ALICE status and early physics prospects

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The 9th ICFA seminar

Stanford Linear Accelerator Center

October 28-31, 2008

The ALICE Collaboration

1187 **Members**

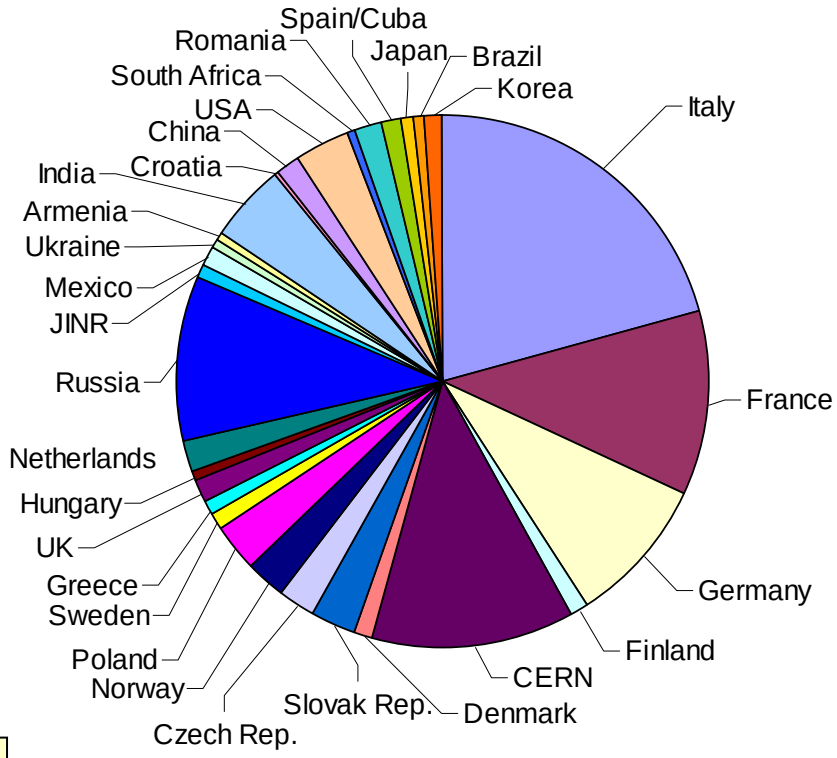
(63% from CERN MS)

109 **Institutes**

31 **Countries**

140 MCHF Investment cost

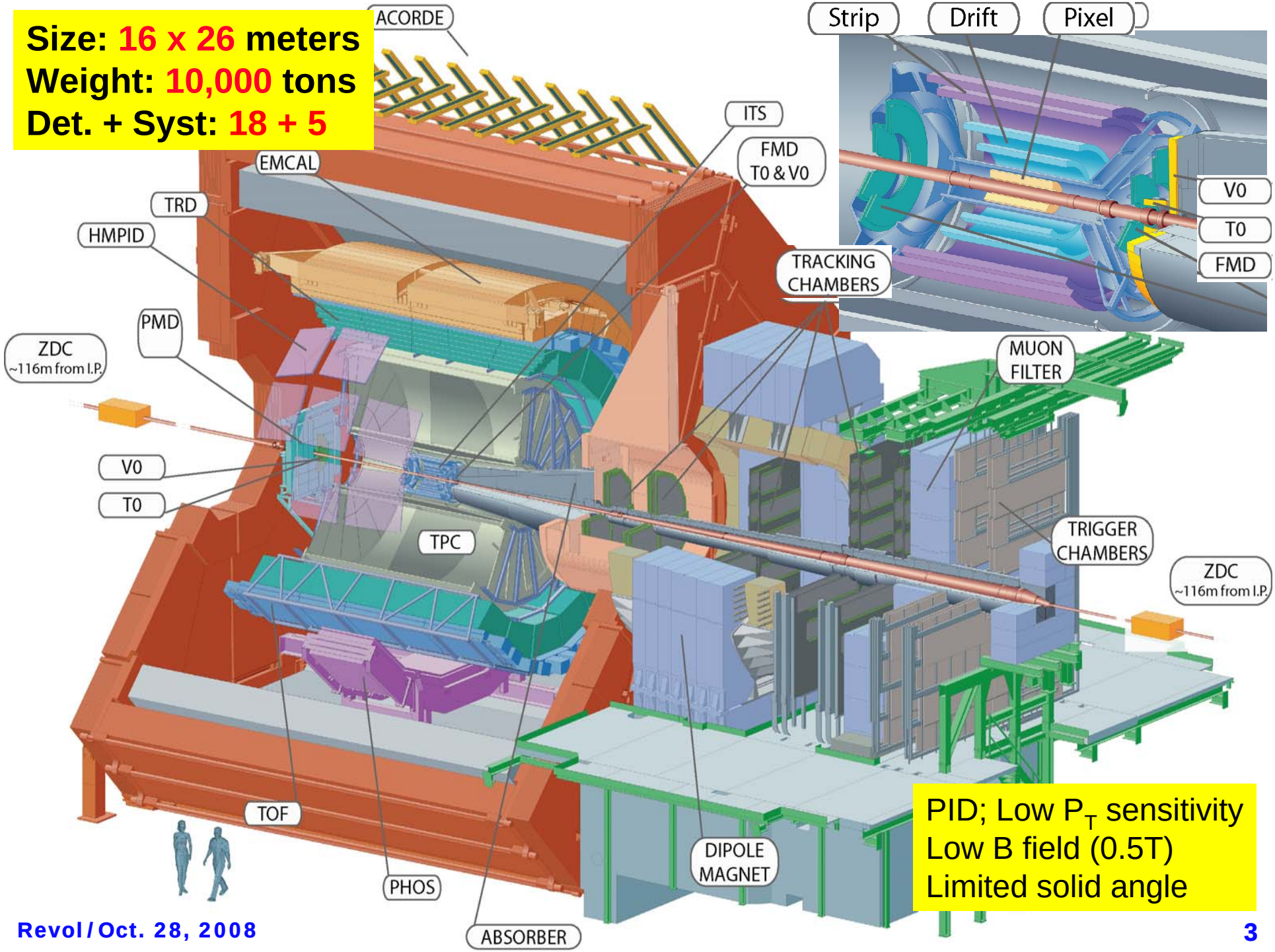
(+ 'free' L3 magnet & cavern)



A brief history of ALICE

1990-1996: Design
1992-2002: R&D
2000-2010: Construction
2002-2007: Installation
2008 - : Commissioning

Size: 16 x 26 meters
Weight: 10,000 tons
Det. + Syst: 18 + 5



PID; Low P_T sensitivity
Low B field (0.5T)
Limited solid angle

ALICE detector installation – mid 2008

Completed:

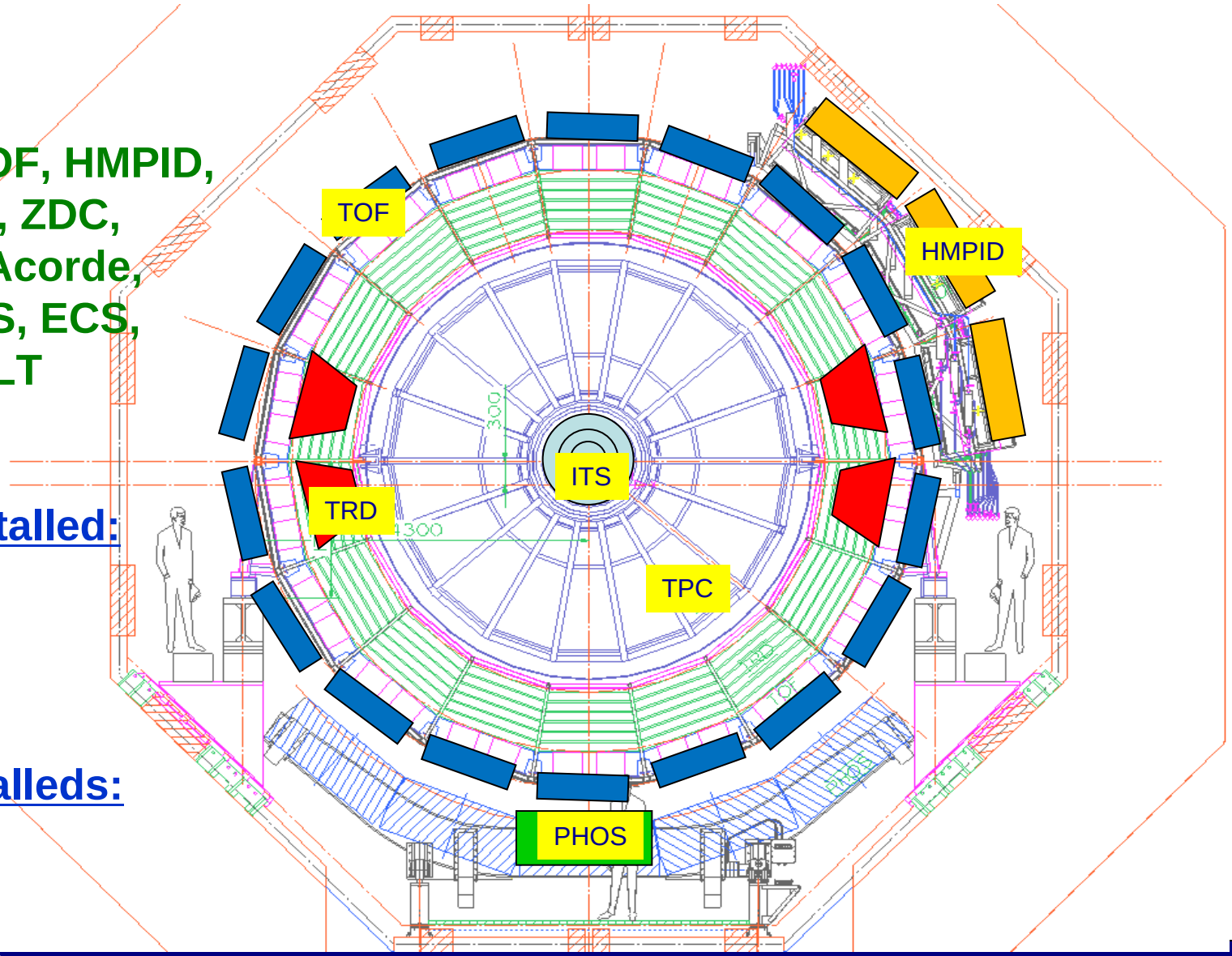
ITS, TPC, TOF, HMPID, FMD, T0, V0, ZDC, Muon arm, Acorde, Trigger, DCS, ECS, 40% DAQ/HLT

Partially installed:

1/5 PHOS
4/18 TRD
9/48 PMD

Not yet installeds:

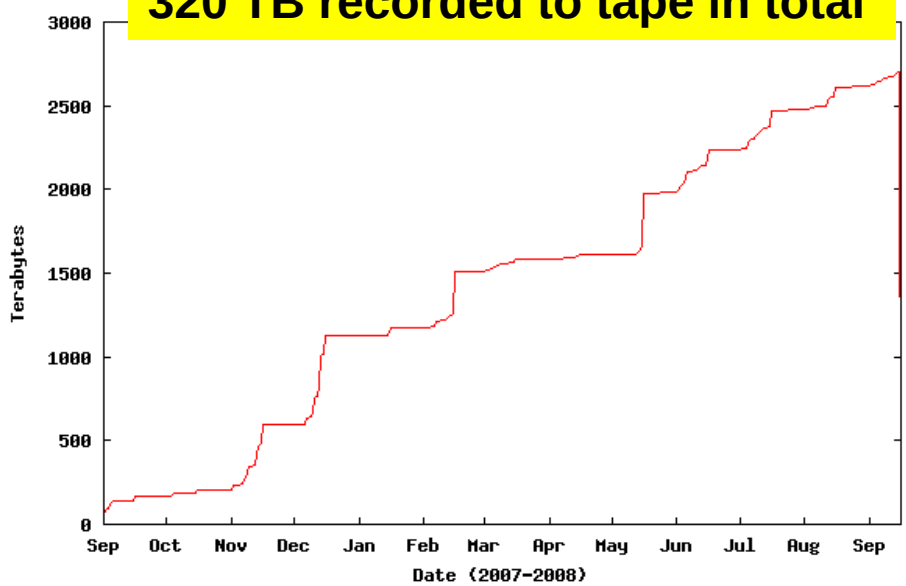
0/6 EMCAL

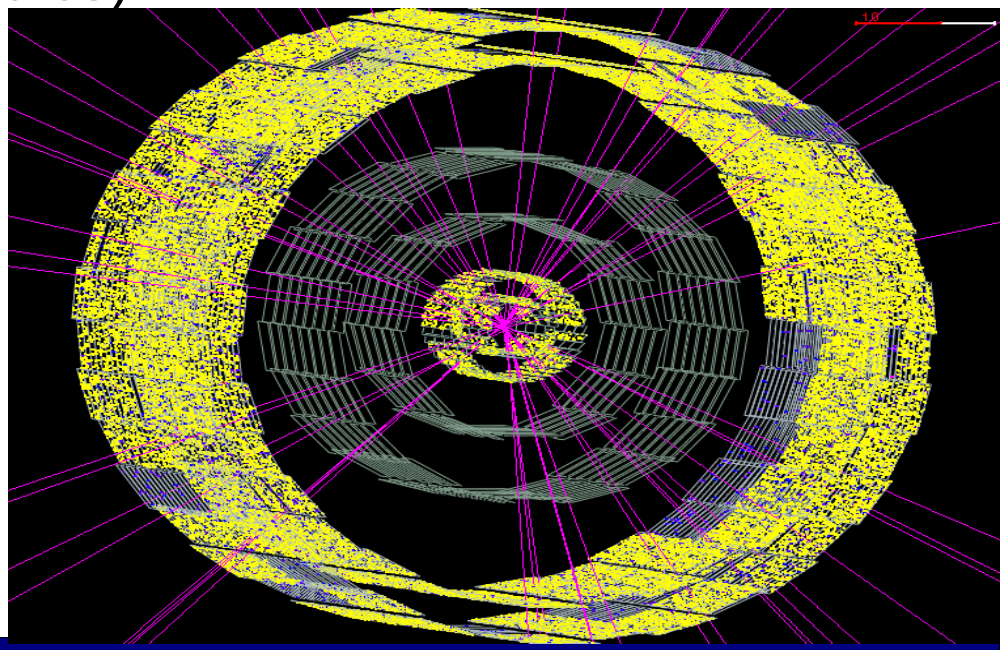


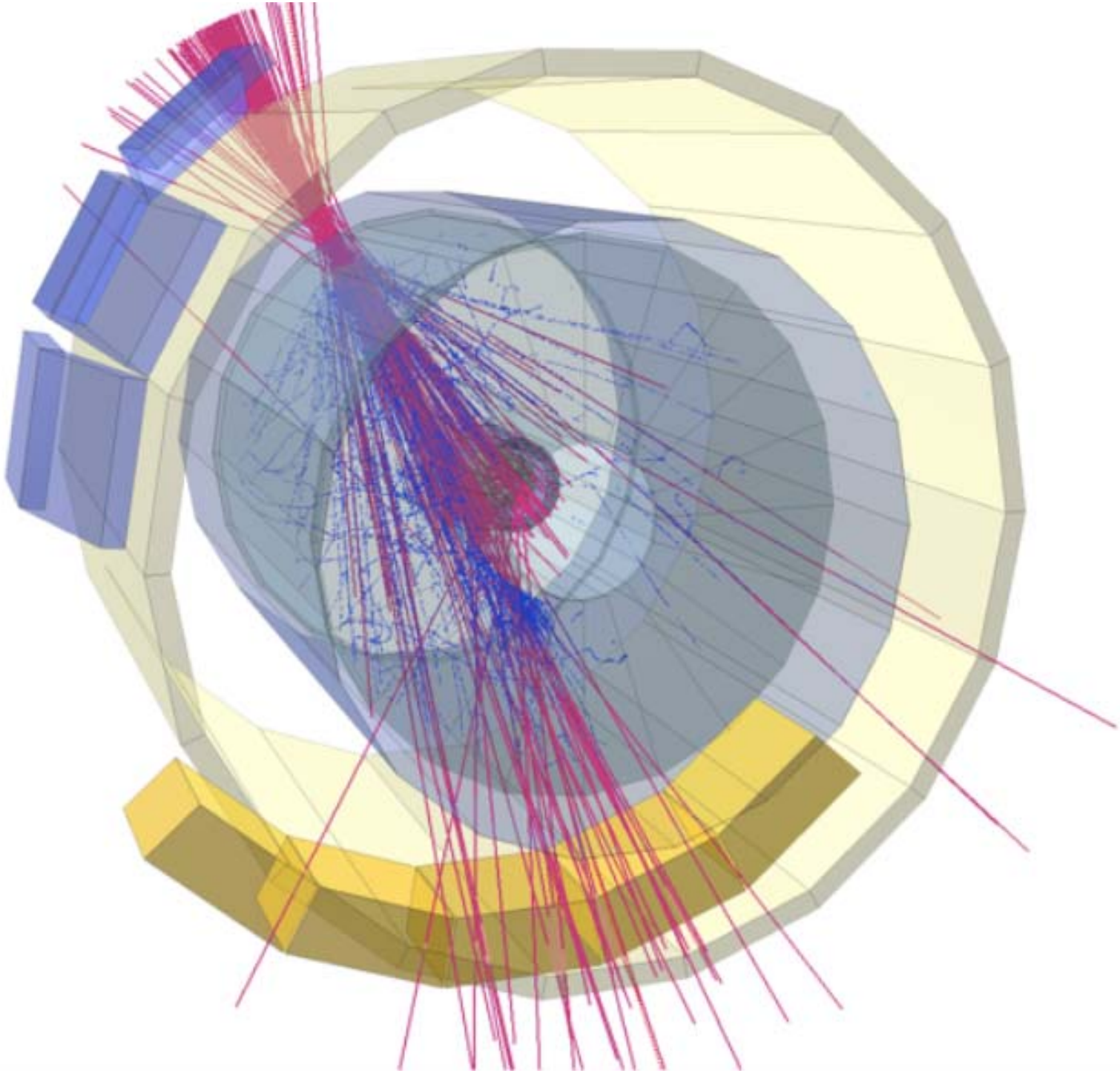
Commissioning

- **DAQ integration** tests and **cosmic muon runs** in December 2007 (2 weeks) and Feb./Mar 2008 (3 weeks); **continuous running from May 2008 to October 12**:
  - 5 million muons in TPC (ACORDE trigger); 50000 pixel triggers
- First LHC activity – injection tests:
  - June: TI2 dump, August: TED (very high particle fluxes, 10 to 1000 particles/cm^2, September 10: first circulating beams, (timing and background studies)

