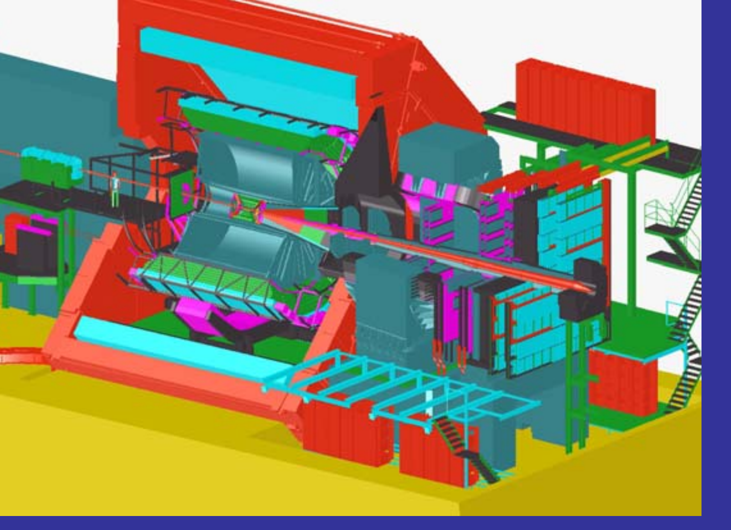
Progress of the ALICE experiment



Outline:

- Experimental layout and status of the main sub-systems
- Detector performance
- Examples of ALICE physics potential

Eugenio Nappi
on behalf of ALICE Collaboration

Physics at LHC
Cracow, July 3-8, 2006

LHC: "The biggest step in energy in the history of heavy-ion collisions"

Running parameters

Collision system	$\sqrt{s_{NN}}$(TeV)	$\mathcal{L}_0$ ($cm^{-2}s^{-1}$)	$<\mathcal{L}>/\mathcal{L}_0$(%)	Run time (s/year)	σ_{geom} (b)
pp	14.0	10^{34}		10^7	0.07
PbPb	5.5	10^{27}	50	10^6	7.7

- **Hard processes contribute significantly to the total AA cross-section**
  $\sigma_{hard}/\sigma_{total}$ = 98% (50% at RHIC)
  - Probe matter at very early times (QGP)
  - Heavy quarks and weakly interacting probes become accessible
  - Predictions by pQCD $\rightarrow$ precision measurements
- Other collision systems: pA, lighter ions (Sn, Kr, Ar, O) & energies
  - Study dependence on **energy density & volume**

LHC Heavy Ion Programme

- **Running time:**
  - **~ 4 weeks/year** (10^6 s effective); typically after pp running (**like at SPS**)
  - first HI run expected end 2008 (1/20th design luminosity)
- **Luminosity**:
  - 10^{27} (Pb) to $>10^{30}$ (light ions) $cm^{-2}s^{-1}$ => rate from 10 kHz to several 100 kHz
  - integrated luminosity **0.5 nb^{-1}/year** (Pb-Pb)

One dedicated HI experiment: ALICE

Two pp experiments with HI programme: ATLAS and CMS

ALICE Physics Programme

ALICE covers in one experiment what at the SPS was investigated by 6-7 experiments, and at RHIC by 4

- Global properties
  - Multiplicities, η distributions
- Degrees of Freedom vs Temperature
  - Hadron ratios and spectra
  - Dilepton continuum
  - Direct photons
- Collective effects
  - Elliptic flows
- De-confinement
  - Charmonium, bottonium spectroscopy
- Chiral symmetry restoration
  - Neutral to charge ratio
  - Resonance decays
- Partonic energy loss in QGP
  - Jet quenching, high p_T spectra
  - Open charm and beauty
- Geometry of emission
  - HBT, zero-degree energy flow
- Fluctuations and critical behavior
  - Event-by-event particle composition and spectroscopy
- Proton-proton collisions in a new energy domain

