncertainties

HO calculations, implement in MC

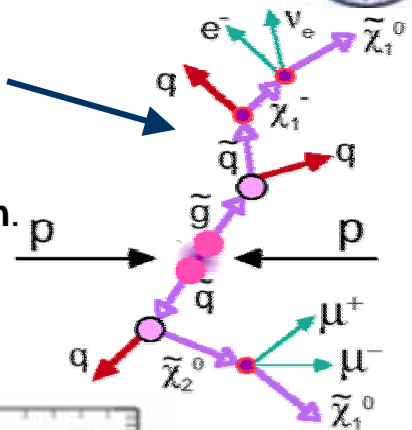


# Early SUSY discovery?

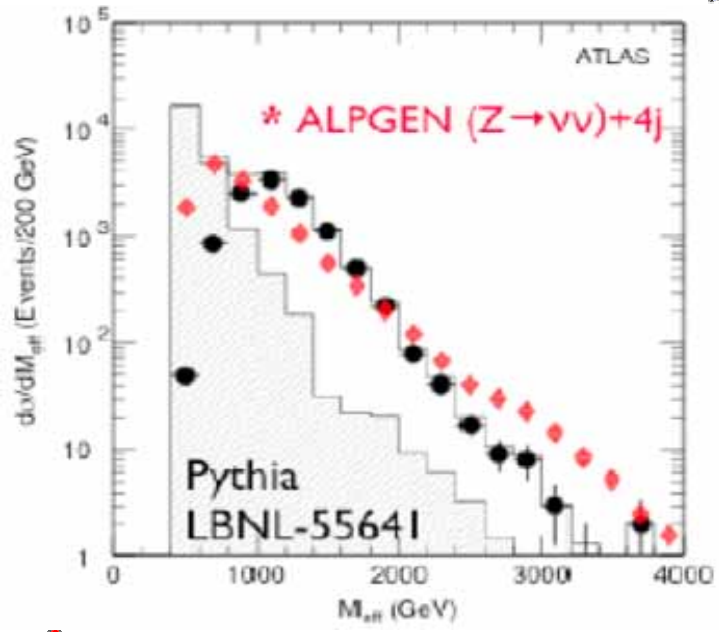
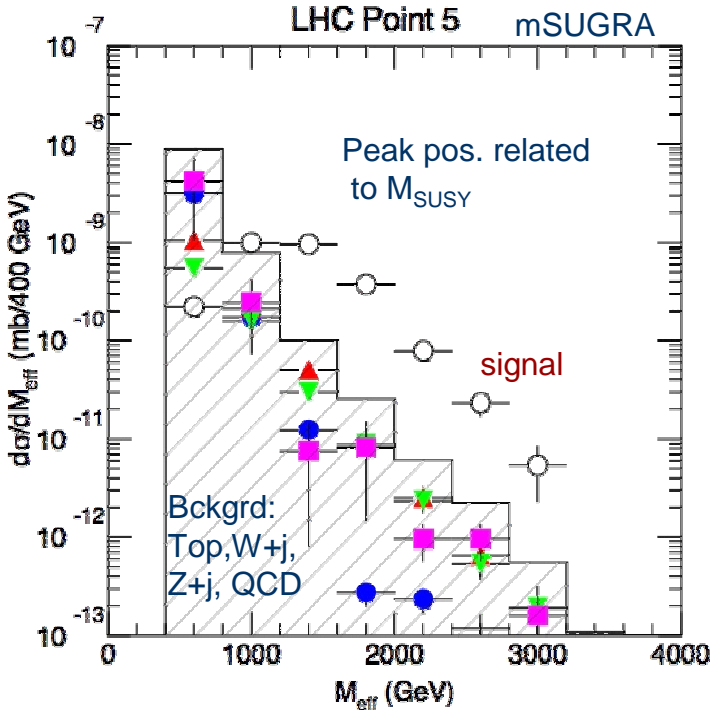


Large squark/gluino pair prod. cross sections, ~100 evts/day at  $10^{33}$  for  $m(\text{squarks, gluinos}) \sim 1 \text{ TeV}$ . Spectacular signatures

Use multi-jet, multi-leptons and  $E_t^{\text{miss}}$  for discrimination.



$$\text{eg. } M_{\text{eff}} = E_T^{\text{miss}} + \sum_{\text{jets}} p_T(j)$$



**Beware !** : Good understanding of detector and SM bckgrds needed!  
E.g. parton shower not enough!

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# Warnings...