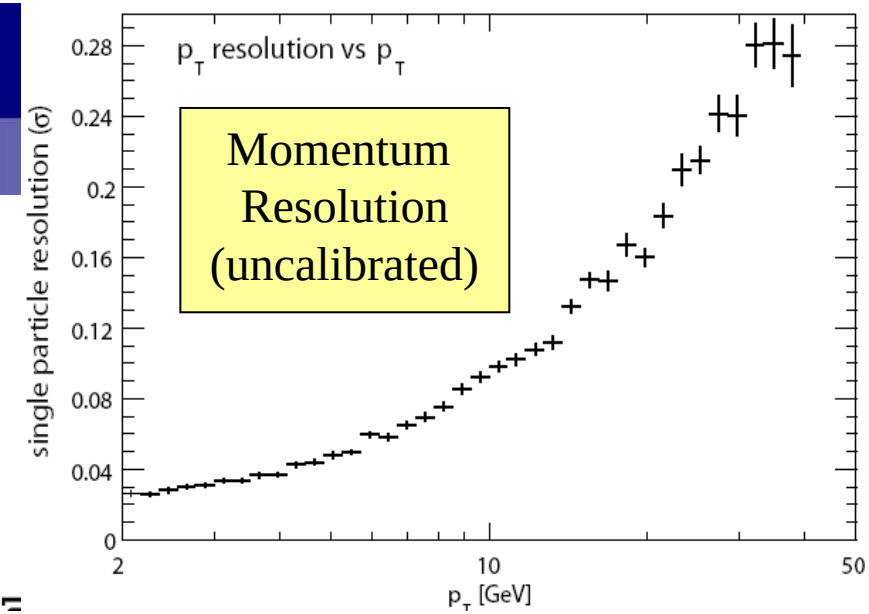
320 TB recorded to tape in total

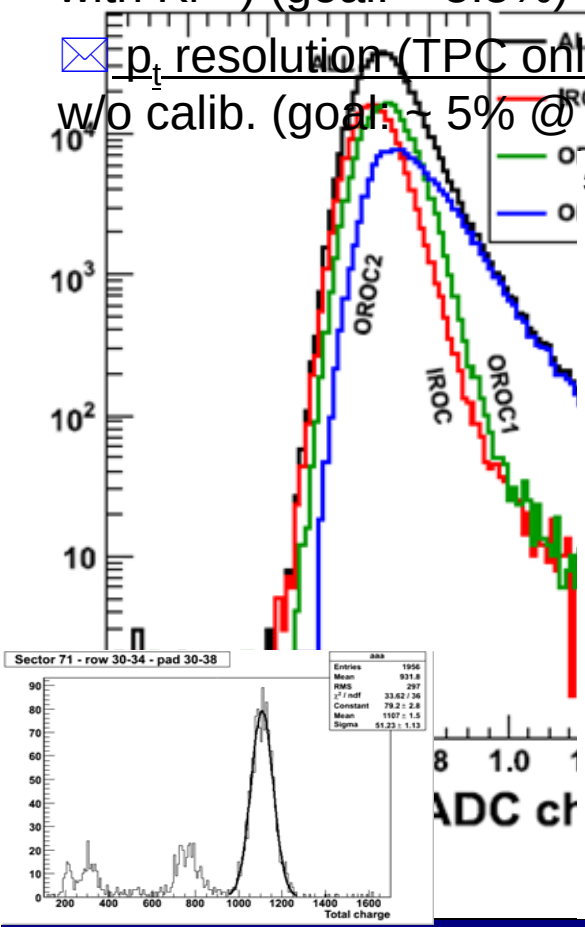


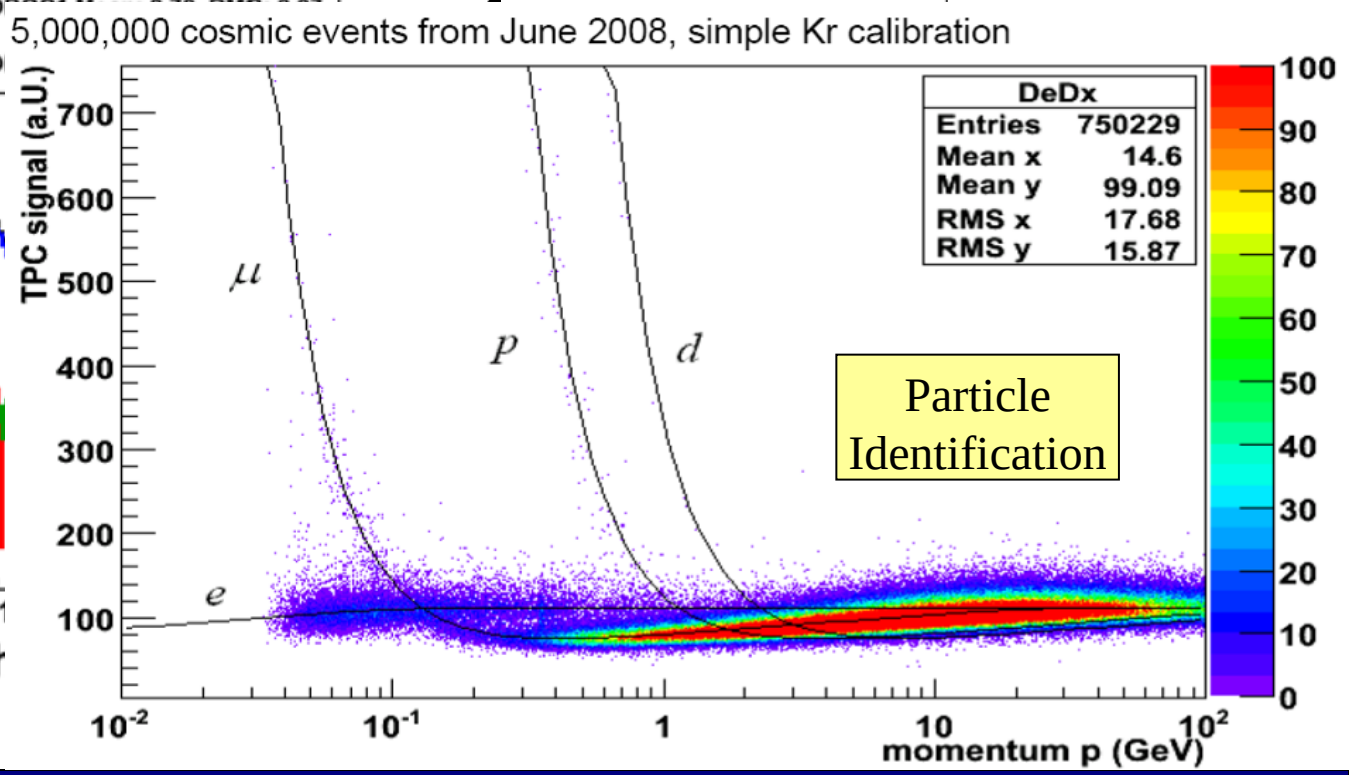




- First performance results at Point 2:
  - excellent noise performance (σ ~ 800 e)
  - dE/dx resolution ≤ 6% (gain calibration with Kr^{83}) (goal: ~ 5.5%)
  - p_t resolution (TPC only) ≤ 10% @ 10 GeV w/o calib. (goal: ~ 5% @ 10 GeV)





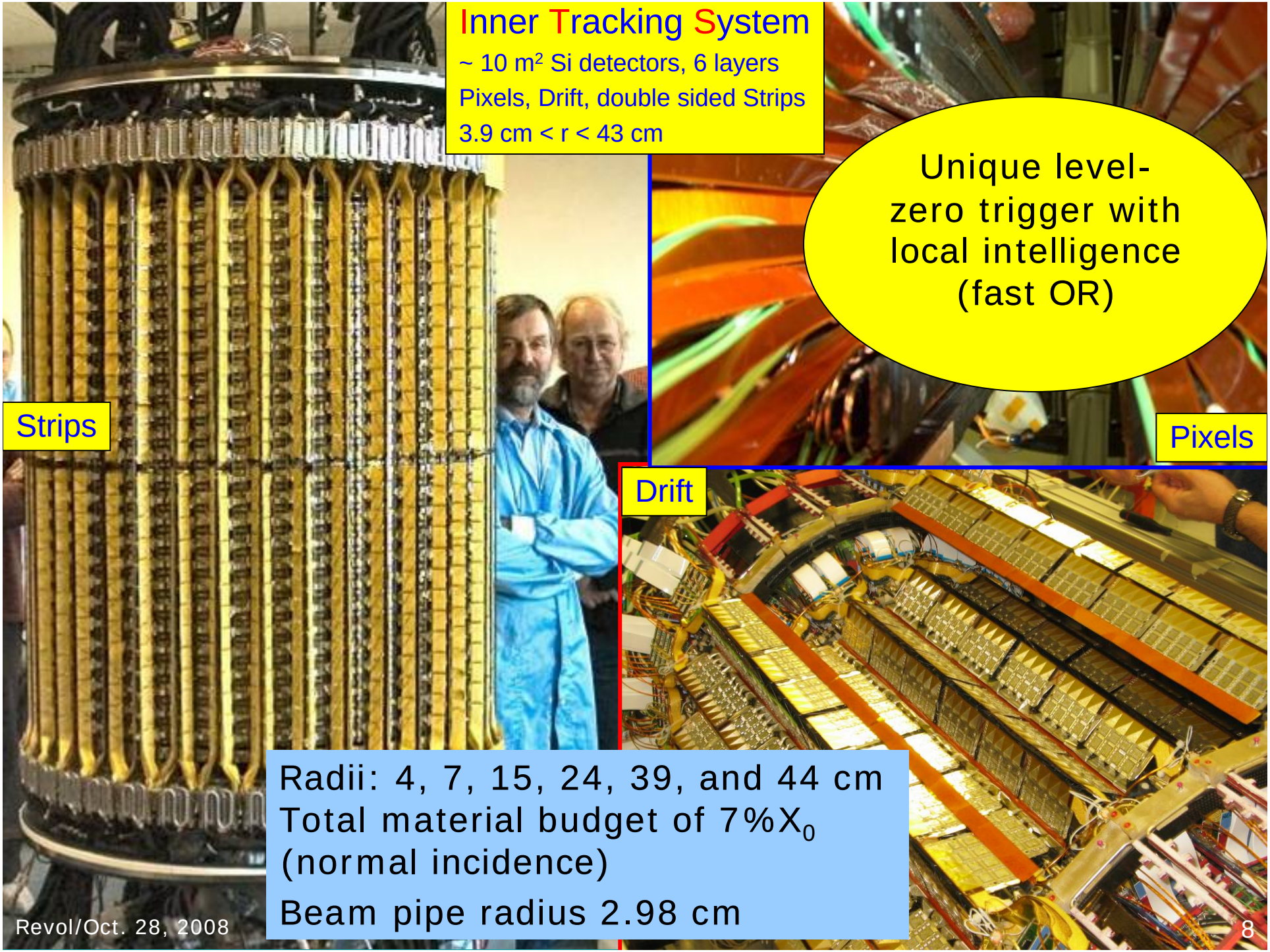


Inner Tracking System

~ 10 m² Si detectors, 6 layers

Pixels, Drift, double sided Strips

3.9 cm < r < 43 cm



Unique level-zero trigger with local intelligence (fast OR)

