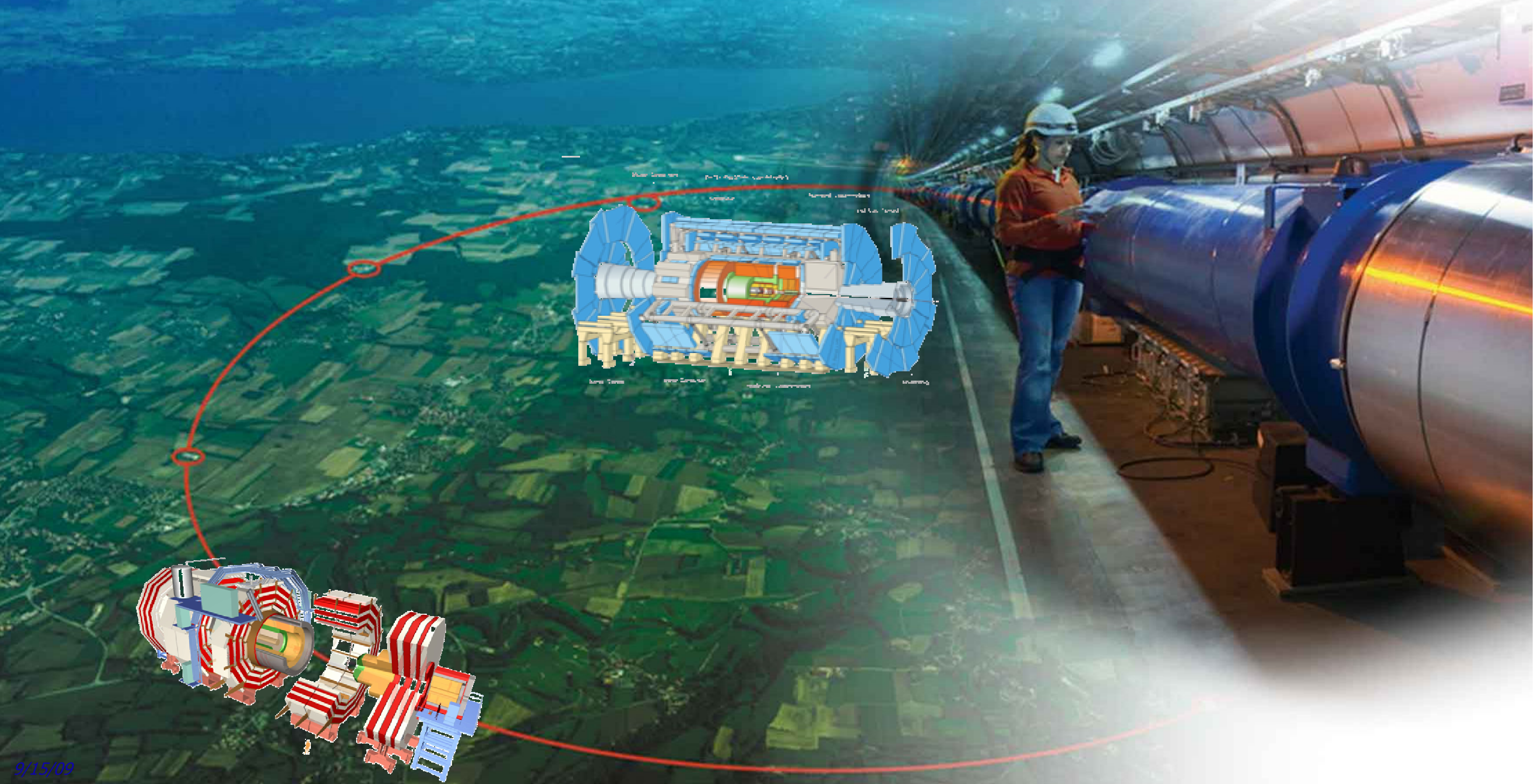
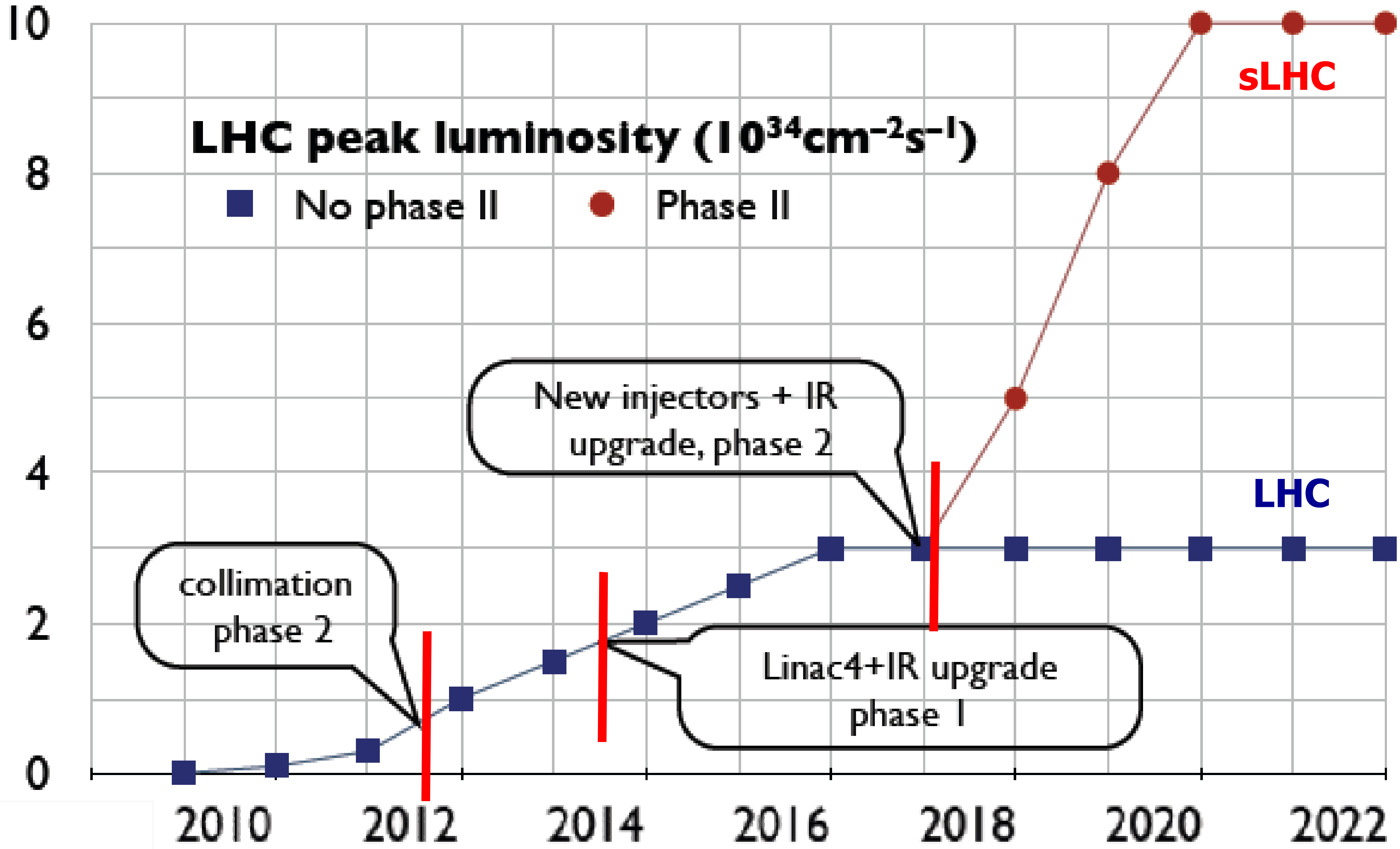
sLHC : view from the experiments

LHC-CC09
Marzio Nessi
CERN, 16th September 2009

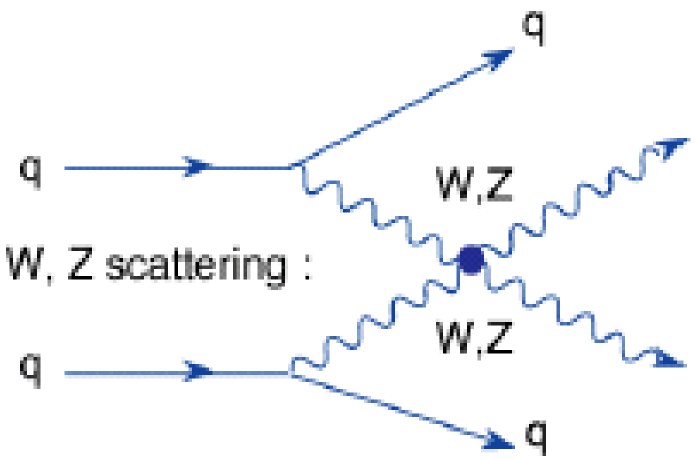


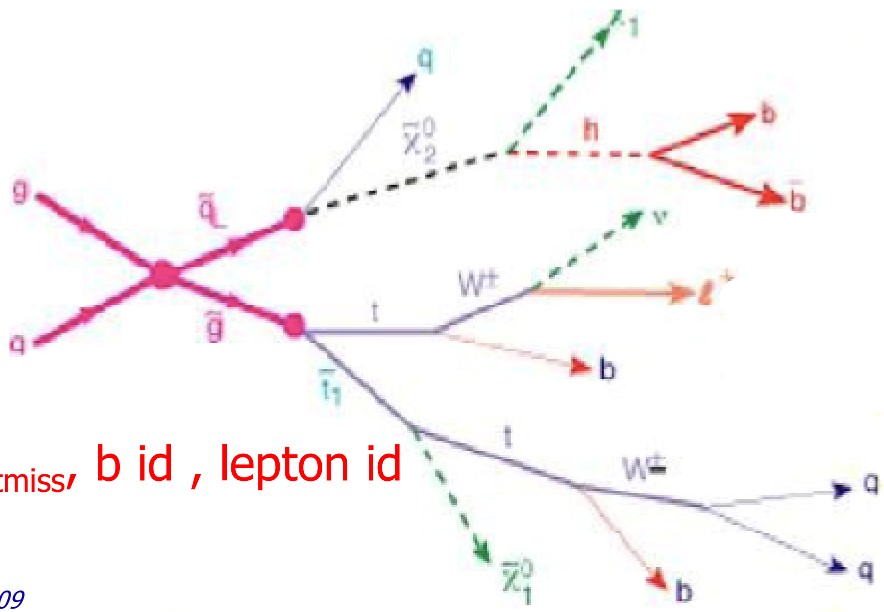
Luminosity road map in 2 phases (2008 CERN Man.)



Detector requirements @ sLHC

Detector performance needs to be maintained despite the new environment we will find at sLHC (pile-up, radiation, ….) …… in particular now when we don't know anything about the new energy domain





E_{tmiss}, b id , lepton id

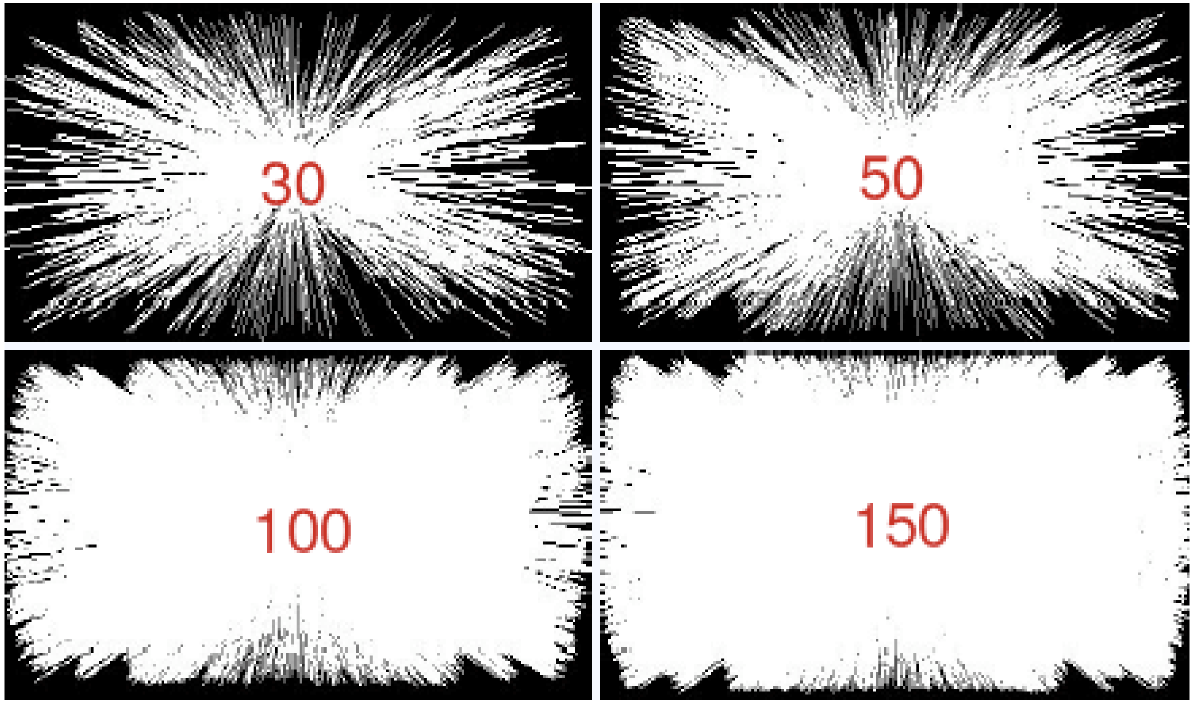
High-mass (~TeV Z',W',..) can tolerate some degradation; backgrounds are low