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- **Always try to be as independent from the Monte Carlo as possible!**
  - E.g. find a “Standard Model candle” for calibration
  - Obtain **backgrounds from the data** whenever possible
    - Easy if we have mass peak (from sidebands)
    - More difficult in case of excess in high-energy tails, in particular in relation to MET or high- $E_T$  jets
  - **But what to do ?**
    - Some examples in the following
    - Study carefully the validity of a Monte Carlo, and what it is exactly based on
      - E.g. LO 2-to-2 process + parton shower, or 2-to-n + parton shower, or NLO+parton shower, or ...
- **Worry in particular about systematic errors in your search analysis when  $S/B \ll 1$  !!**
  - be careful with calculation of significance

## ■ Calibrations

- **Electromagnetic calorimetry**
  - $Z \rightarrow ee, W \rightarrow e\nu$ , Minimum-bias
- **Hadronic calorimetry and jets**
  - Di-jet balance,  $Z (\rightarrow ll) + 1j$ ,  $W \rightarrow jj$  in  $tt$  events, photon + jet
- **MET**
  - $Z (\rightarrow ll) + jets$ , then remove leptonic information
- **Tracker and Muon alignment :**
  - $Z \rightarrow \mu\mu, W \rightarrow \mu\nu$
- **Lepton efficiencies, b-tagging**
  - $Z \rightarrow ee, Z \rightarrow \mu\mu$
  - $\tau$  : look at ratio  $(Z \rightarrow \tau\tau \rightarrow \mu \text{ jet}) / (Z \rightarrow \mu\mu)$
  - b-tag : use  $t\bar{t}$  events to commission

## ■ Important kinematic properties

- $W + n$  jets,  $p_t$  of  $W$  : take  $Z (\rightarrow ll) + n$  jets
- Use  $bbZ (\rightarrow ll)$  as benchmark for  $bbA$  : verify MC tune of  $p_T^b, p_T^Z, ..$

## ■ Backgrounds

- Sidebands, or see next slides..

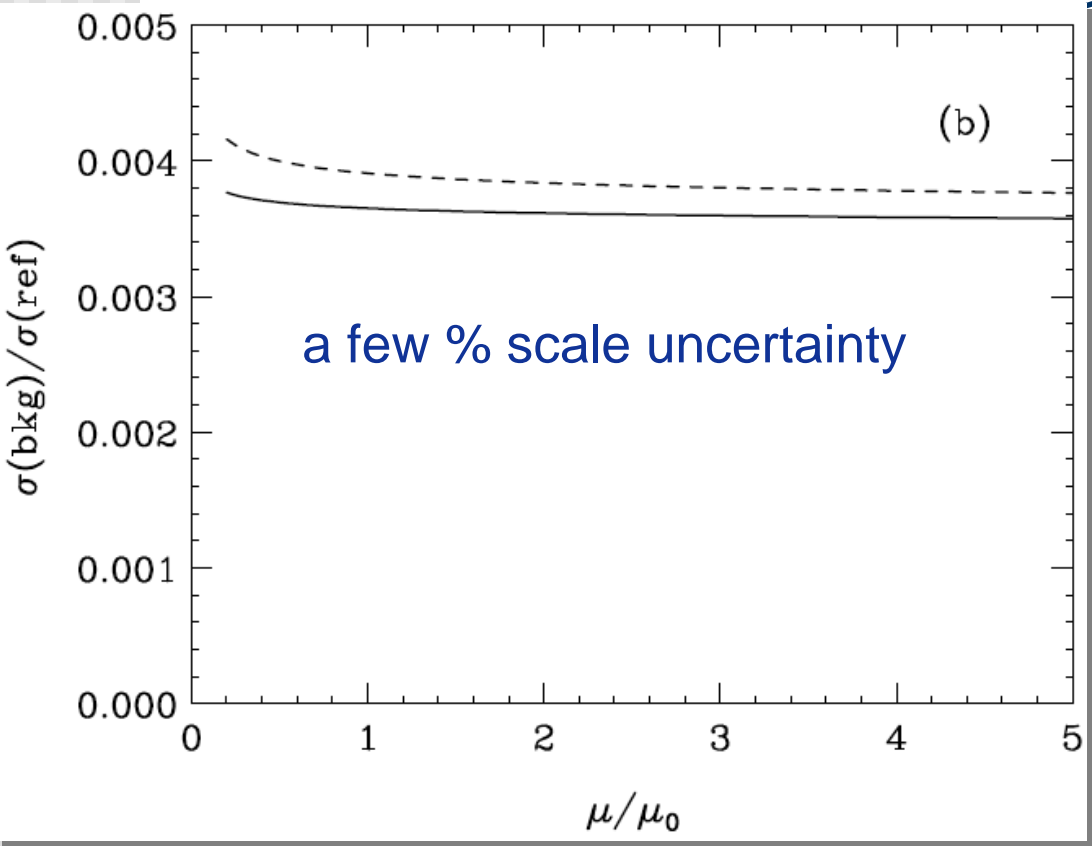


# Background extrapolation



Introduction  
Status of

Backgrounds to  $H \rightarrow WW \rightarrow l \nu l \nu$  :  $t\bar{t}$  for gluon fusion,  $t\bar{t}j$  for qqH



~ 5% background uncertainty

Idea of extrapolation:  
Cavelli, Kauer, Zeppenfeld

$$\sigma_{bkg} \approx \underbrace{\left( \frac{\sigma_{bkg, LO}}{\sigma_{ref, LO}} \right)}_{\text{low theoret. uncertainty}} \cdot \underbrace{\sigma_{ref}}_{\text{low experim. uncertainty}}$$