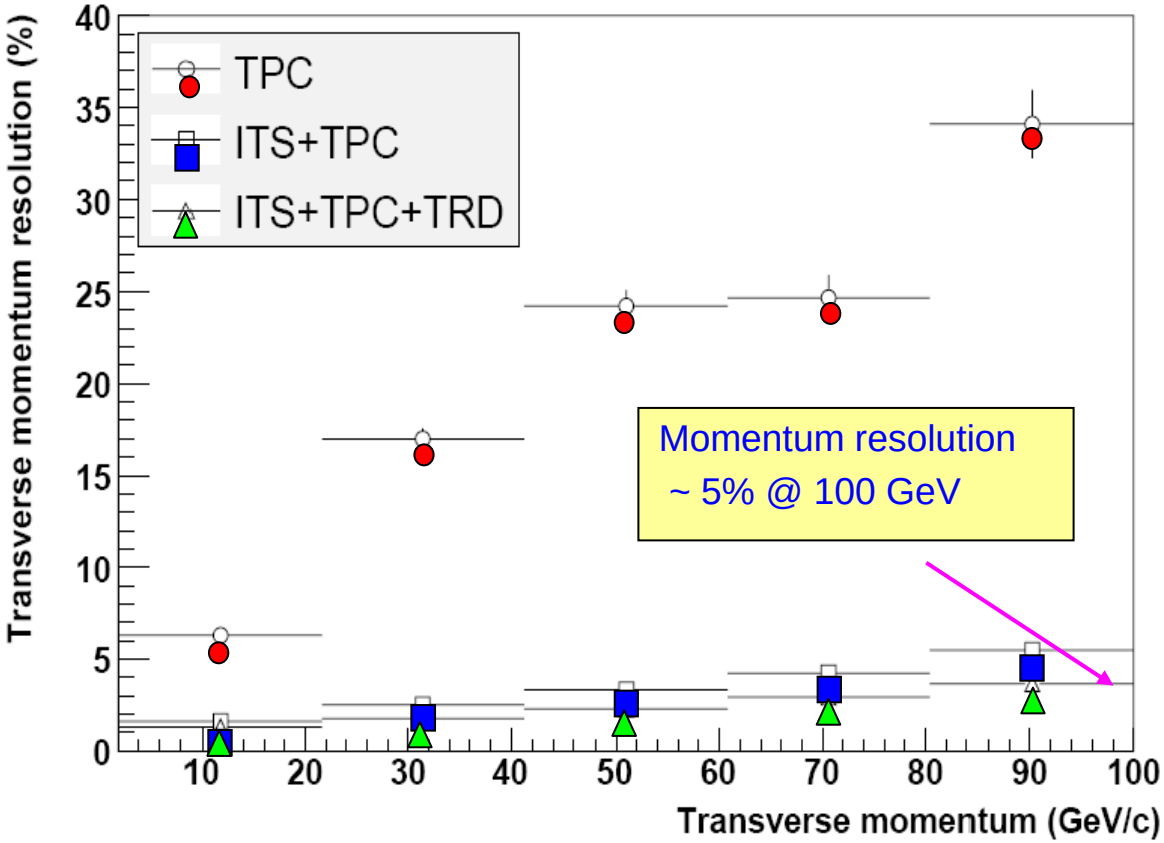
Radii: 4, 7, 15, 24, 39, and 44 cm

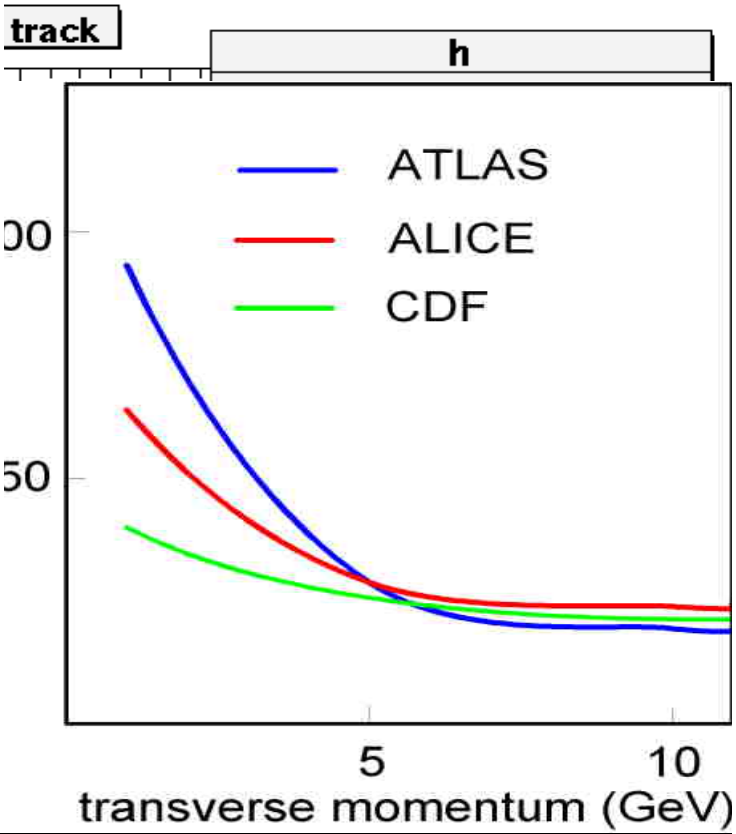
Total material budget of 7%X_0 (normal incidence)

Beam pipe radius 2.98 cm

Inner Tracking System upgrade

- ITS contributing to robust tracking from 30 MeV to 100 GeV
  - Low soleniodal field (0.2-0.5 T)
  - Small material budget: ~ 10% X_0 from vertex to end of TPC (r = 2.6 m
  - Long lever arm (BL^2: Alice ~ CMS > Atlas!)



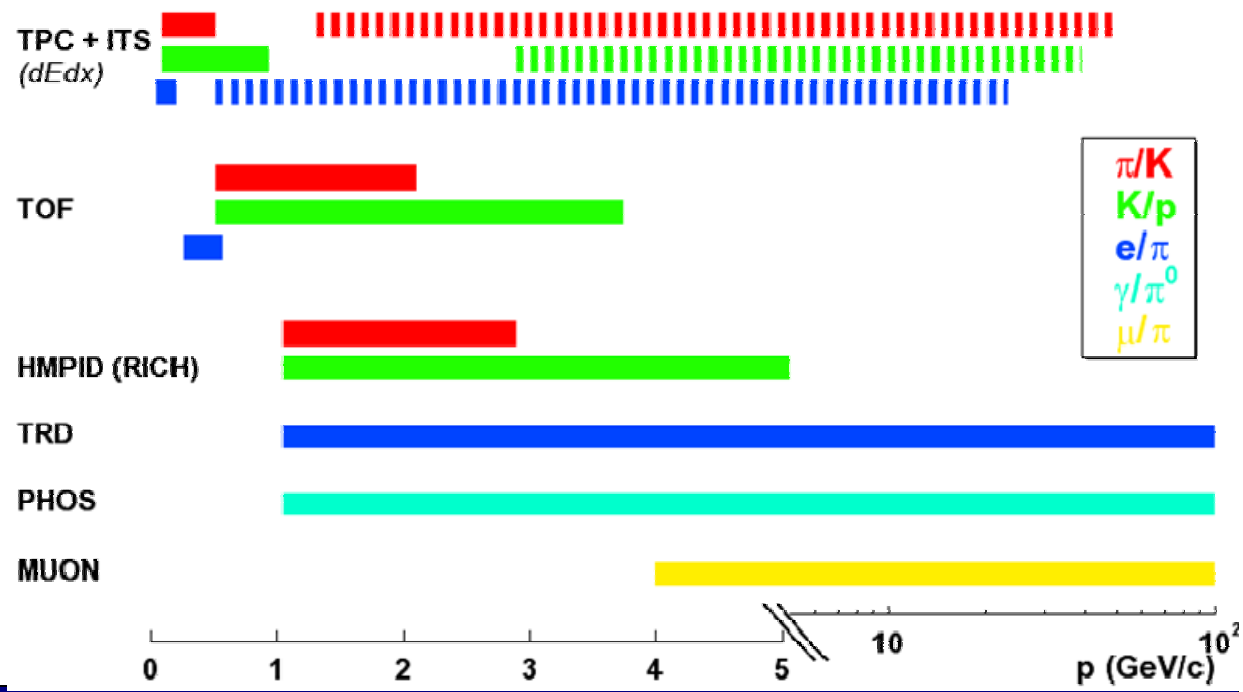


Particle IDentification

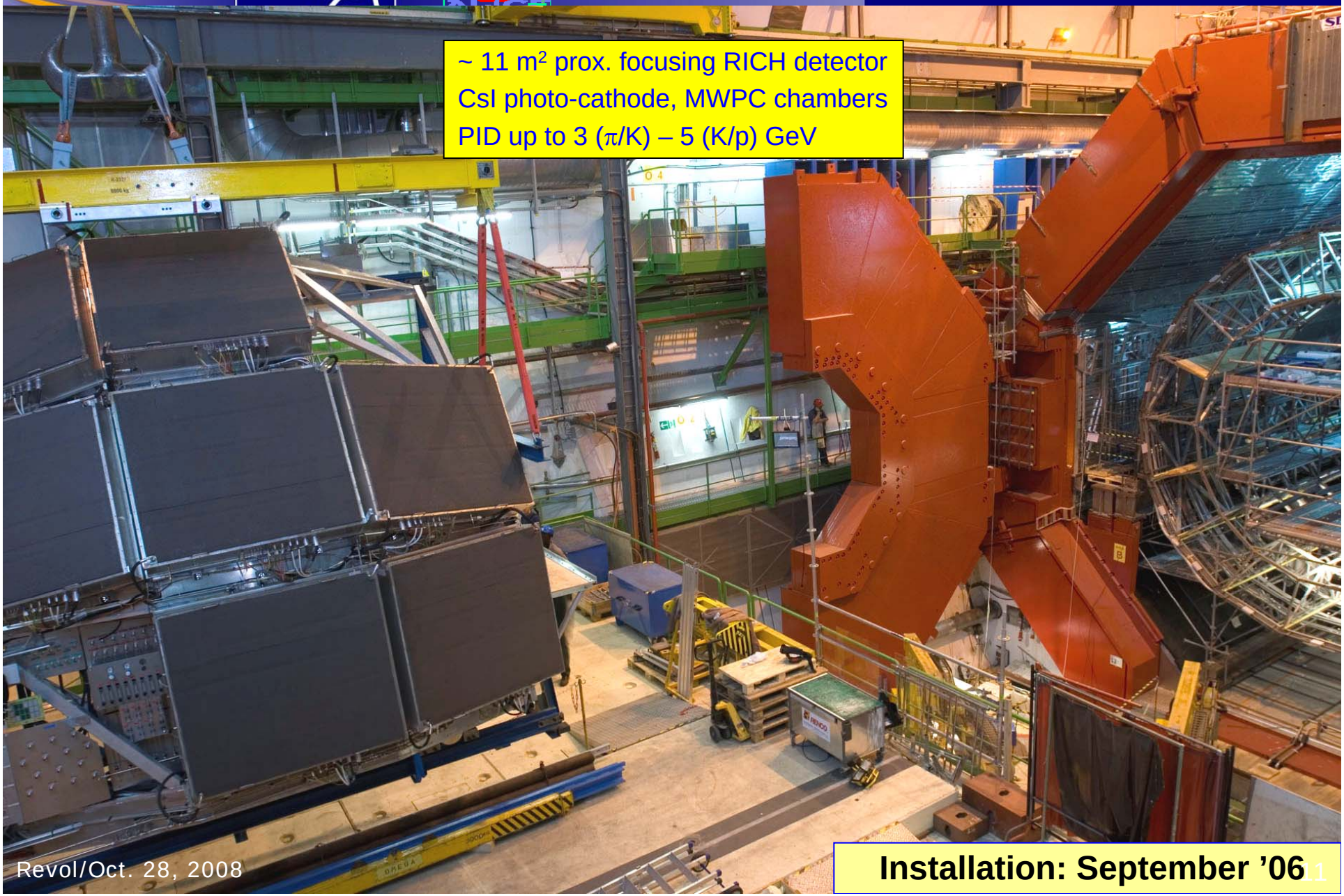
- **Stable hadrons** (π, K, p):
  - dE/dx in silicon (ITS) and gas (TPC) + Time-of-Flight (TOF) + Cerenkov (HMPID)
- **Leptons** (e, μ)
  - transition radiation (TRD), muon spectrometer
- **Photons,** η, π^0
  - e.m calorimeters (PHOS, EMCAL)
- **Decay topology** (K^0, K^+, K^-, Λ, D^+, ..), secondary vertices (c,b)

PID
from ~ 100 MeV
to above 50 GeV

Alice uses ~ all known techniques!