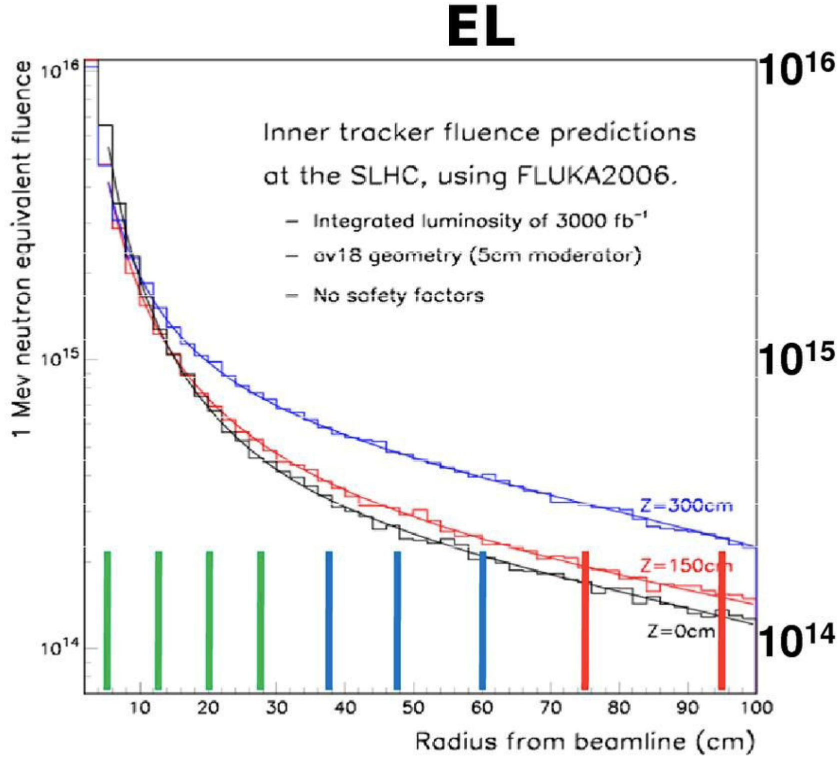
WW scattering (Higgs couplings or vector boson fusion) needs forward jet reconstruction and central jet veto

Vertex, missing E_T, p_T resolution and efficiencies remain important, for many channels of interest

Electron and muon identification fundamental for W/Z, W'/Z', and SUSY

Detector environment and requirements





Minimum bias events ***pile-up*** *dominated by the peak Luminosity. Different sLHC scenarios define the value we have to assume in our design (today's worst case* ***300 to 400 pile-up events / bunch crossing****). Detector granularity, detector transparency and trigger strategy will need to be tuned to it*

Detector ***radiation*** *resistance requirement dominated by the delivered integrated Luminosity. Here the detector radius and pseudo rapidity location (η) are the scaling factors. $10^{17}/cm^2$ neutrons will be the fluence at the front face of the forward calorimeters*

p-p experiments plans/strategies for sLHC

- ✓ Assess and understand which components of the existing detectors can still be used at very high Luminosity (radiation issues, aging process, front end electronics and power distribution consolidation, ….)

  …. One example ATLAS forward calorimetry!

- ✓ Fully rebuild the inner detectors (tracking), mostly using silicon technology

- ✓ Improve the trigger capabilities to cope with ~ factor 5-10 higher amount of hard collisions, in particular at level 1 (μseconds scale)

- ✓ At high Luminosity, new large aperture triplets in front of the IR, will require new radiation shielding protection for the muon spectrometers and a new design of the very forward region (new TAS collimator, new forward shielding,…). Minimize the experimental caverns background will become a major challenge

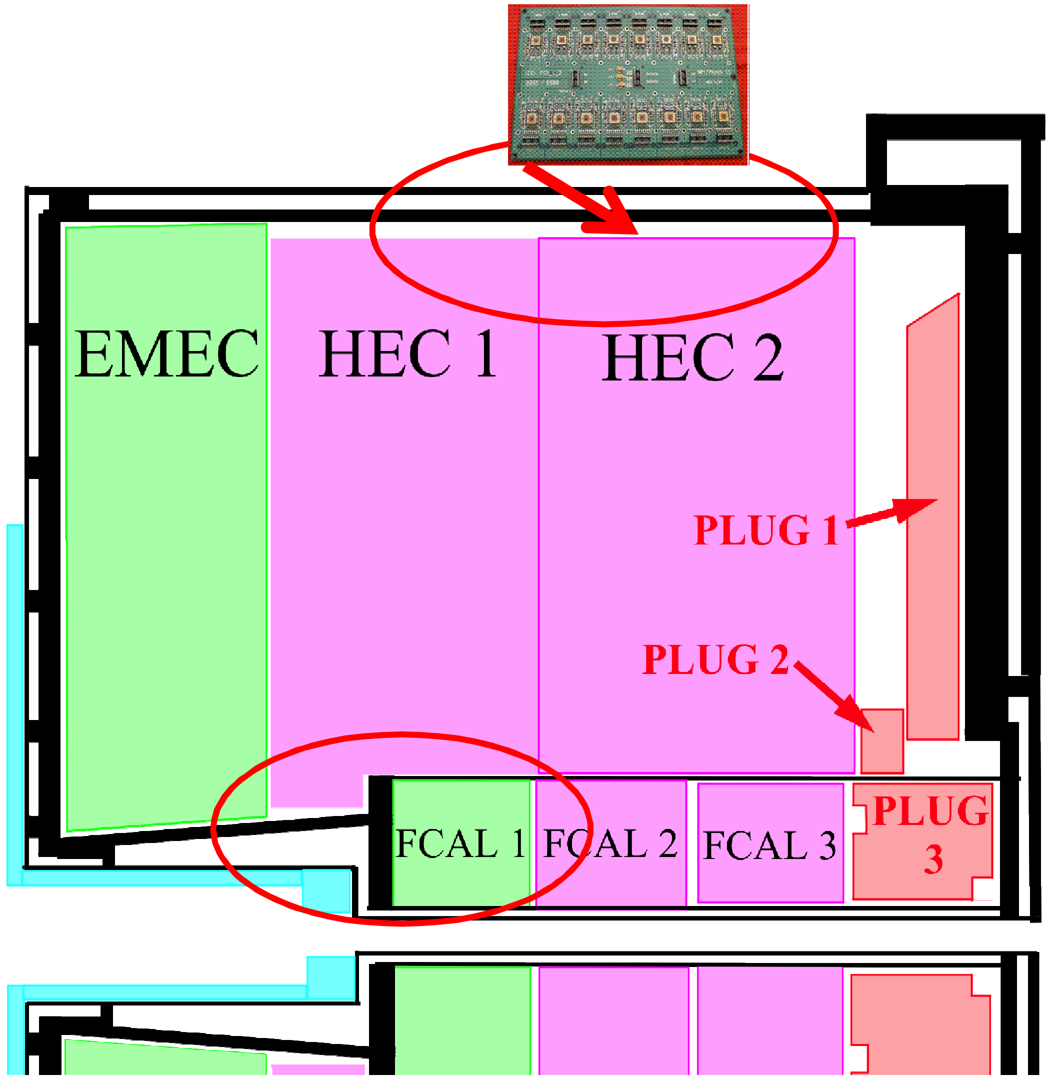
ATLAS LAr Calorimeters problems at sLHC

2 types of problems (mainly related to dose and dose rate):

✓ Hadronic end cap cold electronics: radiation hardness at the limit. Need to measure radiation levels in situ after LHC turn on to clarify safety factors!! The related electronics boards with new preamplifier and summing amplifier IC's can be replaced without taking the HEC wheels apart, but requires cryostat opening in situ. More radiation tests are ongoing!

✓ FCAL : various problems (dose :10^{17-18} neq/cm^2) JM

- *-Boiling of LAr*
- *-Ion build up between electrodes*
- *-Voltage drop over HV resistor*



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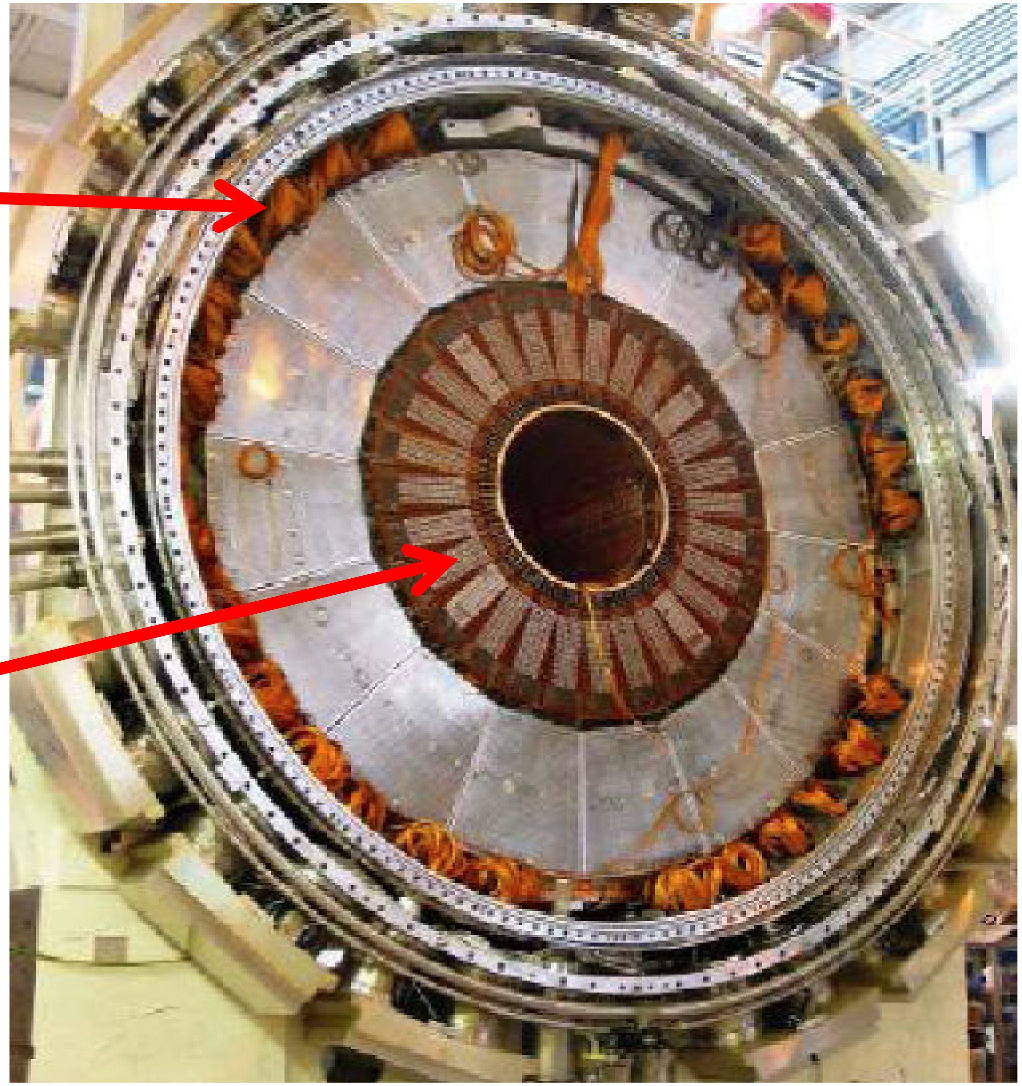


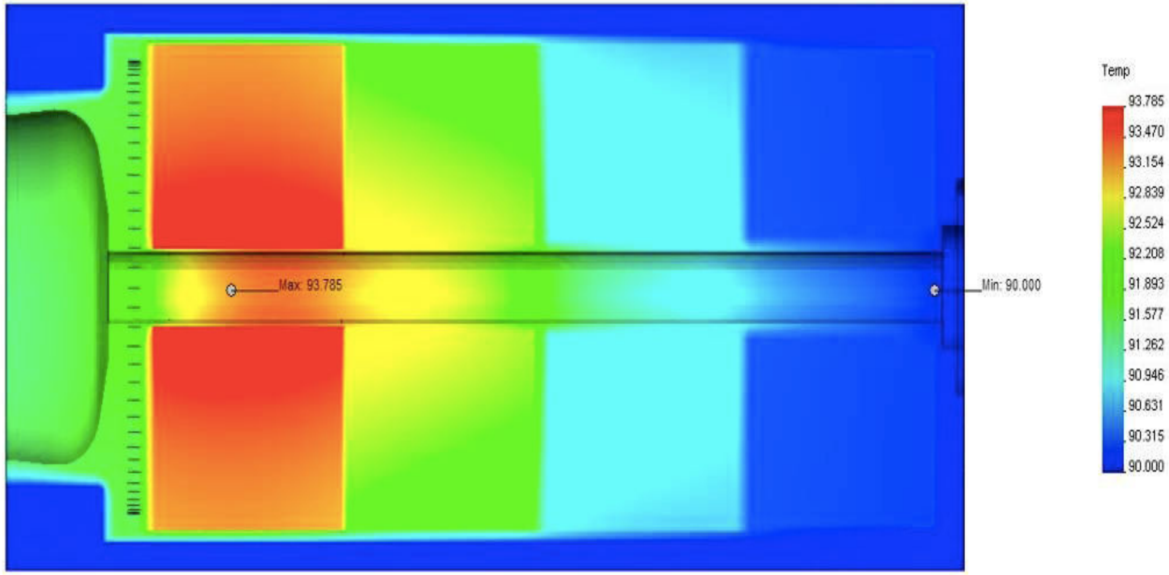
The Lar Calorimeters (forward) will need a major rework

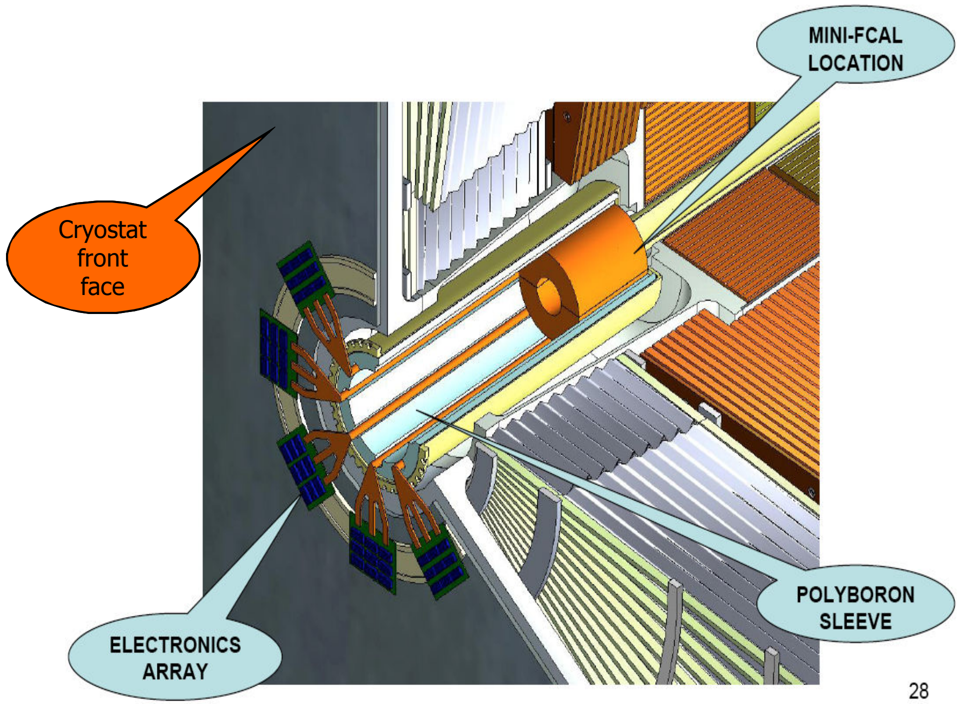
Studies and tests under way; if these show that action is needed, two solutions are considered:

- Warm calorimeter in front of current calorimeter (diamond technology?)