$\sigma_{bkg}$  : background with cuts optimized for finding signal

$\sigma_{ref}$  : background with cuts to enrich background (eg. revert the cuts above)



# Further Remarks



- **What are the important calculations needed, where is phenom. work wanted? Signal and Bkg:**
  - **NLO wherever possible**
  - **MC@NLO wherever possible!**
  - **NNLO, fully differential**
    - at least for the basic processes
  - **Backgrounds are important now, especially :**
    - tt, ttj ,ttjj, W/Z+jets
    - Investigate ratio method for more processes
  
- **Other interesting processes**
  - **Jet + photon/Z : gluon pdf**
  - **Excellent understanding of incl. jet and di-jet prod.**

■ **SLHC : The upgrade of an upgrade**

- **Phase 0** : Performance upgrade, without hardware modifications
- **Phase 1** : Performance upgrade with IR modifications
- **Phase 2** : Performance upgrade with major hardware modifications

parameter \ value	nominal	phase 0	phase 1
# bunches	2808	2808	<b>5616</b>
N / bunch	$1.15 \cdot 10^{11}$	$1.70 \cdot 10^{11}$	$1.70 \cdot 10^{11}$
$\beta^*$	0.55 m	0.5 m	<b>0.25 m</b>
$\epsilon_n$	$3.75 \mu\text{m}$	$3.75 \mu\text{m}$	$3.75 \mu\text{m}$
$\sigma^*$	$16.7 \mu\text{m}$	$16 \mu\text{m}$	$11.3 \mu\text{m}$
$\sigma_L$	7.55cm	7.55cm	3.8cm
full crossing angle	$285 \mu\text{rad}$	$315 \mu\text{rad}$	$445 \mu\text{rad}$
events per crossing	19.2	44.2	88.4
peak luminosity	$1.0 \cdot 10^{34} \text{ cm}^{-2} \text{ sec}^{-1}$	$2.4 \cdot 10^{34} \text{ cm}^{-2} \text{ sec}^{-1}$	$9.6 \cdot 10^{34} \text{ cm}^{-2} \text{ sec}^{-1}$
luminosity lifetime	15 h	10 h	<b>5 h</b> → <b>integrated</b>
E[TeV]	7	7 → 7.45	7 → 7.45 <b>luminosity and</b>
E [MJ]	366	541	<b>1082</b> → <b>efficiency?</b>

O. Bruning

■ **Detectors :**

- Radiation hardness, faster and more granular (increased pile-up noise)
- Forward regions particular under “pressure” : improved shielding?
- Change L1 triggers if going to 12.5 ns bunch spacing

Gianotti, NPB (Proc. Suppl)  
 D. Green, AIP Conf. Proc.



# CMS Physics Analysis in Peking University

(**Profs.** 冒亚军, 班勇, 钱思进)

- **J/ $\Psi$  极化与 NRQCD 课题(赵光达教授建议)**
- **t 夸克的极化与宇称破坏(李重生教授建议)**
- **带电轻子伴随大横动量的丢失(朱守华教授建议)**



# Summary (1)



- **We ARE getting ready for the LHC**
- **CERN is fully committed to the LHC project**
  - **Everybody (machine and detectors) is working like crazy to be in time**
- **Many efforts now concentrating on the very details of the start-up procedure**
  - **How to analyze the first data coming out**
- **Physics studies**
  - **be careful when using Monte Carlo programs for background (and signal) evaluation**
  - **The ingenuity of the experimenters really becomes visible when working on methods to get as much as possible from the data**

*“If we don’t succeed, we run the risk of failure” (B. Clinton)*



# Summary (2)



- **Hardware contribution to CMS experiment from Peking University** is progressing well, and is going to be completed in this year.
- **CMS physics analysis program in Peking University** was started a year ago under the support from 国家自然科学基金委的重点项目。We have got the significant progress in last year, our work has been recognized by CMS physics project and our result has been used in “CMS Physics Technical Design Report (pTDR)”.
- **CMS physics analysis effort in PKU has been enhanced** from the beginning of this year. Professors in ITP gave us many valuable helps and we shall continue the close collaboration extensively.
- Much more work need to be done in order to share the most important HEP physics harvest in the world in next 10+ years. **All suggestions and real participations to this exciting program are warmly welcome!**



# Acknowledgements



- Many thanks to all these people:
  - G. Rolandi, O. Brüning, F. Gianotti, P. Jenni, D. Treille, L. Pape, H. Burkhardt, F. Pauss, L. Evans, A. De Roeck, F. Moortgat, P. Janot, J. Virdee, 班勇, 冒亚军, 赵光达, 李重生, 朱守华
- Special thanks to Günther Dissertoni who collected many info from above colleagues
- Thanks for the invitation to ITP of PKU!

谢谢!