High Momentum PID



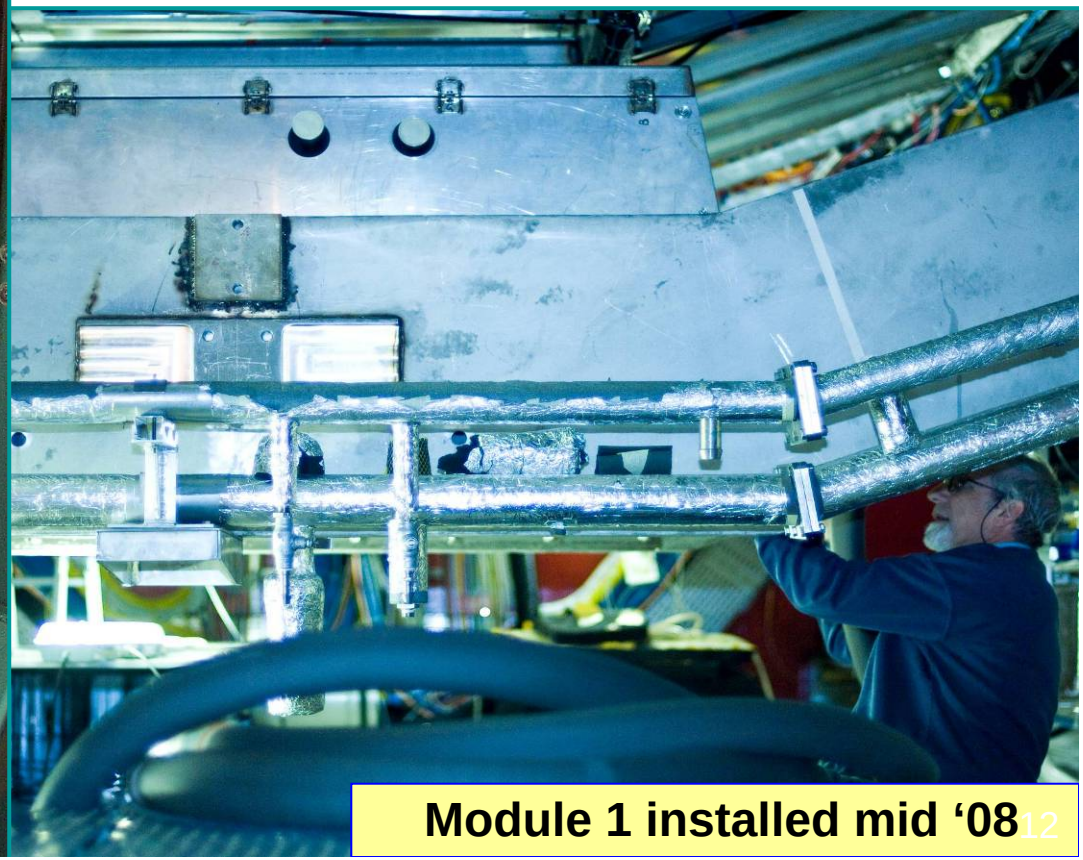
~ 11 m^2 prox. focusing RICH detector
CsI photo-cathode, MWPC chambers
PID up to 3 (π/K) – 5 (K/p) GeV

Installation: September '06

PHOton Spectrometer

- Status: 3/5 constructed
  - 2 more modules to be constructed
    - funding stretched to 2010
  - **only 1 installed & commissioned**

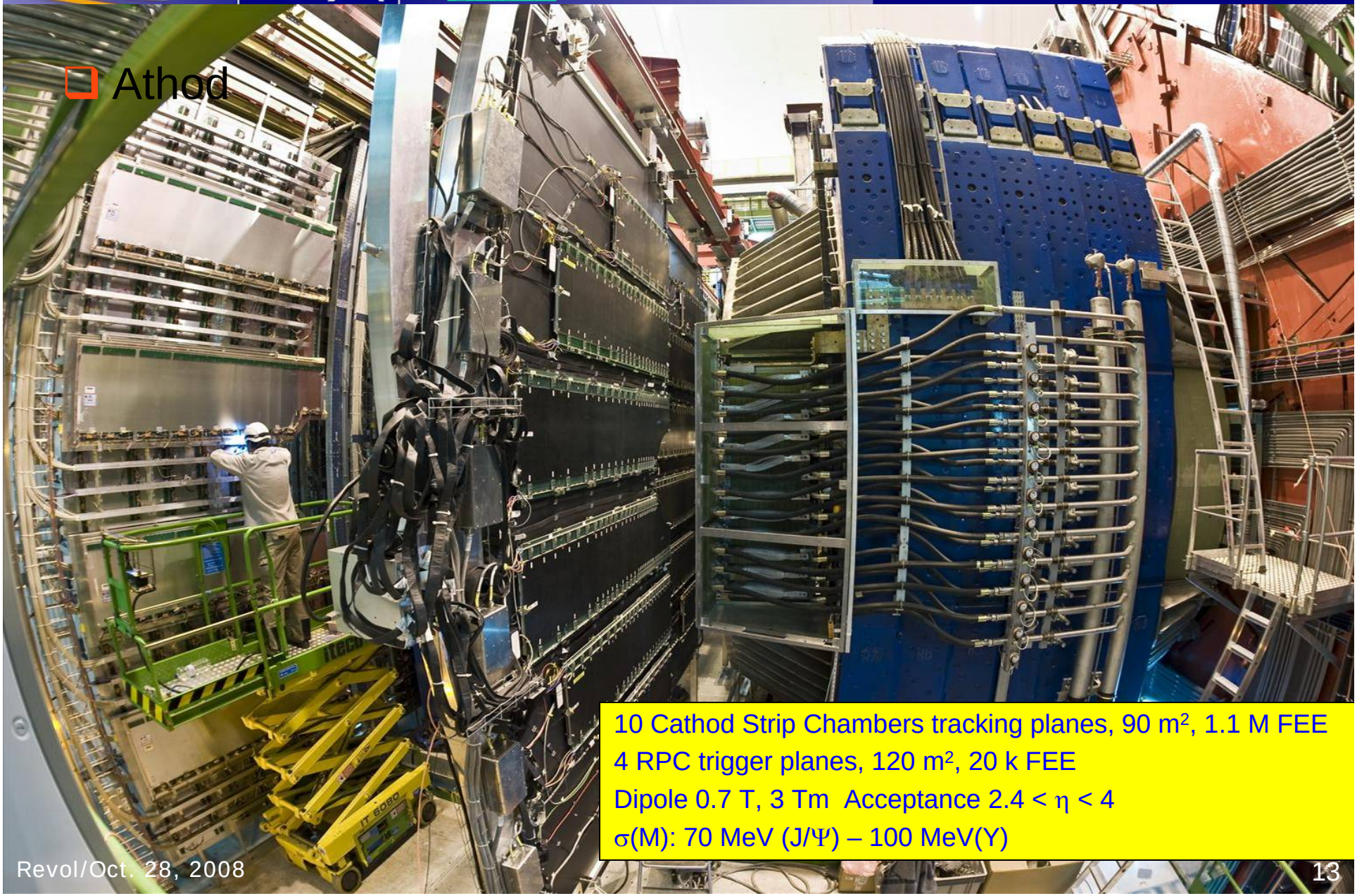
~ 8 m^2 $PbW0_4$ crystals, r ~ 5m
18 k channels, $20X_0$ APD R/O
high resolution & granularity



Module 1 installed mid '08

Muon Spectrometer

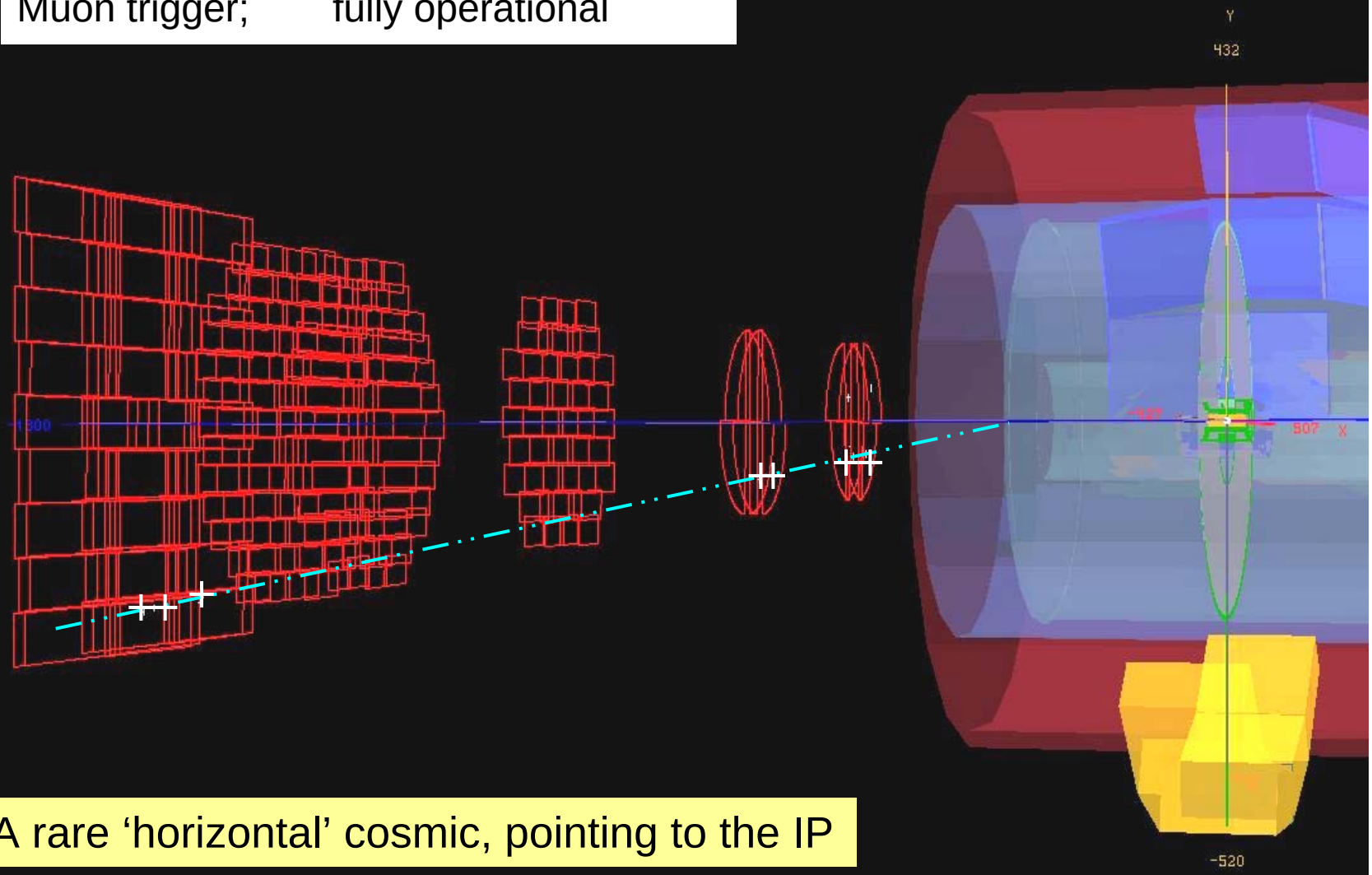
- Athod



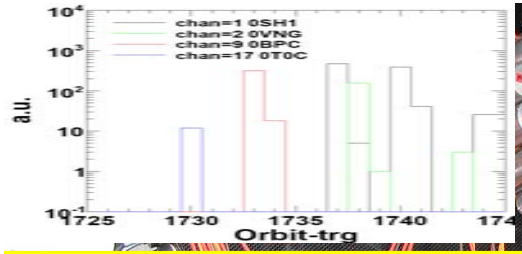
10 Cathod Strip Chambers tracking planes, 90 m^2, 1.1 M FEE
4 RPC trigger planes, 120 m^2, 20 k FEE
Dipole 0.7 T, 3 Tm Acceptance $2.4 < \eta < 4$
σ(M): 70 MeV (J/Ψ) – 100 MeV(Y)