-Open cryostat, insert complete new FCAL with smaller gaps and more cooling power

All this will require a major shutdown of about 15 months to operate in the experimental cavern

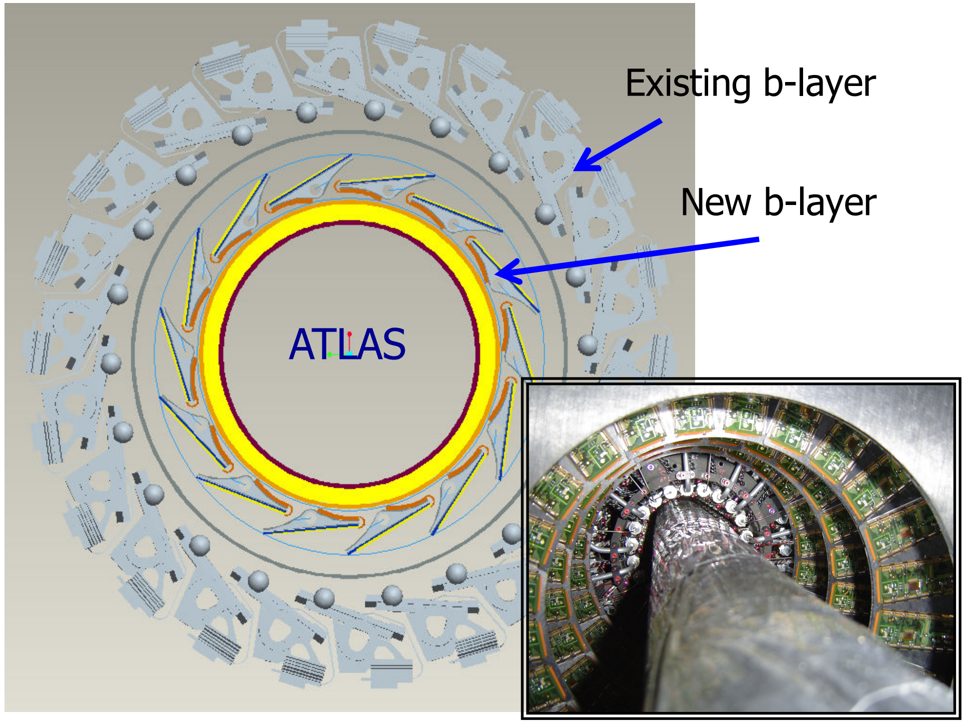




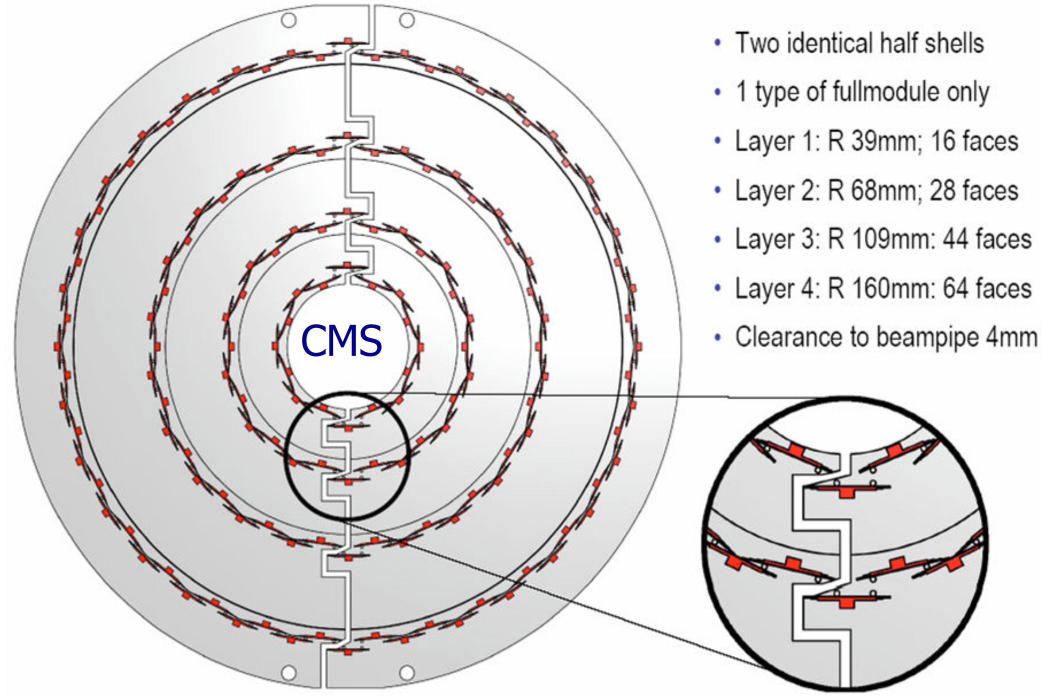
Inner Tracking Detectors

Phase 1 : > 300 fb^{-1}, L ~2-3 10^{34} cm^{-2} s^{-1}, ~ 2014

- ✓ Present Pixel detector, in particular b-layer will become inefficient
- ✓ Both ATLAS and CMS plan a major upgrade



Add new b-layer around a smaller beam pipe, stave structure, 160 MHz readout, CO_2 cooling



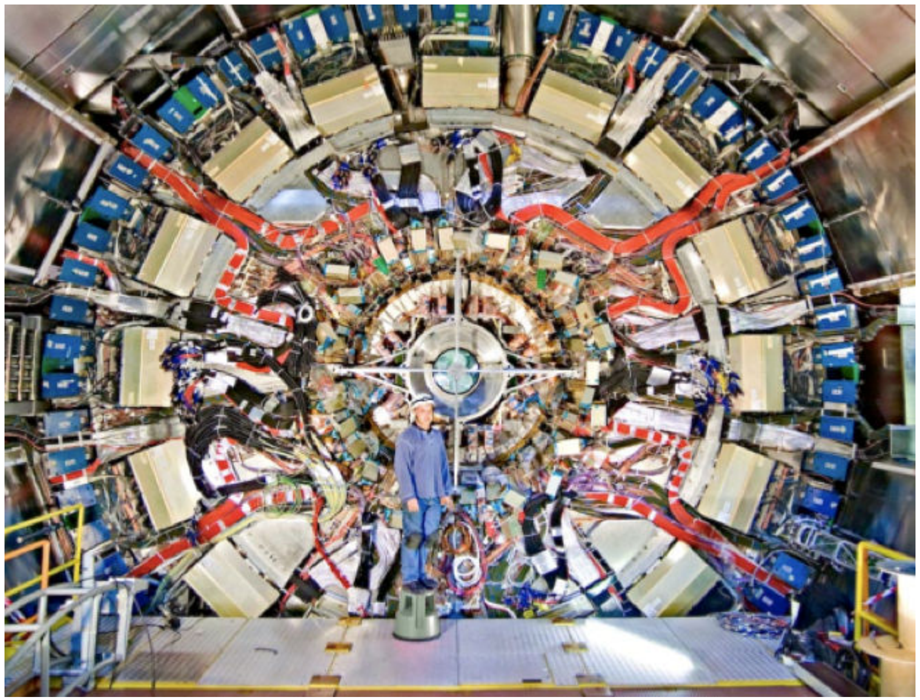
Full substitution : 4 barrel layers + 3 disks per side, weight a fact 3 down, 160 MHz readout, CO_2 cooling

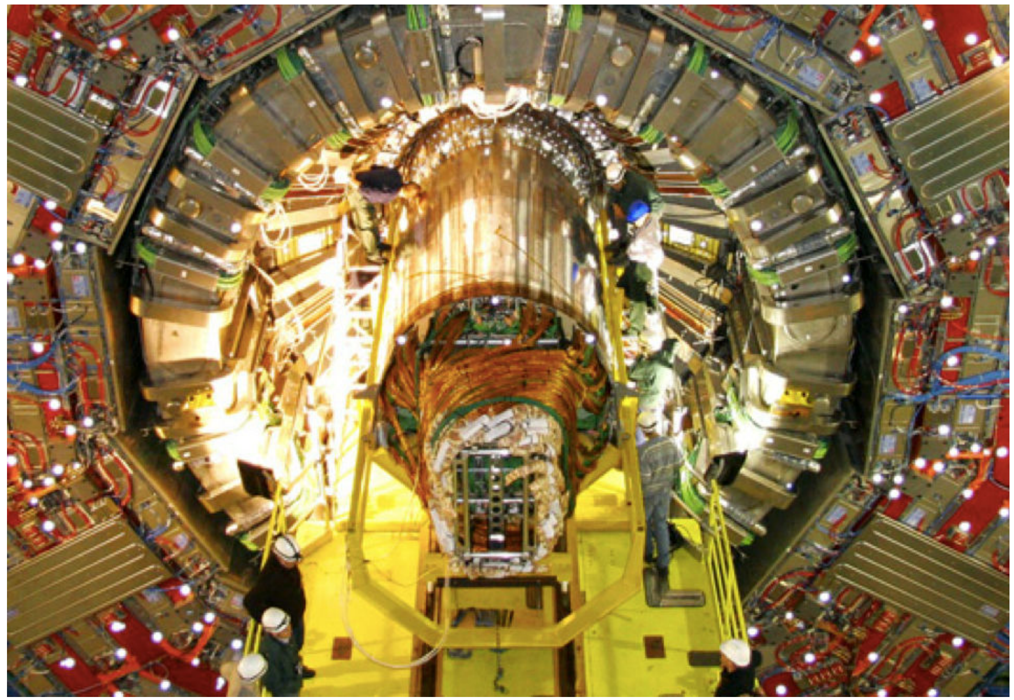
Inner Tracking Detectors

Phase 2 : > 600-700 fb^{-1}, L ~ 10^{35} cm^{-2} s^{-1}, ~ 2018

- ✓ The present silicon and straw tracker will definitely not survive and will need to be replaced

- ✓ Both ATLAS and CMS plan a major upgrade, needing a substantial shutdown (ATLAS ~18 months) for in situ installation/integration