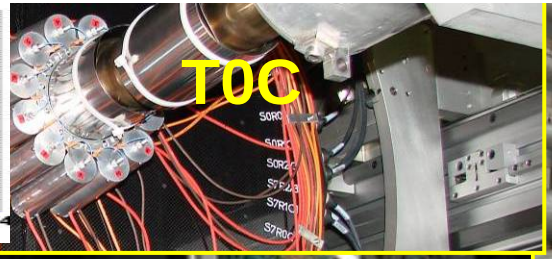
Muon Arm status

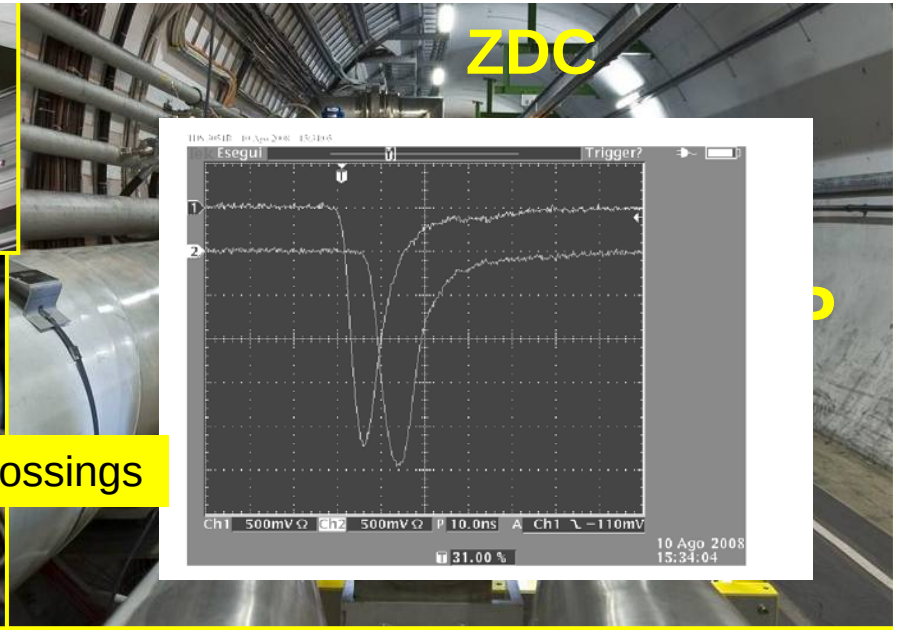
Muon tracking: ~ 70% commissioned
Muon trigger; fully operational

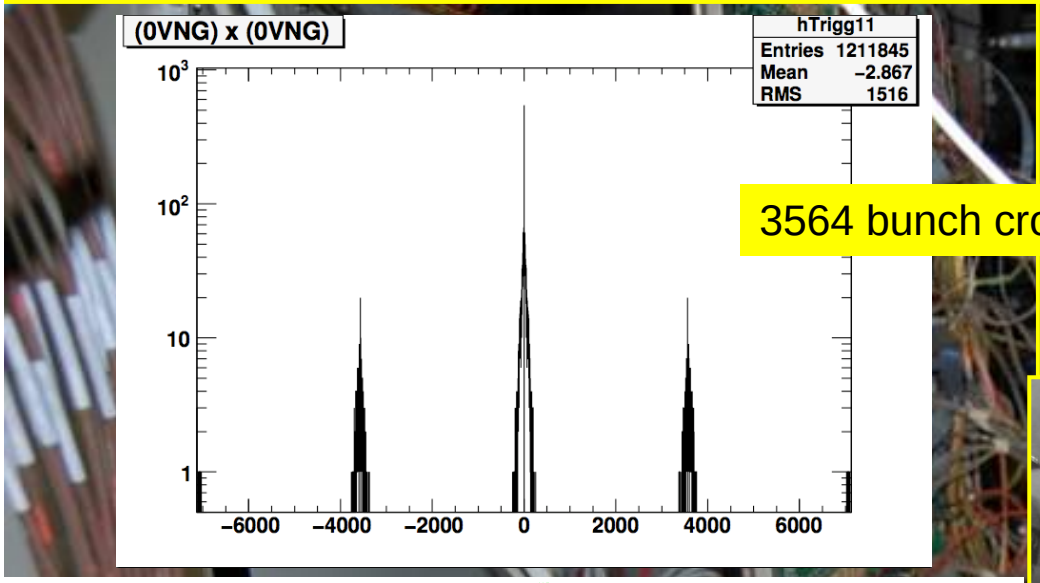


A rare ‘horizontal’ cosmic, pointing to the IP

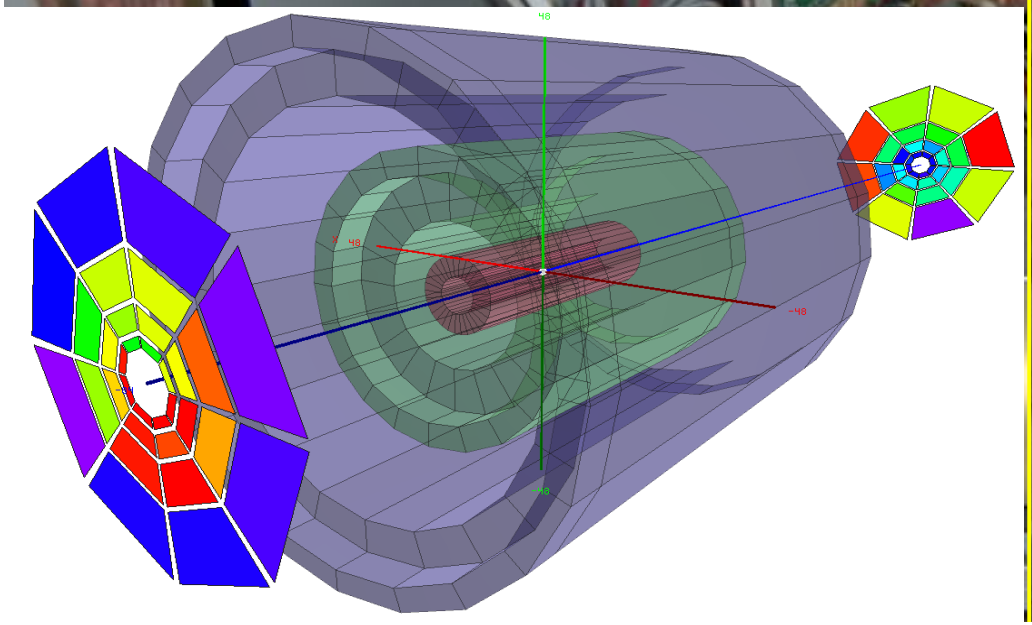


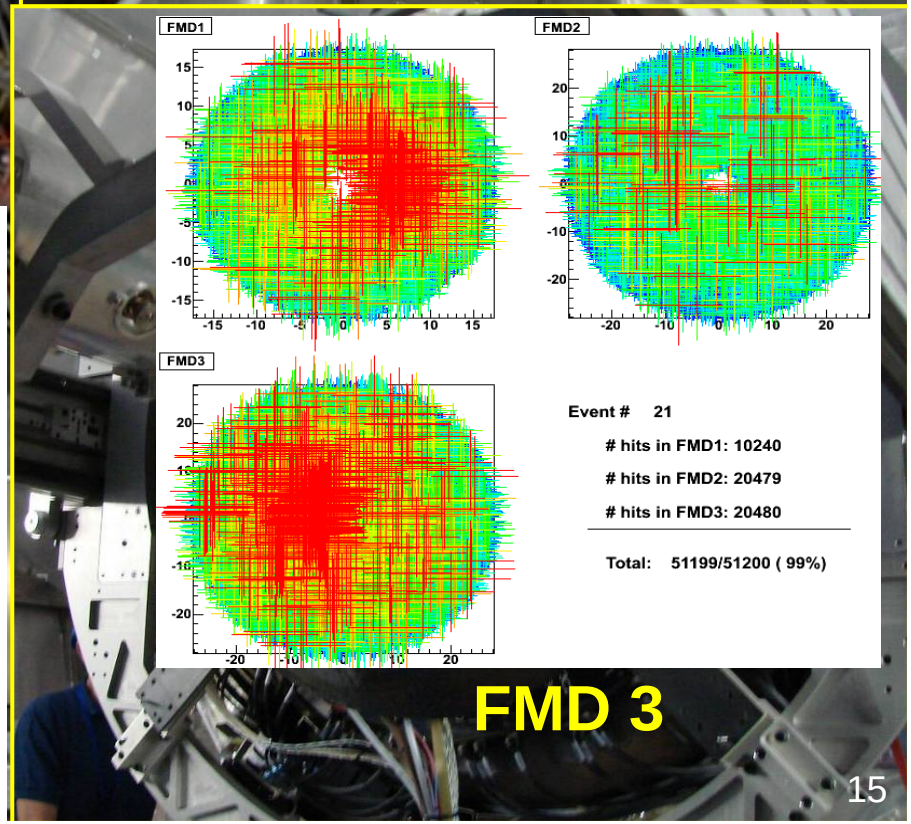






3564 bunch crossings



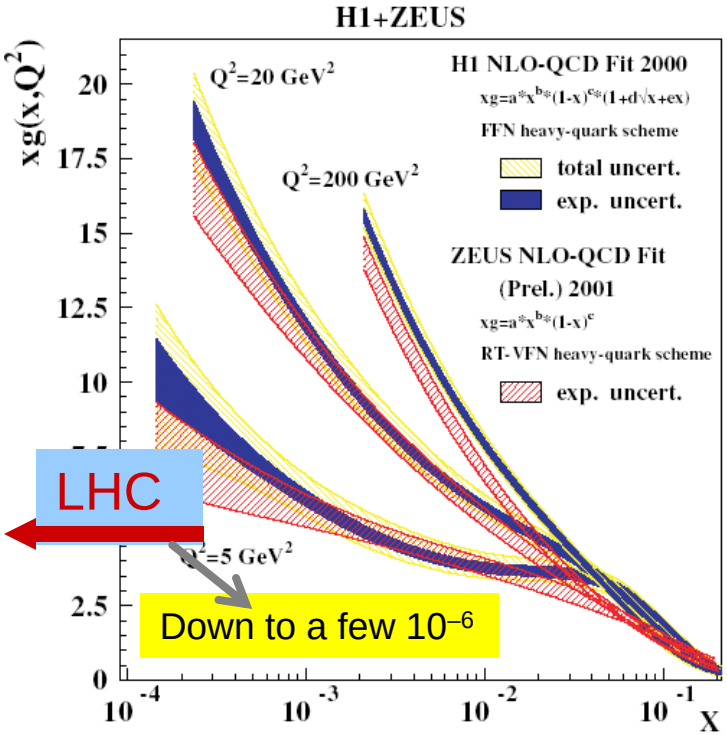


- Use LHC commissioning (low luminosity) to study large cross-section phenomena (strong interaction), non-elastic pp collisions.