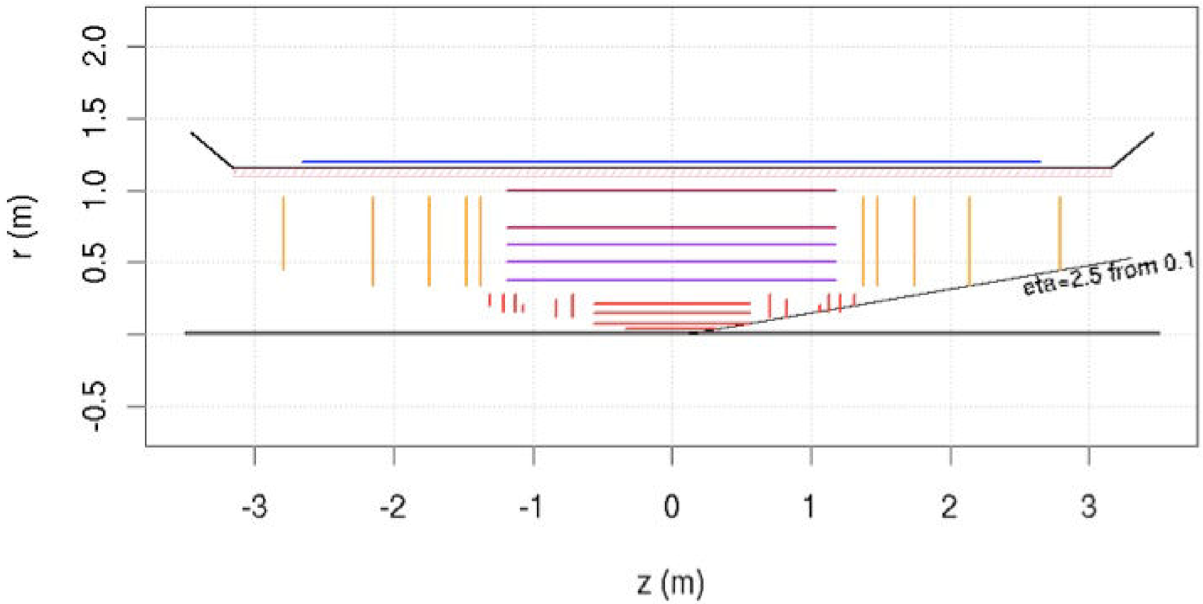


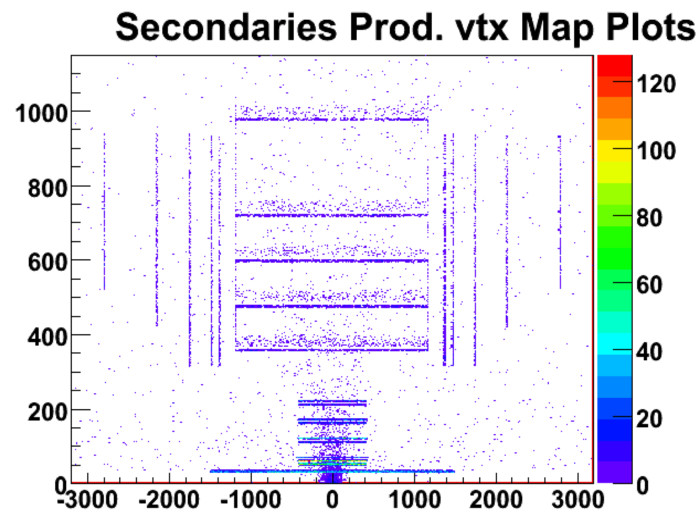


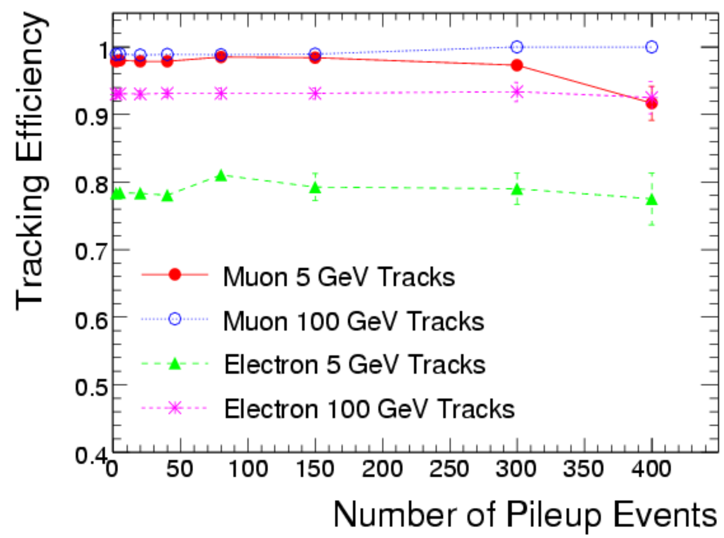
ATLAS ID layout for simulation and engineering

Full semiconductors solution : strips (~160m^2) and pixels, organized in staves !

Patter recognition efficiency being optimized (14 hits system)!





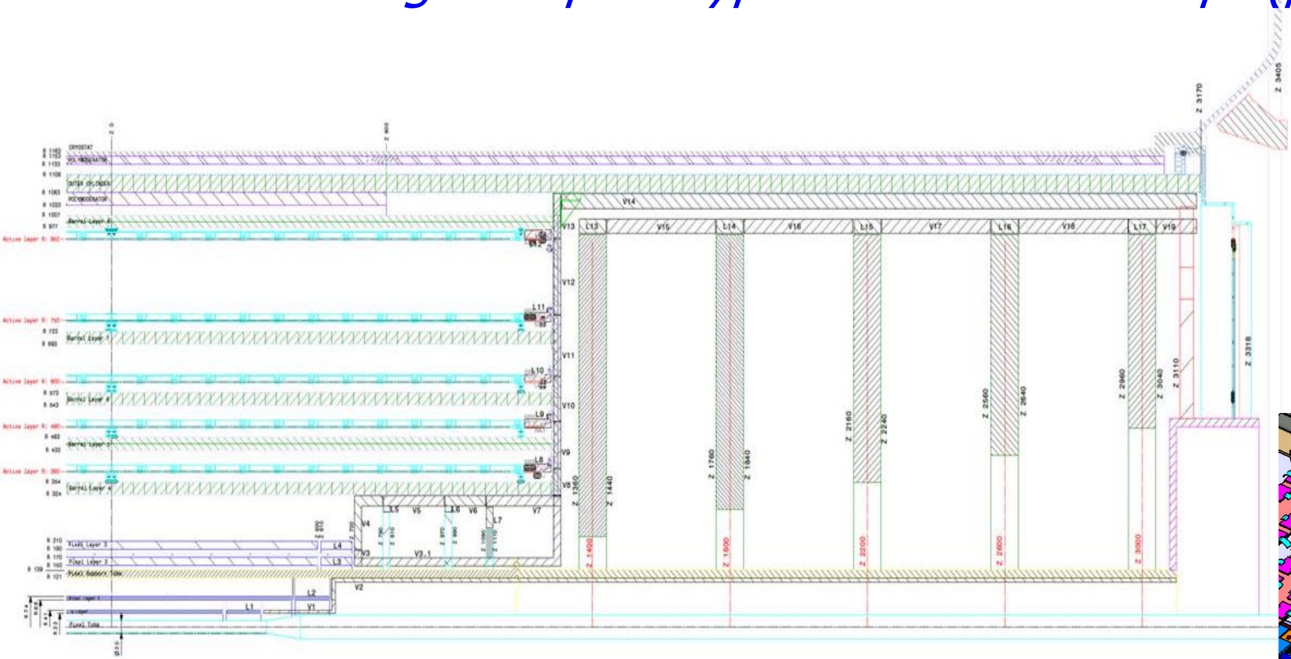


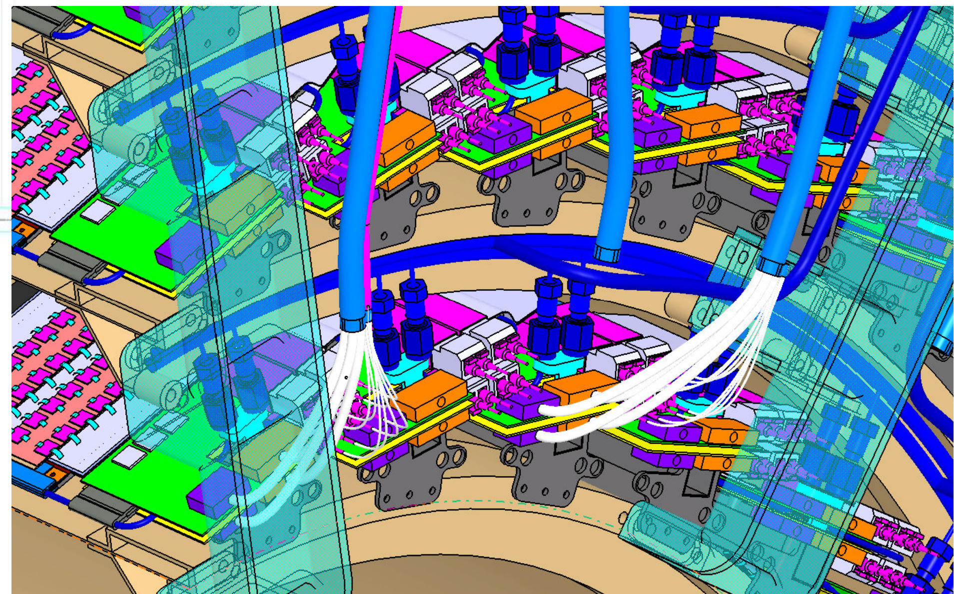
- ✓ *More granularity for similar occupancy at higher luminosity*
- ✓ *The crucial point is to reduce as much as possible the material budget*
  - e, γ conversion, hadronic interactions
  - mass driven by power & cooling

Bringing more realism in the layout (services and supports)

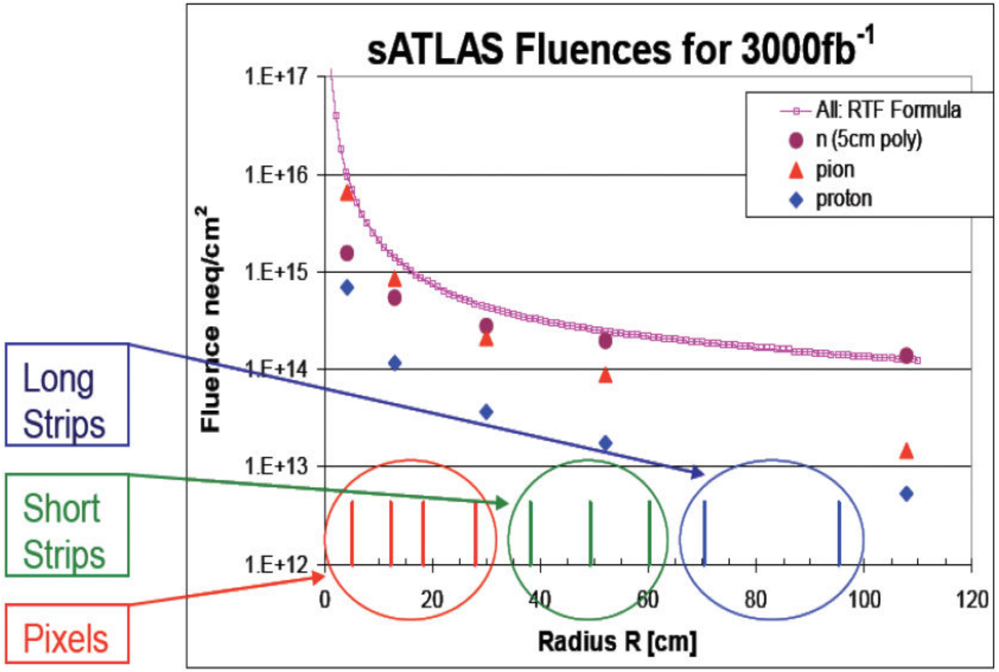
Key issues are:

- ✓ *an effective cooling system (~-30 C, CO_2 .... smaller diameter pipes)*
- ✓ *an effective power distribution (serial/parallel power, less copper needed !)*
- ✓ *testing with prototypes the stave concept (prototyping phase just starting)*



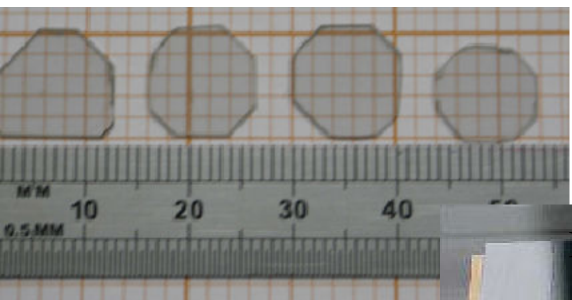


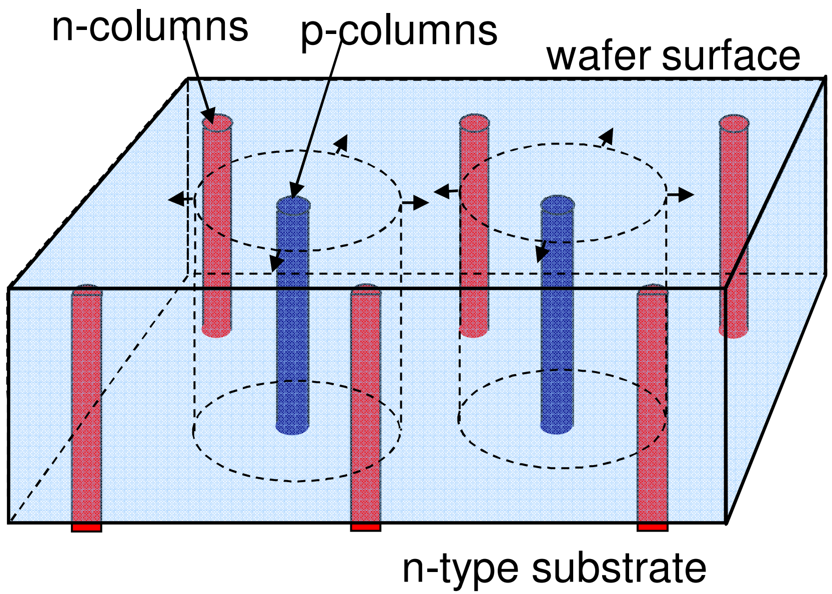
Choice of the sensor technology still in the R&D phase



While in the strips region, the existing Si planar technology (n-in-p) will probably be OK from the point of view of radiation (tested ~10^{15}n/cm^2), the solutions for the innermost layers might need to be different or revisited !