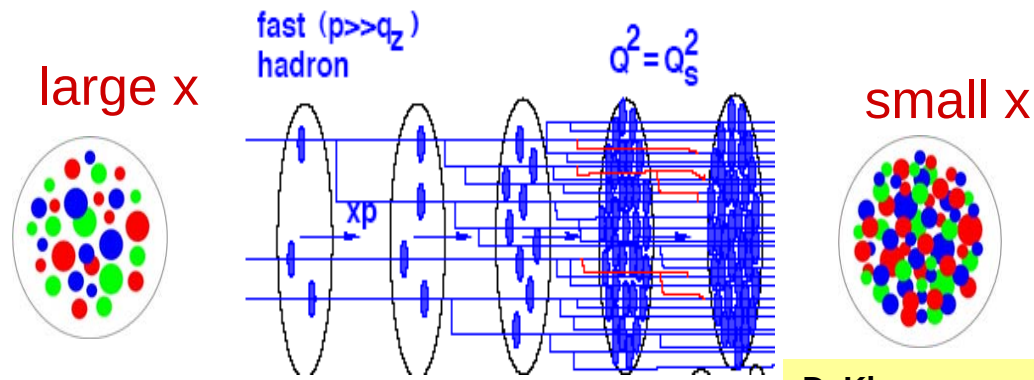
- QCD is an excellent description of the strong interaction at large Q^2, where asymptotic freedom is ideal for perturbative methods to work, but **QCD needs to be also understood** at low Q^2 (soft phenomena), **in the non-perturbative regime**, which dominates low p_T particle production.
  - **LHC should bring non-perturbative phenomena to relatively large Q_s^2** (~ 1 GeV^2), large enough to be studied directly;
  - This expected new regime in proton-proton collisions is of **course very relevant to the understanding of heavy ion collisions** (pp energy densities overlapping with RHIC HI densities).

A new regime in pp collisions at LHC?

- **As lower x (~Q^2/s) values are reached, both parton density and parton transverse size increase**, there must be a scale (at $q^2 < Q_s^2$) where partons overlap. When this happens, the increase in the number of small x partons becomes limited by gluon fusion (gg → g).



$$\left\{ \#\, partons \propto \left(\frac{1}{x}\right)^{c\alpha_s} \right\} \times \left\{ Transverse\, size \propto \frac{1}{x_T} \right\} \approx \sqrt{\sigma_{tot}}$$



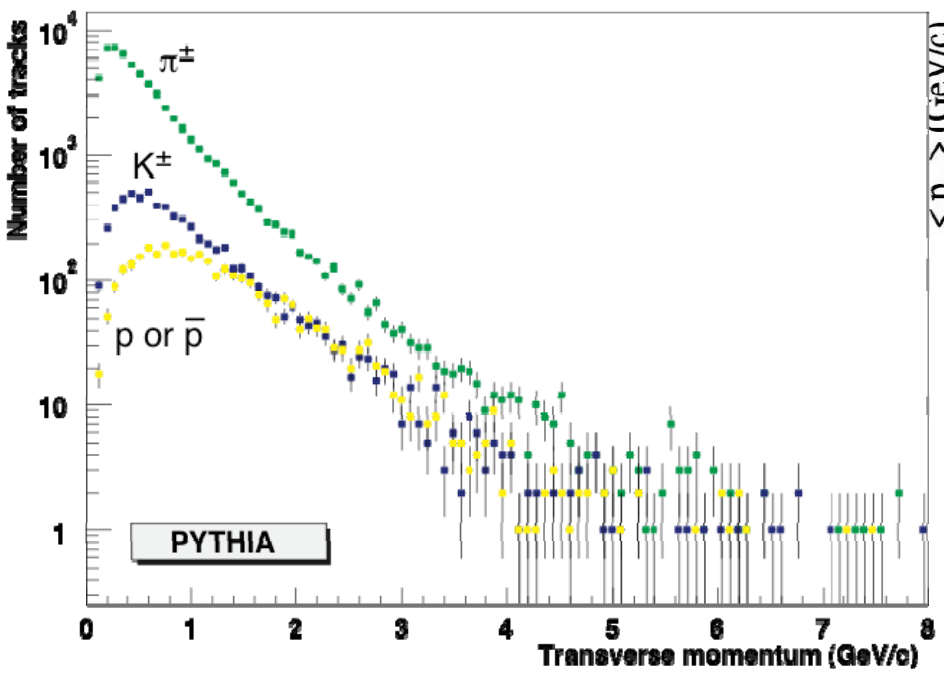
D. Kharzeev, CERN May 2007

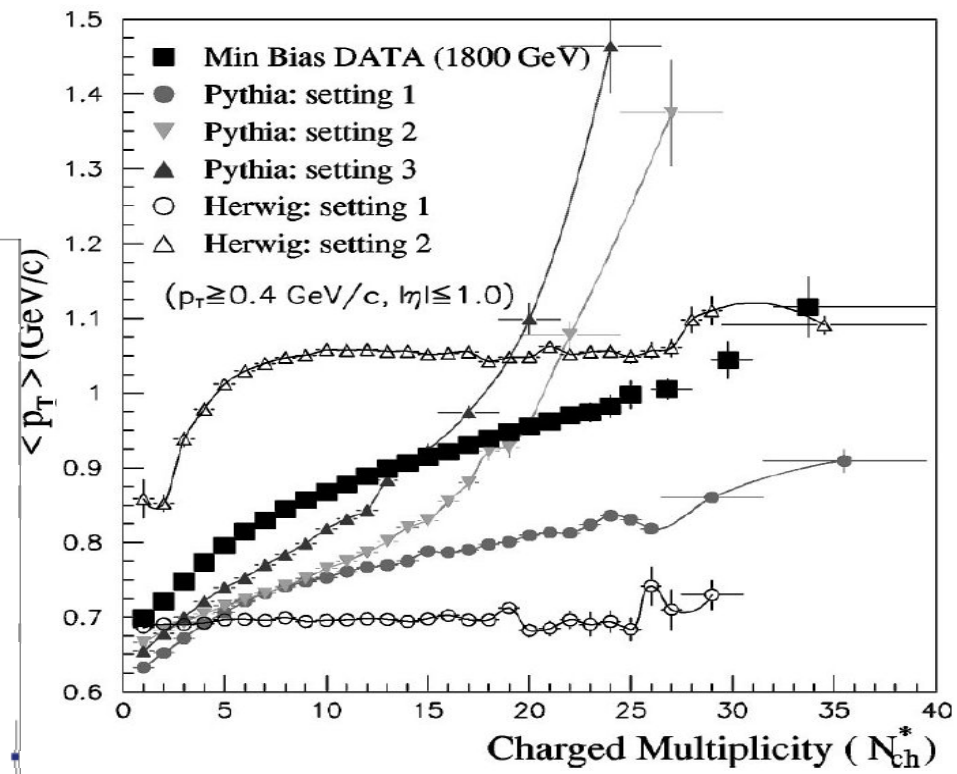
(Kharzeev Q_s^2 ~ 0.7 GeV²), where the effect must be visible

(BRAHMS in Au-Au, forward region: **$Q_s^2 \sim A^{1/3}$**)

Physics with global event properties

- p_T distributions and multiplicities of charged particles, in the low momentum range where the bulk of particle production occurs, **will constitutes the initial ALICE physics, with/without PID. Hopefully more than Monte Carlo tuning**.





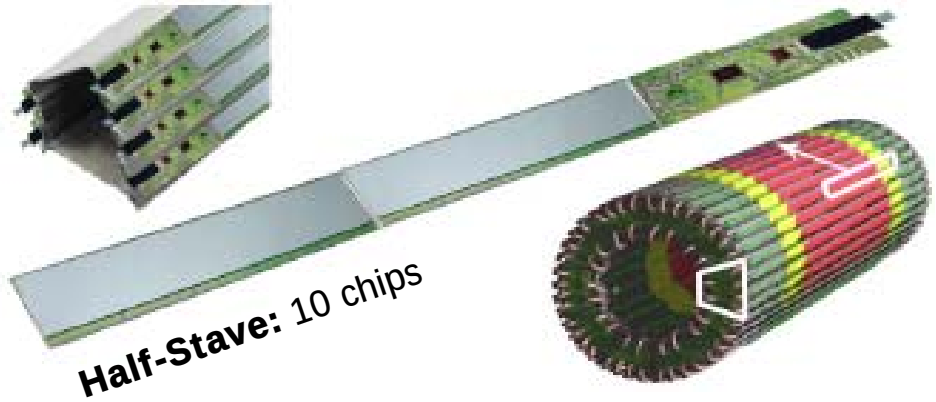
CDF:
Phys. Rev.
D65,72005(2002)

Mean p_T vs multiplicity

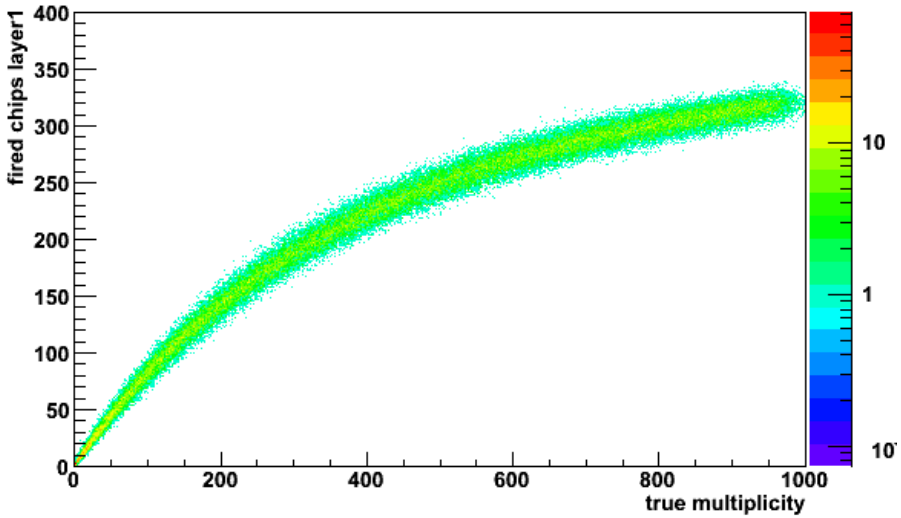
ALICE High Multiplicity Trigger

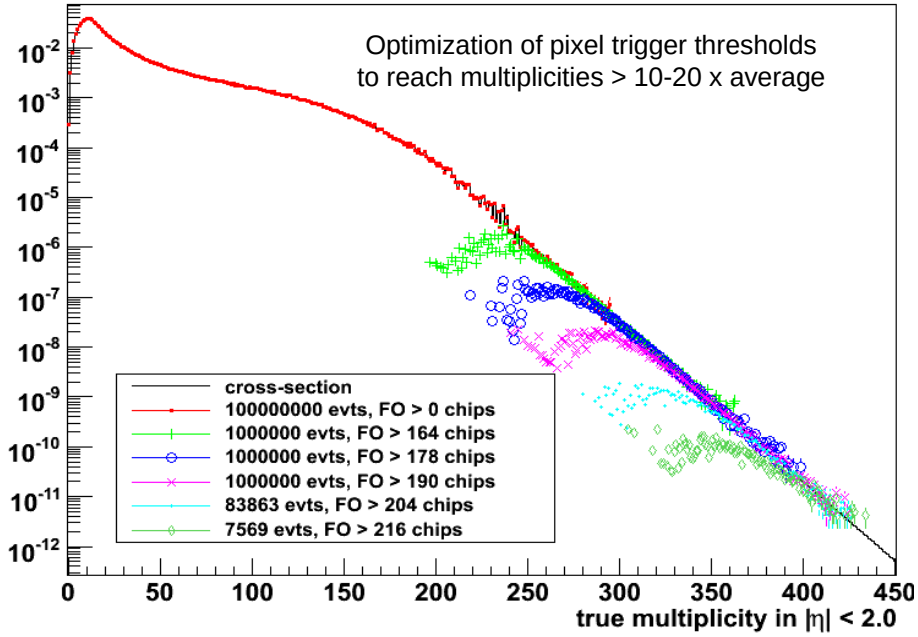
- **S**tudy of the extreme energy densities, where parton overlap is maximum
- **Pixel Fast OR Trigger (level0)**
  - Trigger on number of fired chips (per layer), or more sophisticated, using correlations with FPGAs
- No topology bias in trigger:
  - Topology studies
  - Comparison with Heavy Ions