Diamond : low leakage, radiation hard, low capacitance, heat spreader … but lower signal … and difficult to mass produce

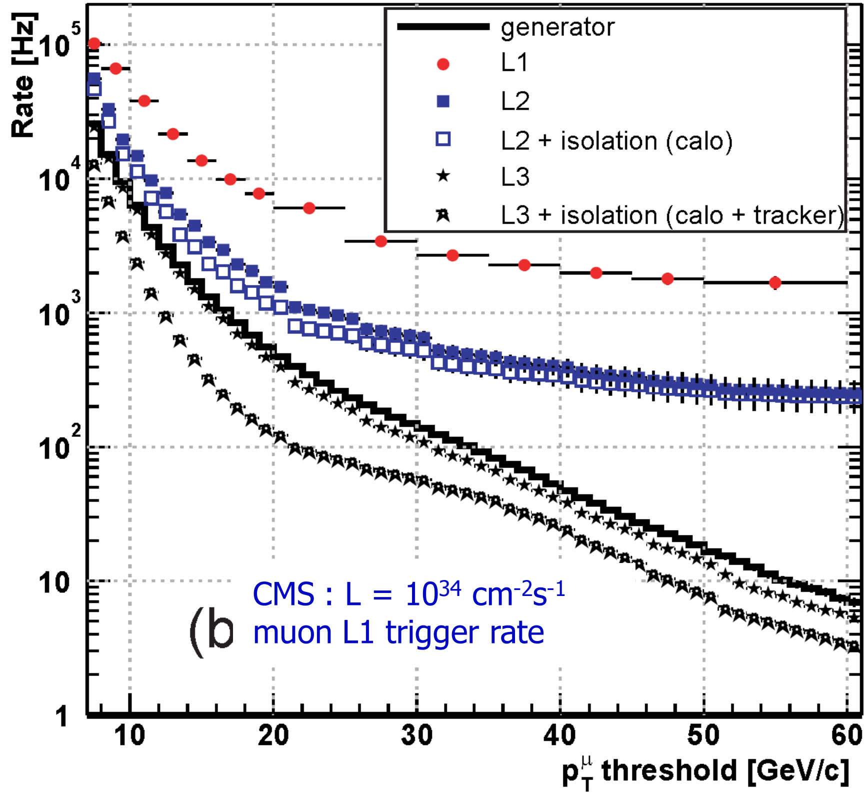




3D silicon : 250 μm have been tested , high eff. ~ 10^{16} p,n/cm^2, S/N ~ 60

Trigger upgrade

- The goal is to maintain the trigger rates. At 10^{35} $cm^{-2}s^{-1}$ the single e and μ trigger rate will easily exceed 100 kHz. Increasing the p_T thresholds (and using isolation from calorimeters) will not help much

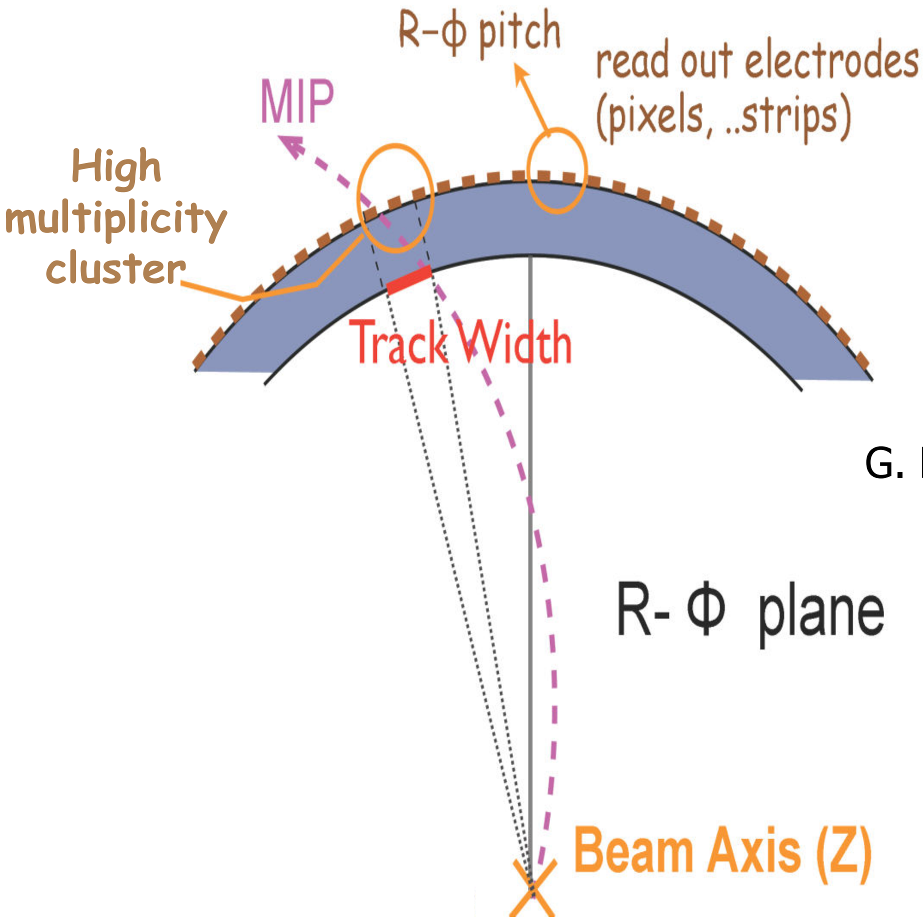


- Still challenging! We have to reject 10 times more events at LVL1 and process much more data at (pile-up → bigger events)
- For sure there will be a continuous process over years of replacing and increasing the processor to get more efficiency and rejection power level
- One could consider increasing the LVL1 latency (from ~2.5μs to 5-6μs) to allow more complexity at the early stage
- Bringing in the tracker information at LVL1 is an interesting solution (CMS is very active on this!)

High P_T track trigger

Cluster width

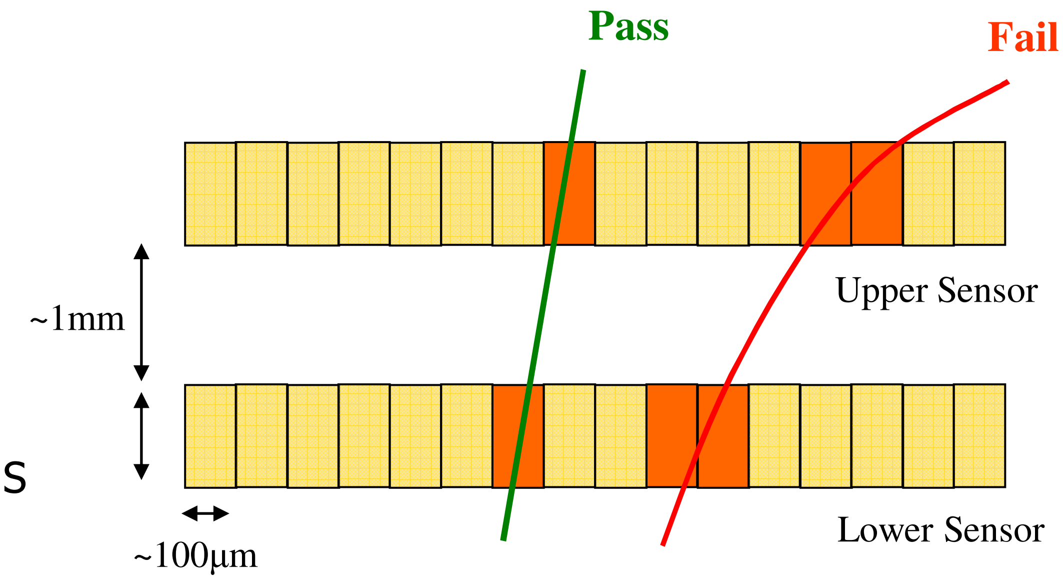
select hits with low strip multiplicity



Stacked layers

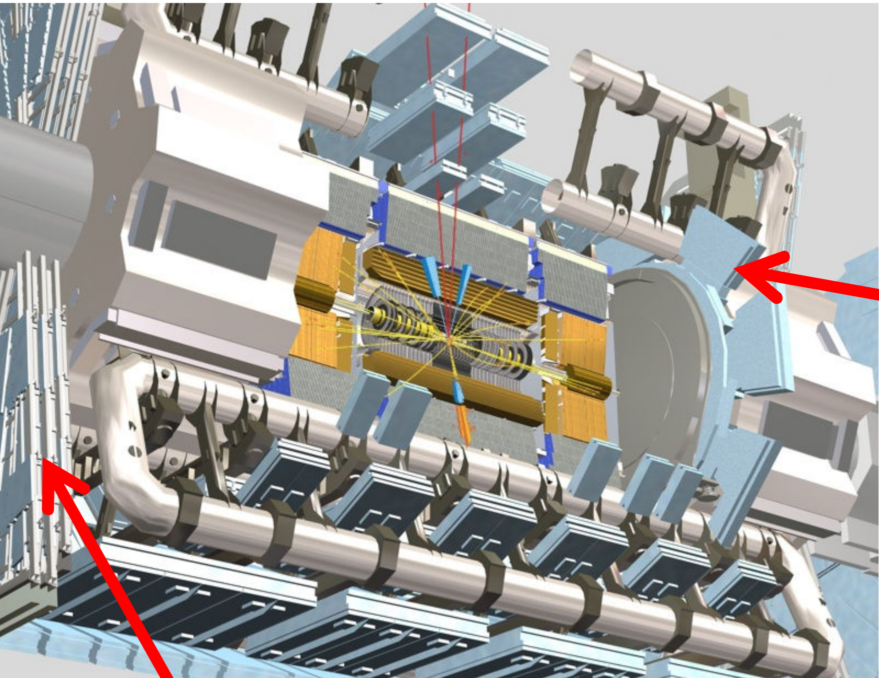
Correlate hit positions in closely spaced (~mm) layers

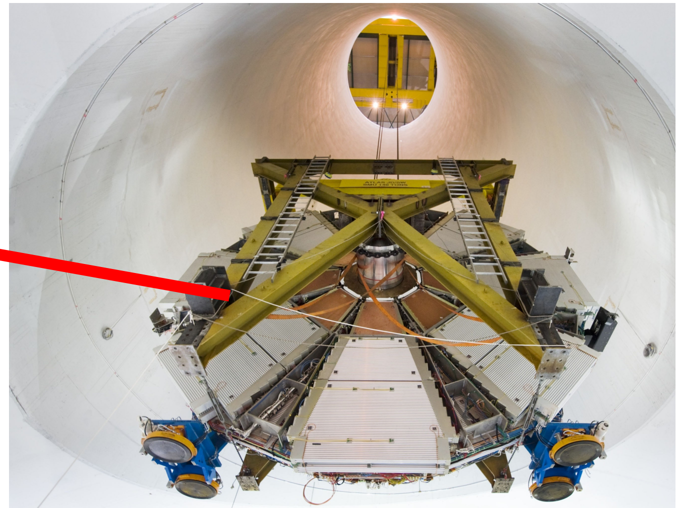
G. Parrini, CMS

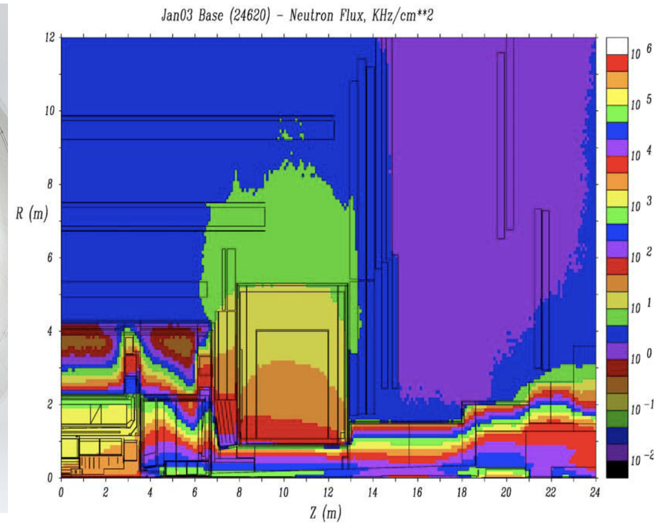


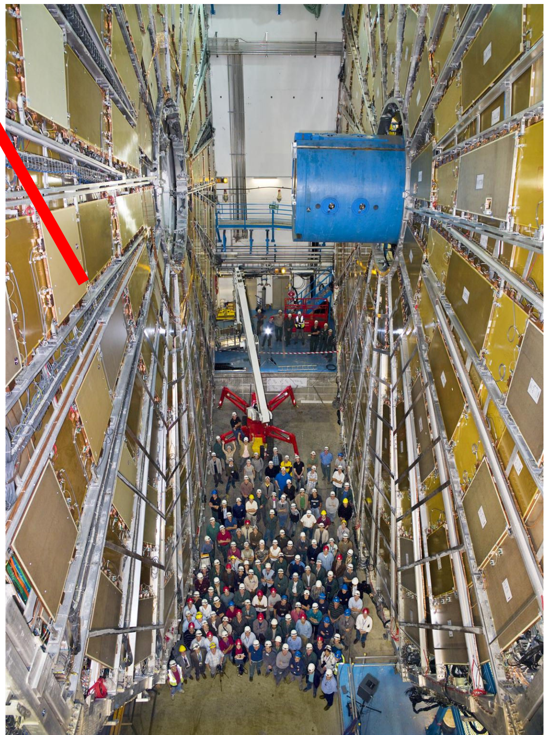
First simulation results show a very good potential : at R=25, 2mm separation rejects almost 100% below p_T=3 GeV/c

Forward muon spectrometer





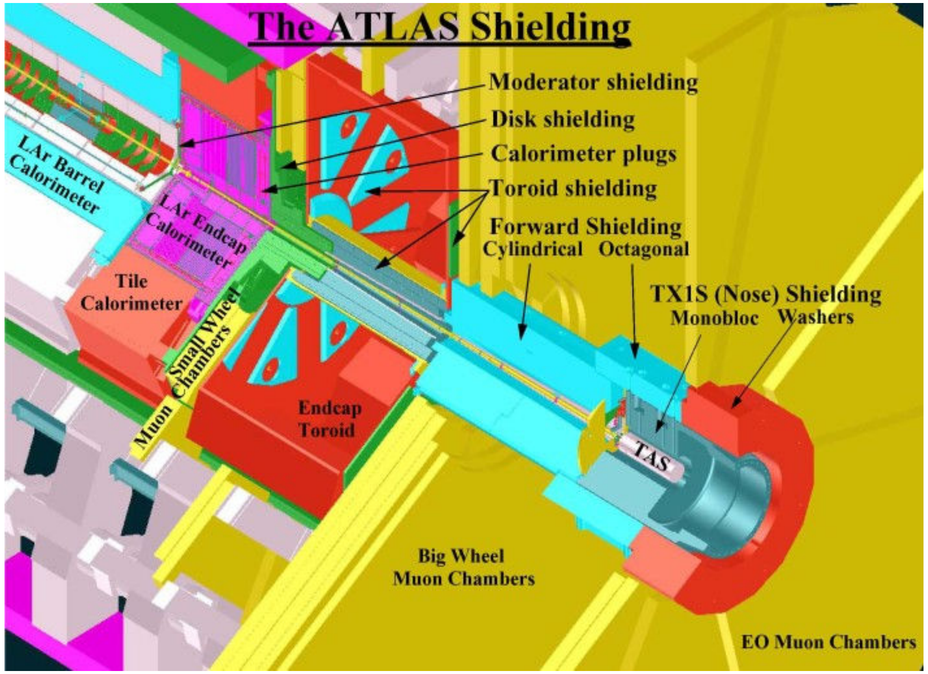




By its nature the muon spectrometers (trigger and precision chambers) sit in large neutron clouds. Neutrons will be captured, will convert to photons and electrons, contributing substantially to the overall signal/trigger background

This problem is particularly acute for ATLAS with the Toroid air core concept

Forward radiation shielding



Radiation shielding optimization in an air core toroid is a really difficult problem

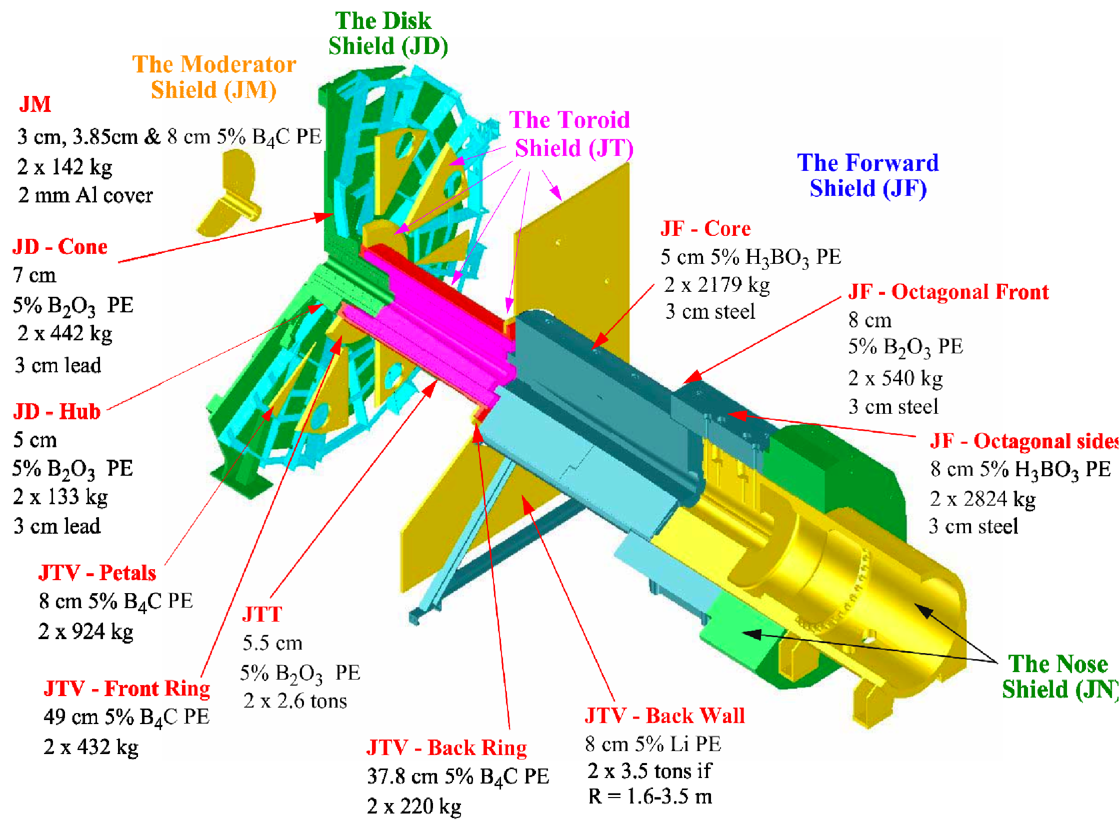
The muon spectrometer occupancy and its LVL1 trigger depend on it severely

New additional layers of trigger chambers might become necessary, even in the barrel region

Years of optimization have been spent

Most of the available space is used. The new large aperture triplets will require a new painful optimization of the forward region

We will need for sure transparent Be beam pipe everywhere (factor 2)!



Detectors Upgrade Strategy

- All this requires major R&D and construction work. Even if we learned the lesson with the first LHC detectors, it will take a good 6-7 years of construction work and few years to integrate it and getting it operational (ID in particular). This means that we have to start now, before knowing the real LHC environment, freezing therefore practically all experimental requirements of the original detector

- Designing today also means that we assume the technical feasibility of sLHC and we need to integrate in the design the worst pile-up and radiation/activation environment

- While the financial green light for this new enterprise will probably take a few years and will be tuned to the first LHC discoveries, the detector community has to act now, preparing technology, making choices, testing prototypes and going deeply in the engineering design. ATLAS and CMS are in the process of writing exhaustive LOIs for phase II Upgrade. The ATLAS one will be submitted for peer reviewing in the mid of 2010.

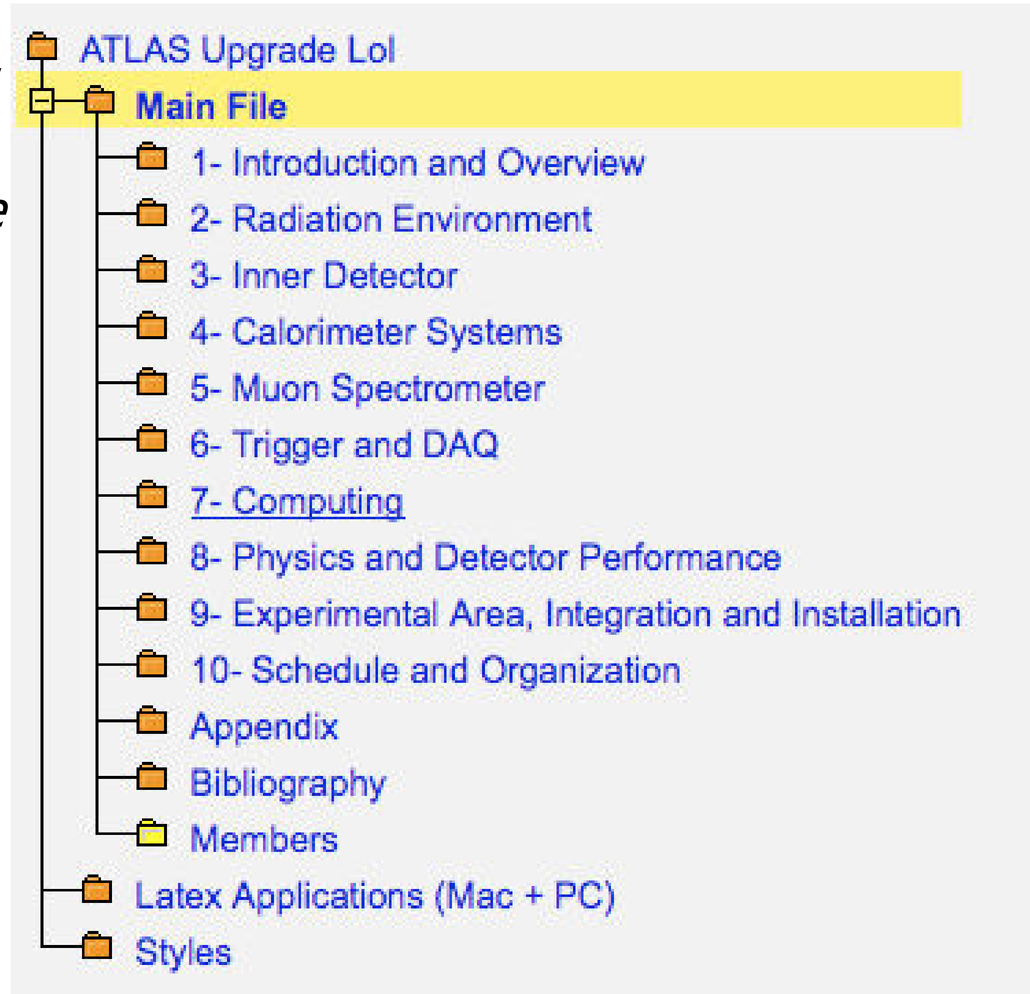
ATLAS Letter of Intents

The LoI process was launched at the end of June this year without removing resources from LHC commitments

Today:

- *Main editors and chapters editors are identified*
- *The scientific content of the LoI is agreed*
- *A coherent chapters and sub-chapters structure is drawn*
- *Topical meetings to monitor progresses are organized*

Under review:
the performance requirements of the overall detector in the sLHC environment



Complete documentation repository: EDMS

LoI schedule and next steps

- ✓ *30-06-2009 : Launch process, chick off meeting*

- ✓ *01-09-2009 : Definition of the chapters substructure and complete indexes with brief summaries presented by the main editors*

Systematic reviews of the status of various R&D projects to be considered and included in the LoI document

24-11-2009 : Release of the first draft of the various chapters

16-02-2010 : Release of the second draft

06-04-2010 : Release of complete LOI, ready for a general distribution for comments

25-05-2010 : Release of the final version, approved by the collaboration

31-05-2010 : Printing and submission to the LHCC

Summary

- *The experimental challenge for the detectors is in the tracking and in the trigger, which will need to be fully rebuilt around 2018*

- *The detector upgrade projects have started and will now enter the usual phase of proposals and approvals (LOI, TP, TDRs, MOU, ….). The project organization is slowly taking shape!*

- *I am sure, once the first LHC discoveries will be evident, the luminosity upgrade strategy will become a natural and necessary road map of the LHC program and of the HEP community at large*

- *The big question today is which scenario for peak luminosity and for integrated luminosity we should adopt in our planning*

Peak Luminosity vs Integrated Luminosity

- *If we go beyond the LHC program, we need to plan for a substantial increase of integrated luminosity on tape …… 3000 fb^{-1} …. to be cumulated in the period 2020-2026 ….. probably going further will not be necessary … at some point we will need more CM energy, then statistics*

- *A peak Luminosity of 10^{35} complicates a lot the construction and operation of the detectors : more ID granularity, bigger events to be acquired and to trigger on, more noise induced by neutrons, more radiation hardness requirements, more complexity in the physics reconstruction!*

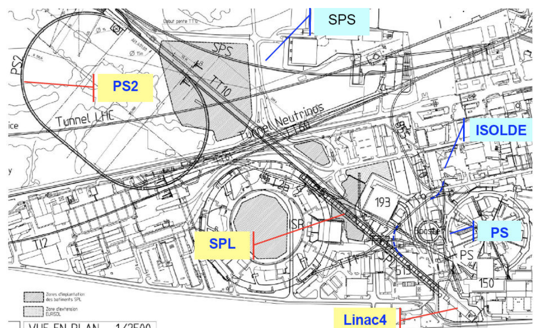
- *We have not demonstrated yet that at 10^{35} we can do physics in the forward region, that the end-cap and forward calorimeters will work, that we do not need much more muon chambers in the entire spectrometer …..*

- *Despite what all my colleagues will tell, I am mostly afraid to be unable to control the induced background in the forward region and to complicate our life with activation problems*

- *Introducing additional magnets inside the detectors, going to a new triplet with large aperture will not be easy …. we might need a factor 2-3 more in noise suppression*

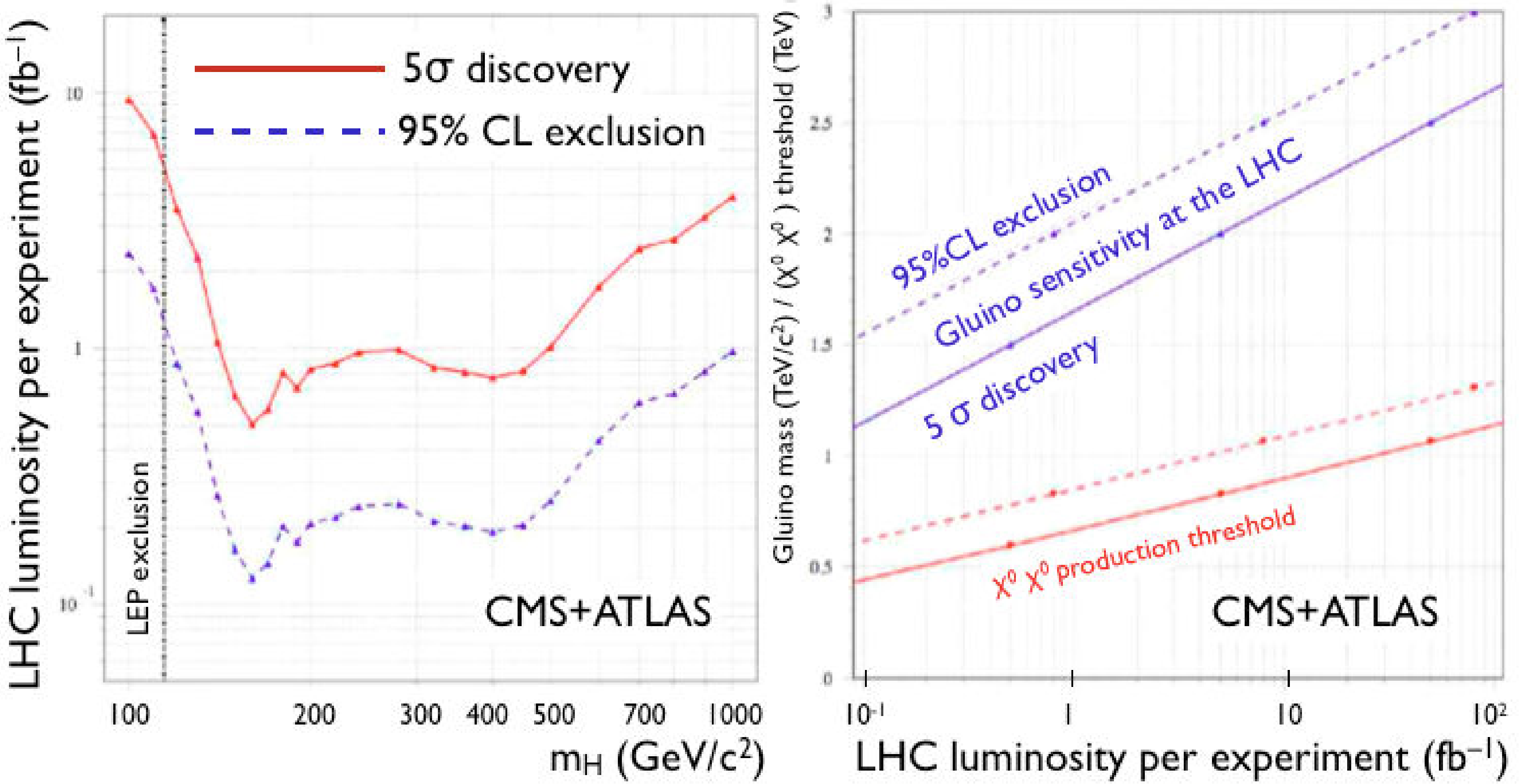
Peak Luminosity vs Integrated Luminosity

- Luminosity leveling around $4*10^{34}$ might be the winning factor if it can deliver 300-400 fb^{-1} per year
- A full crab cavity solution will be a very elegant solution … we will support it
- The redesign of the last 50m of beam line (including TAS collimator, forward shielding, triplets,….) goes together
- The experiments are embarking in a very complex upgrade road map, with material resources of ~250M per experiment and 8-9 years of intense construction work
- Once this process has started, it will be difficult and dangerous for the HEP community to stop it. Are the machine plans today able to grant success in the year '20 ?... Will CERN have enough resources for it ? …. Can we for example decouple the construction of the new injectors (aside LINAC4) from the initial sLHC road map ?