Sector: 4 (outer) + 2 (inner) staves



SPD: 10 sectors (1200 chips)

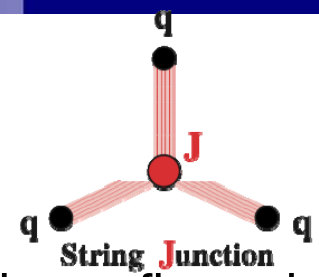


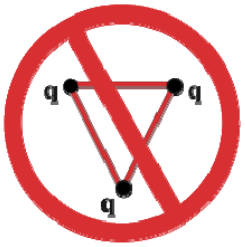


Baryon Transport to the Central Rapidity Region

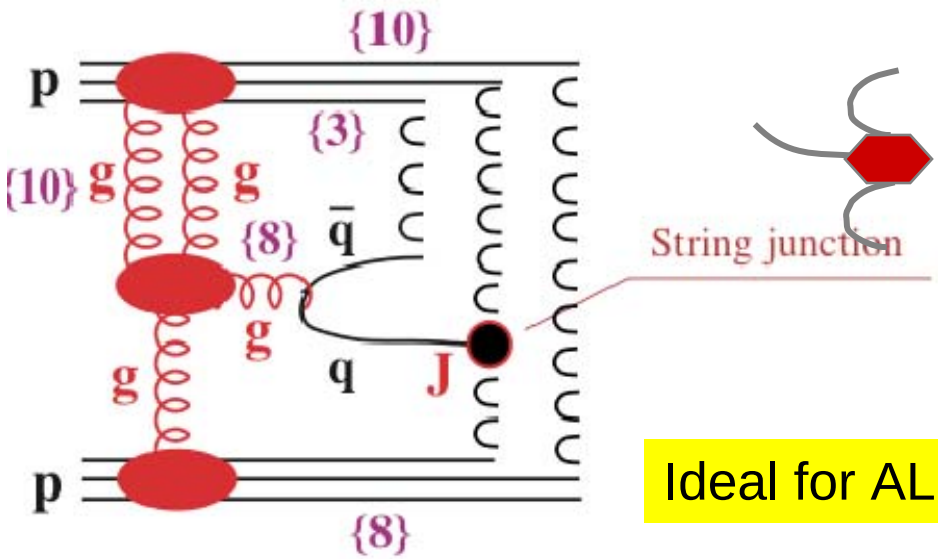
- Can gluons carry baryon number?
  (Rossi, Veneziano String Junction model)

$$\pi^- + p \rightarrow \Omega^- + K^+ + 2K^0$$



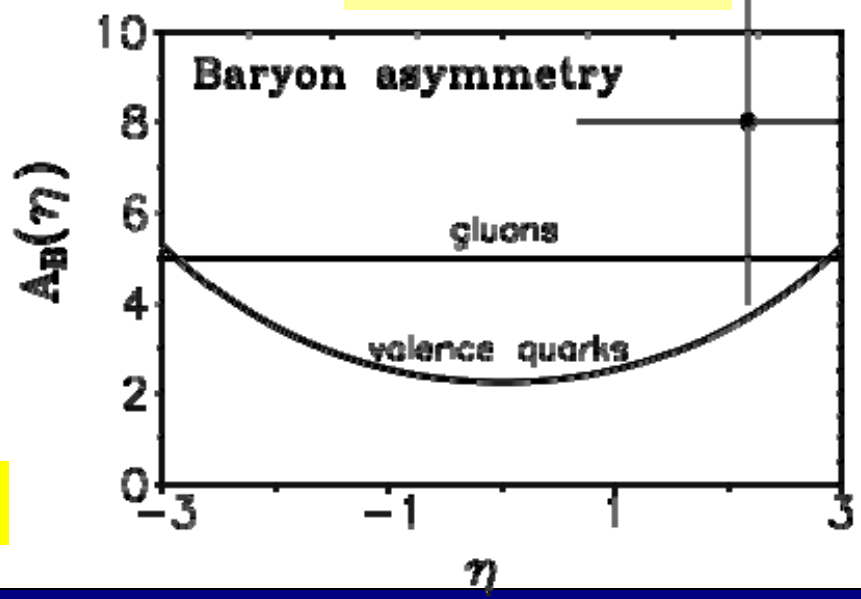


- Baryon number can be transferred by specific configuration of the gluon field: (B. Z. Kopeliovitch and B. Zakharov, Z. Phys. C43 (1989) 241).
- At LHC huge rapidity interval between incoming protons ($y_p = \pm 9.6$) and central rapidity. Veneziano's model would result in substantial net baryon production in central rapidity region.



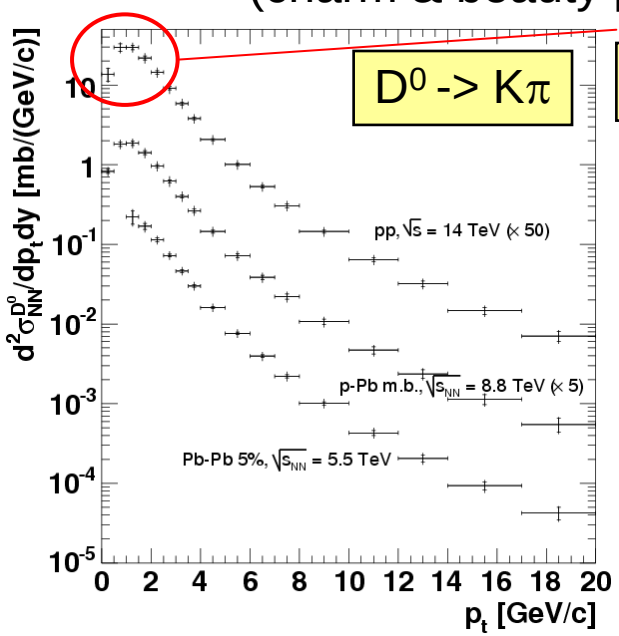
Ideal for ALICE

HERA point plotted at rapidity 9.6 - 7.4 = 2.2

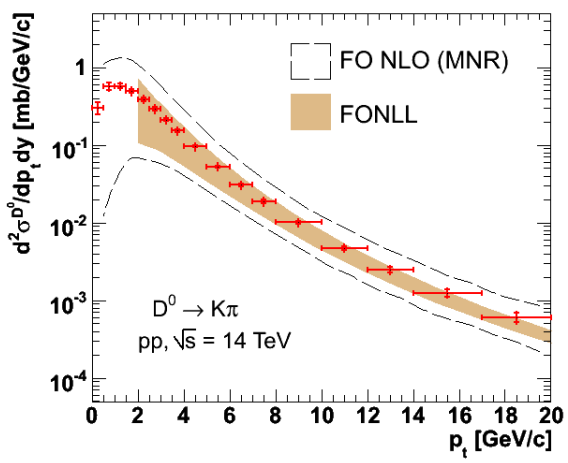


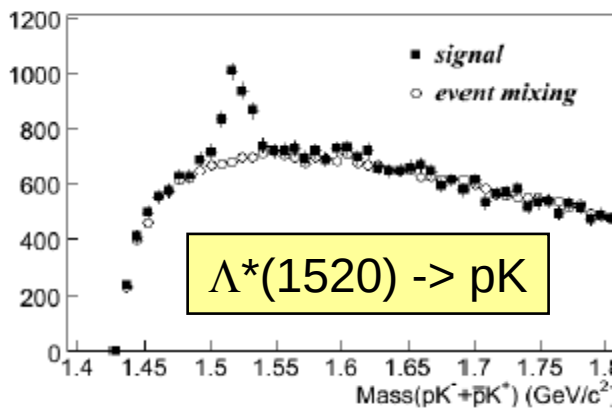
ALICE physics with pp

- Taking 'comparison data' for the heavy ion program
  - eg: J/ψ & ϒ suppression in AA requires measuring J/ψ & ϒ production in pp
- Survey and characterization of typical ('Minimum Bias') events
  - Detailed measurements of particle composition, strangeness, charm, baryon, etc.
  - Specific QCD measurements for which ALICE is particularly well suited (charm & beauty production at low p_T)



acceptance down to $p_T \sim 0$





Conclusion

- ALICE was **ready for first physics** in September 2008.
- We will take full advantage of the long shutdown to complete some of the installation, improve integration (access), and for maintenance and small repairs.
- We have learned a lot from first circulating beams.
- First data confirm that **performance of the tracker and of PID detectors,** in some cases even a bit better than expected.

- ALICE has an ambitious proton-proton programme, which is the best preparation for future heavy ion physics.

ALICE programme

- **First 5 years**: exploitation of present ALICE detector:
  - Continuous running with **p-p** (comparison data and some genuine pp physics: charm, baryon, high multiplicity, etc.)
  - 1 yr (10^6s) **Pb-Pb** at low Luminosity (initially ~1/20th design, i.e. $L \sim 5 \times 10^{25}$ $cm^{-2}s^{-1}$)
  - 1-2 yrs **Pb-Pb** at nominal $L \sim 10^{27}$, targeting integrated $L \sim 0.5\text{-}1 nb^{-1}$: $\langle L \rangle \sim ⅓$ or ½ L_{max} depending on sharing among exper.
  - 1 yr **p-A** (initial state interaction effects); 1 yr **low mass A-A** (system size dependence)
- **Following 5 years**:
  - Lower energies (energy dependence, thresholds, pp@5.5 TeV); Additional AA and pA combinations; Increased PbPb statistics.
  - Detector upgrade:
    - 2010-2011 Decision on upgrade.
    - 2013-15 Inst. of upgraded detectors (depending on LHC schedule)