Thank you!

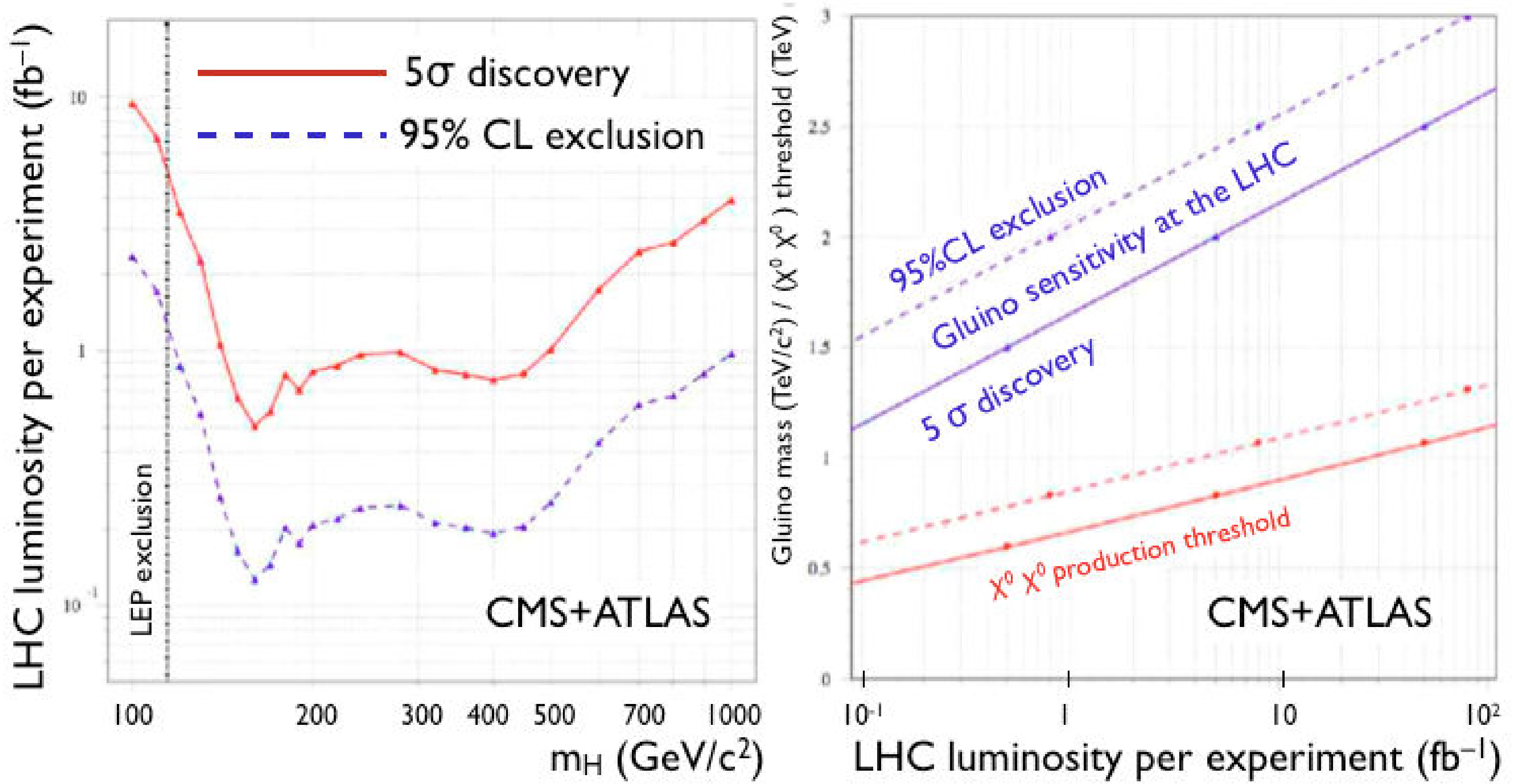
Why should we go beyond 600 fb^{-1} ?



With 10fb^{-1} the LHC will either discover or exclude the SM Higgs and Gluinos up to 1.8-2 TeV. This probably after 2 years of running at 14 TeV and at 10^{33} cm^{-2}sec^{-1}

Whatever the results will be, we will be left with a lot of new questions and problems to solve. There will be no limit to the need of accuracy after that!

Why should we go beyond 600 fb^{-1} ?

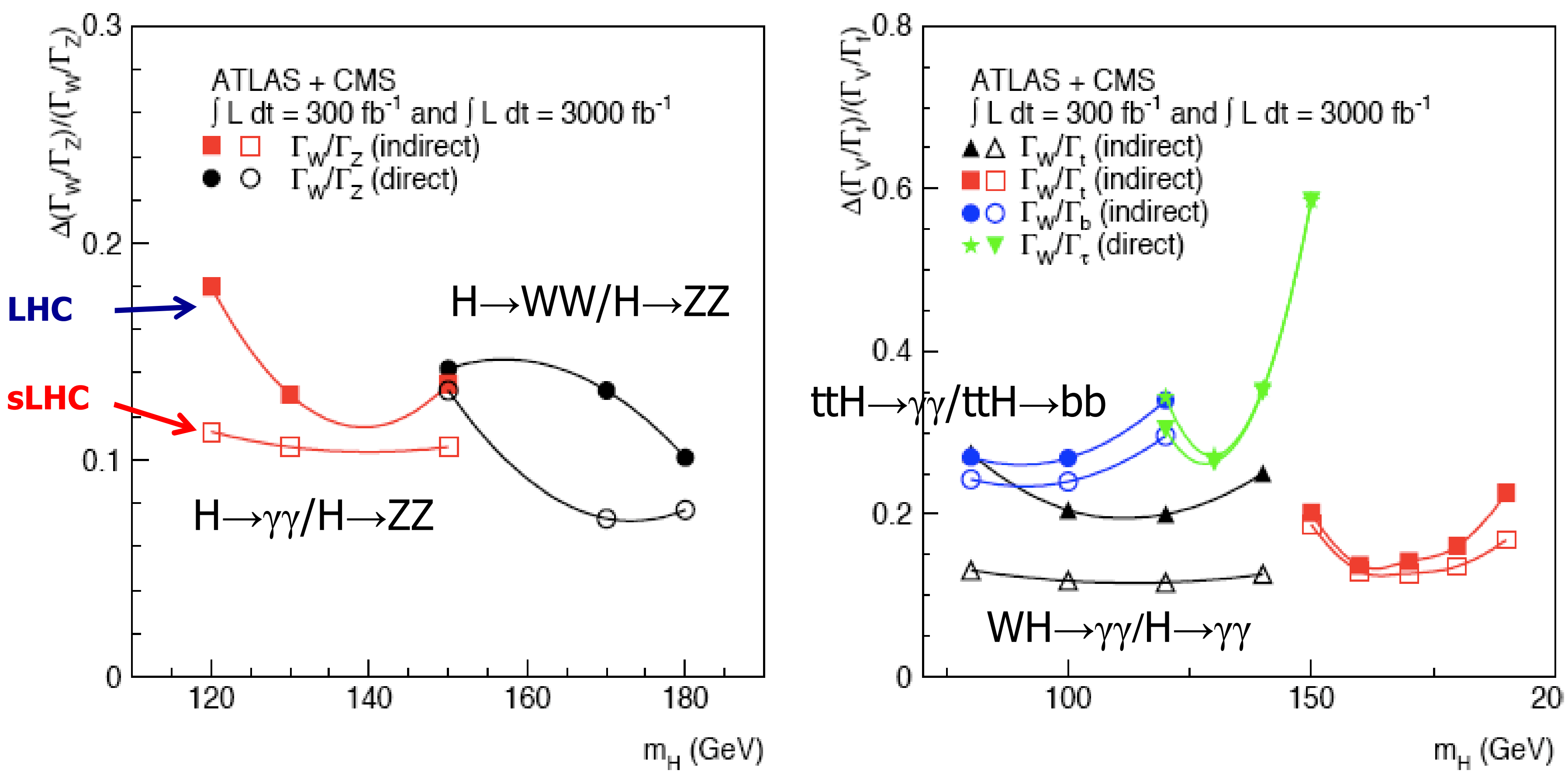


More particles in the Higgs sector? Is the Higgs boson elementary or composite?

Origin of fermion masses ?

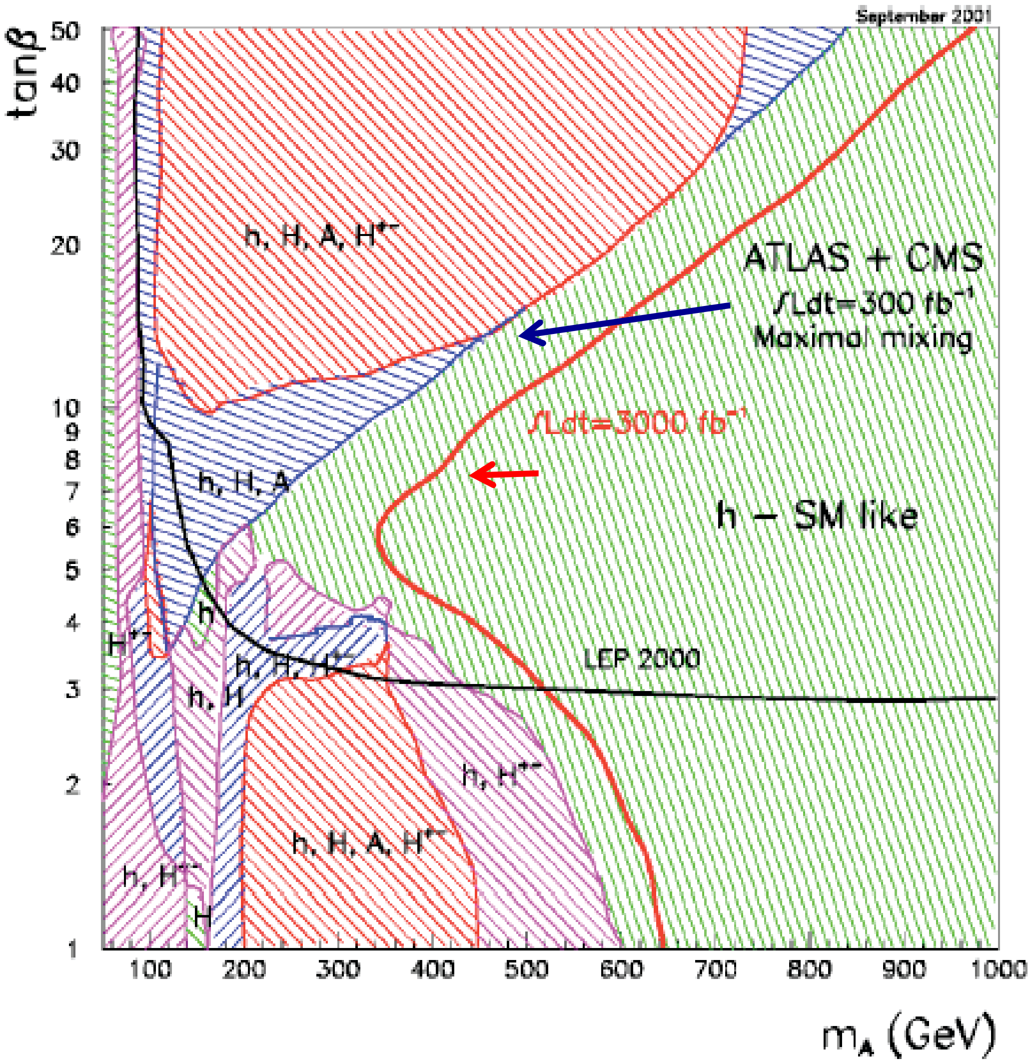
Extend the mass reach of new particles ! Determination of SUSY masses and parameters !

Precision measurements of the SM Higgs sector



- Higgs couplings to fermions, gauge bosons
- Rare decay modes : H-> Zγ (~10^{-3} BR), H-> μμ (10^{-4} BR)
- Self couplings λ : H -> HH -> WWWW -> lνlνjjj (sLHC 20-30%)
- □.

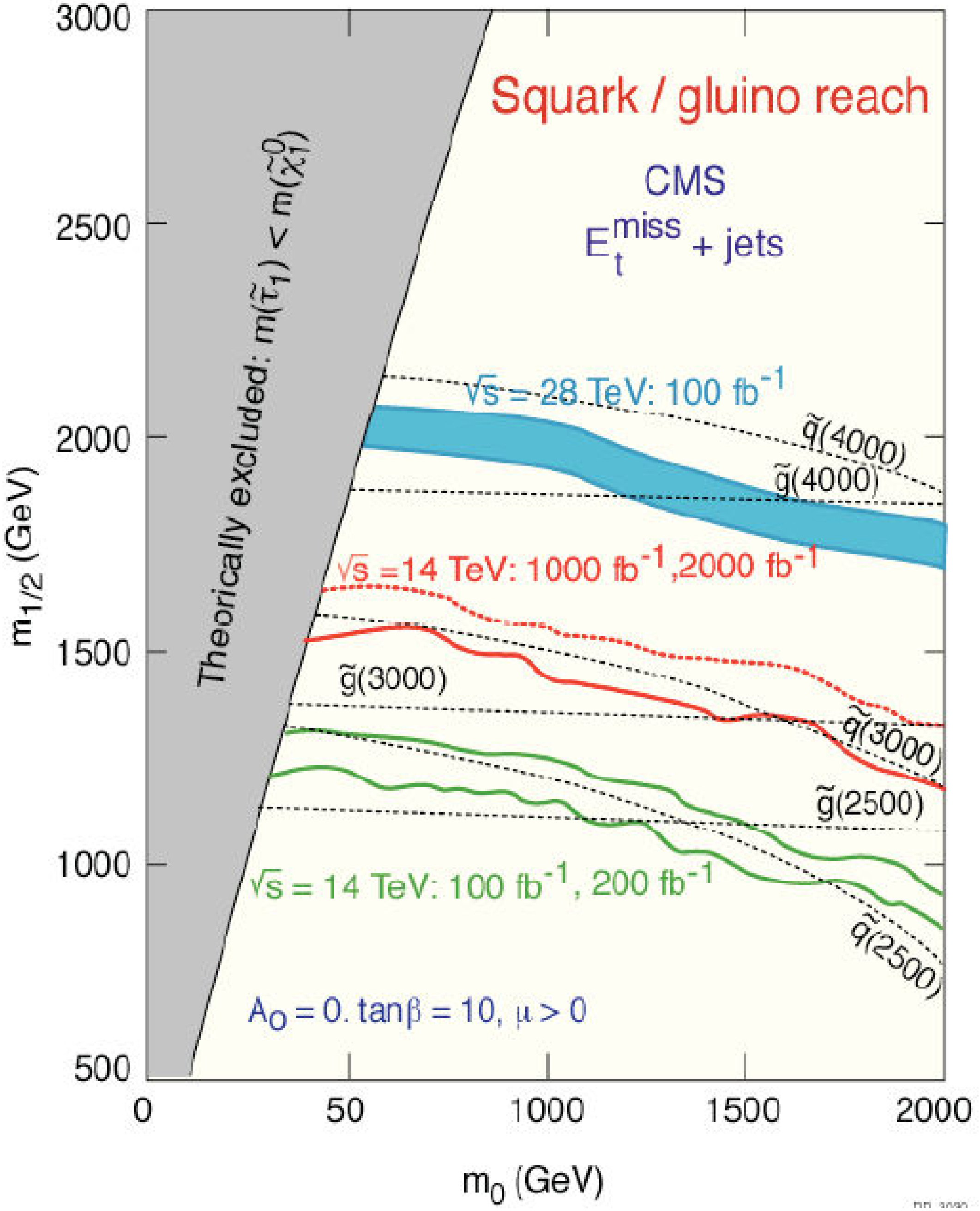
MSSM Higgs (h, H, A, H^{+-})?



Over part of the parameter space the LHC should be able to discover two or more SUSY Higgs bosons

The sLHC should extend significantly the region over which only the lightest Higgs boson h can be observed

SUSY mass reach !



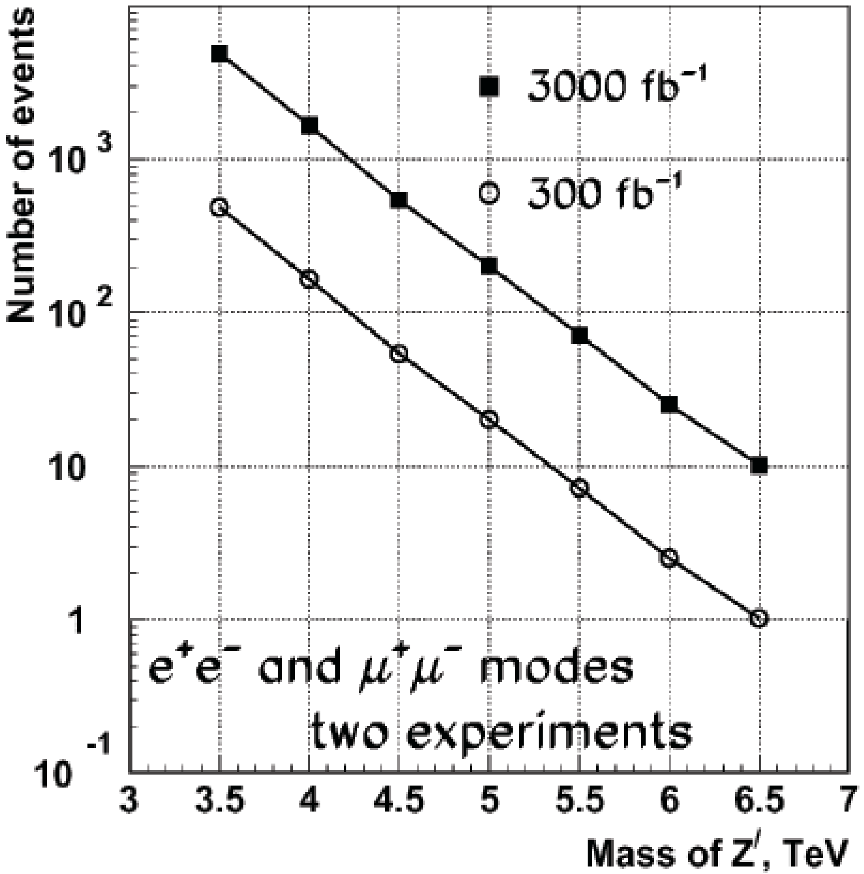
The mass sensitivity grows logarithmically with the statistics

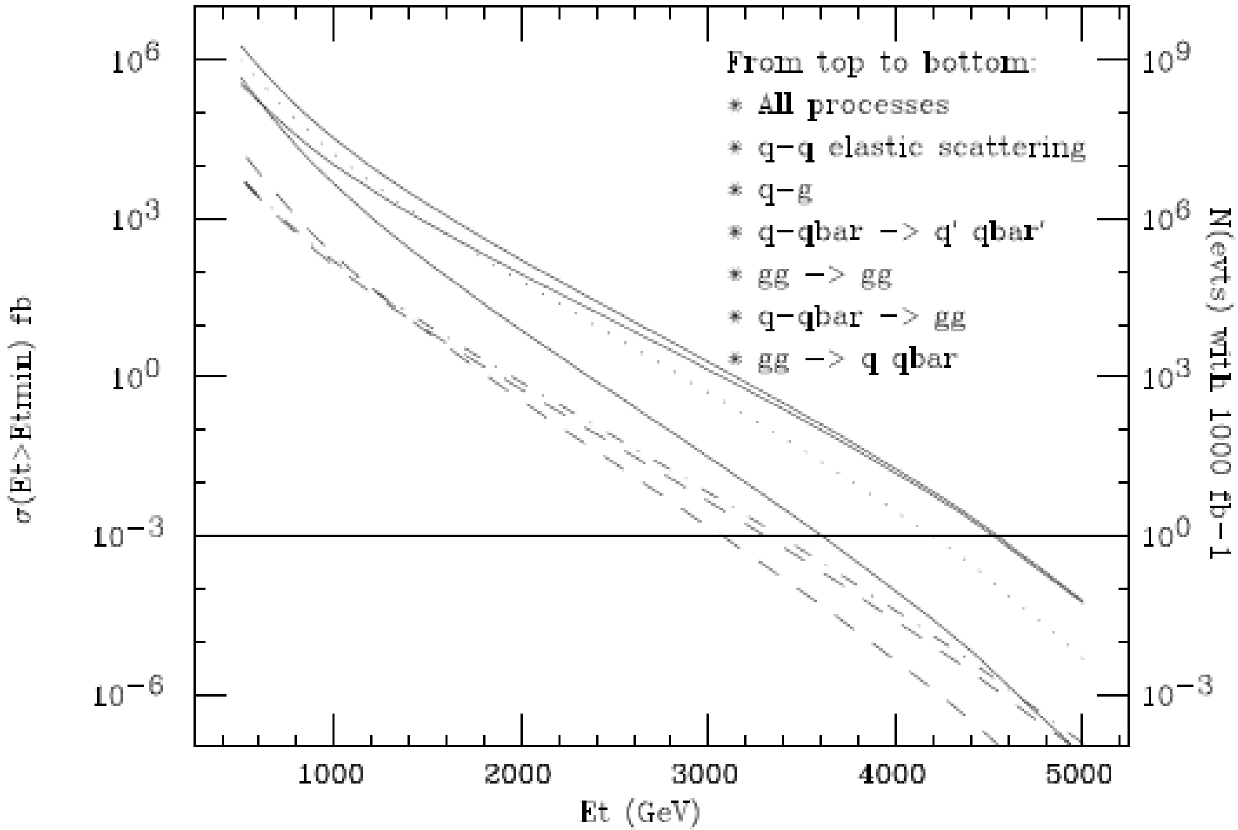
A factor 10 in Luminosity -> 500 GeV

This will increase the mass reach around 3.0-3.3 TeV at sLHC

M reach ~ 500 GeV more than LHC

New forces (Z′, W′) ? , Compositeness ?



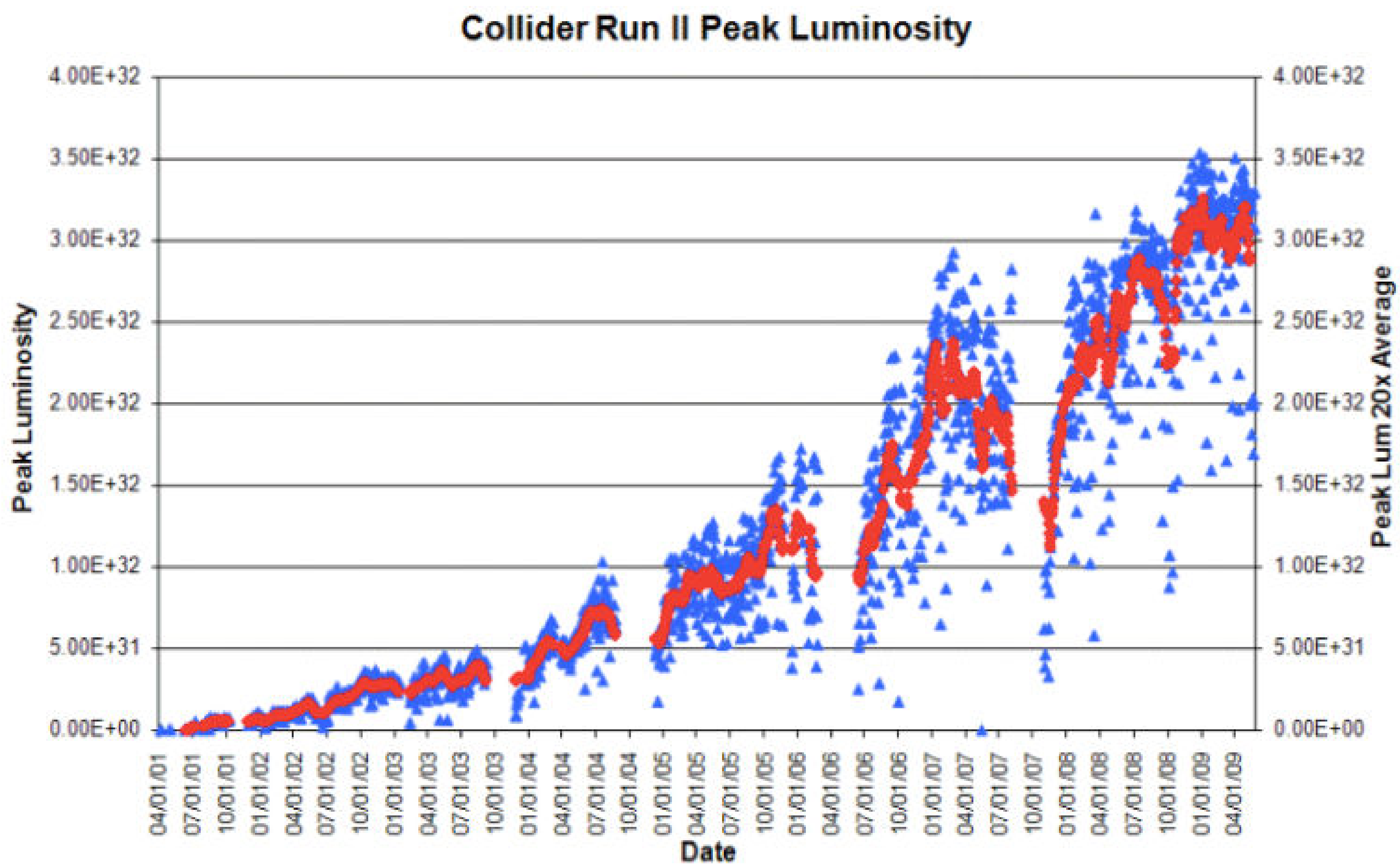


The mass reach can be pushed by ~ 1.1TeV to 6.5 TeV

$\Lambda >$ 40 TeV limit at LHC

$\Lambda >$ 60 TeV limit at sLHC

Lesson from the Tevatron



The lesson from the Tevatron is that once data are available, the experimental ingenuity can deliver the "impossible" (M.Mangano)