More on ALICE Physics

- **Physics Performance Reports**
  Published in two volumes:
  PPR Vol I: CERN/LHCC 2003-049 and
  ALICE coll. (2004) J. Phys. G 30 1517 – 1763
  PPR Vol II: CERN/LHCC 2005-030 (part 1 & part 2)
  in press in J. Phys. G

- **Talks in the working group session:**

First physics with ALICE detector	*C. Jorgensen*
Physics with ALICE transition radiation detector	*K. Oyama*
Heavy-flavour production with ALICE	*R. Turrisi*
Soft physics in ALICE	*A. Mastroserio*

- **Poster session**

Short lived resonances in ALICE	*F. Riggi*

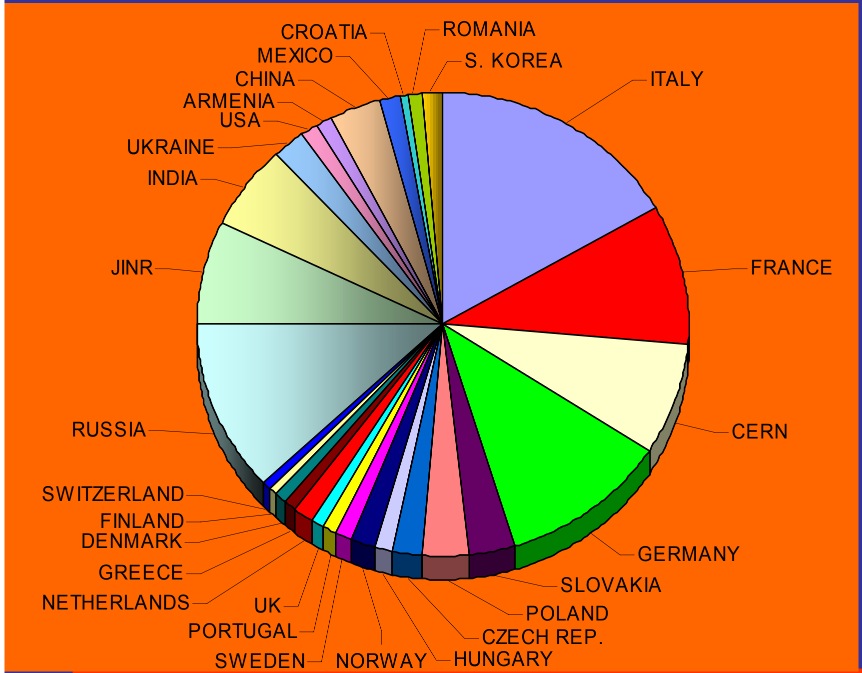
The Alice Collaboration

~1000 collaborators total
(63% from CERN MS)

~ ½ ATLAS,CMS; ~ 2x LHCb

30 Countries

90 Institutions



A large community which has been constantly growing over the years, and still grows:

Spain joined few weeks ago

13 US institutions submitted a proposal to DOE of about **10 M$ for a large EMCAL in ALICE**

Brazil is applying for membership

ALICE Design Parameters

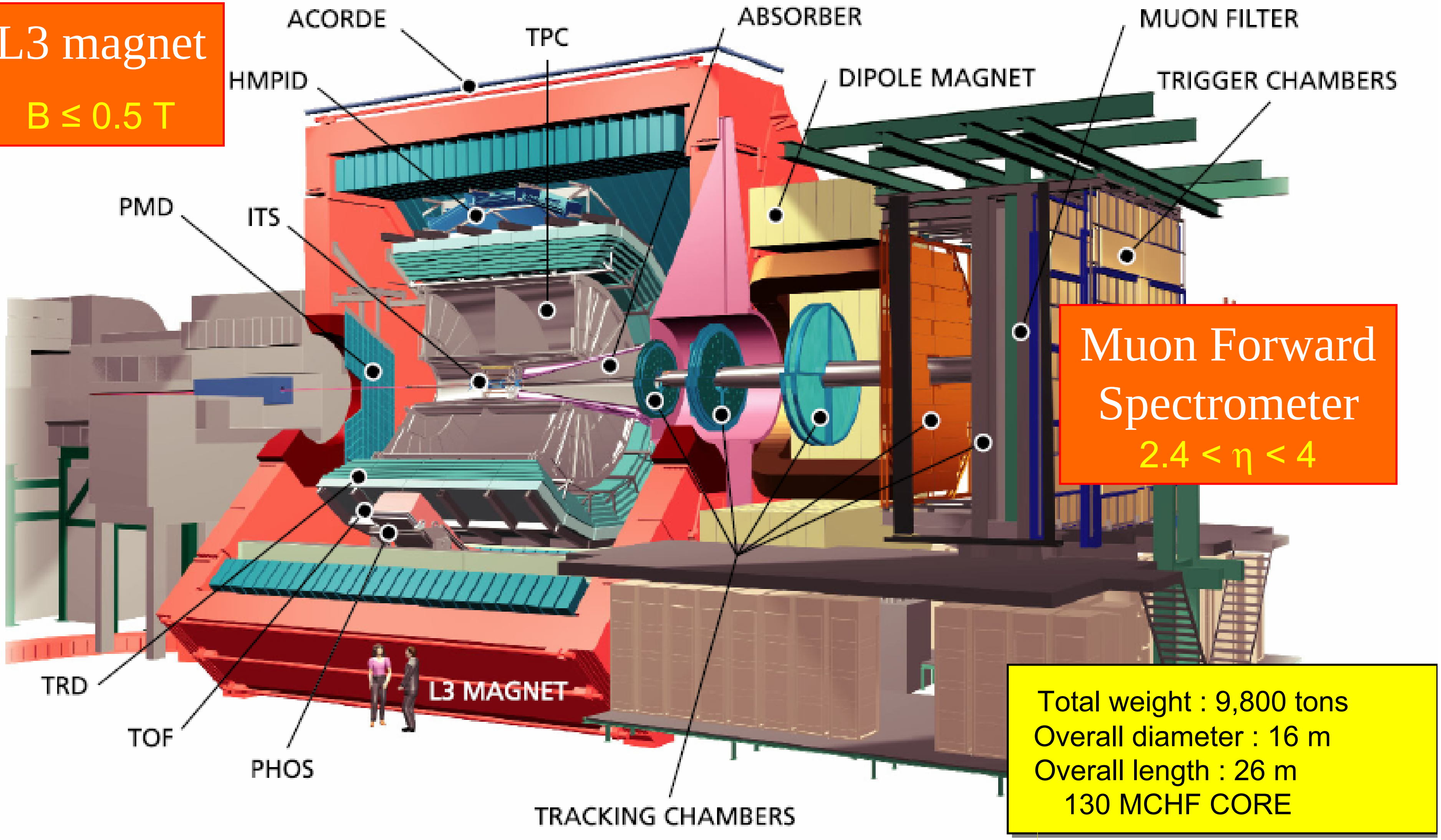
- Guideline: to measure flavor content and phase-space distribution event-by-event
  - Track and identify most (2π * 1.8 η units) of the hadrons from very low (< 100 MeV/c; soft processes) up to fairly high p_T (~100 GeV/c; hard processes)
  - Vertex recognition of hyperons and D/B mesons in an environment of very high charged-particles density (up to $dN/d\eta = 8000$)
  - Dedicated & complementary systems for di-electrons and di-muons
  - Excellent photon detection (in $\Delta\varphi = 45^\circ$ and 0.1 η units)
  - High throughput DAQ system + powerful online intelligence ('PC farm')

Compromise: the fragmentation region is not addressed (difficult at LHC, $y_{beam}=9$)

ALICE Experimental Layout

L3 magnet

B ≤ 0.5 T



Muon Forward Spectrometer

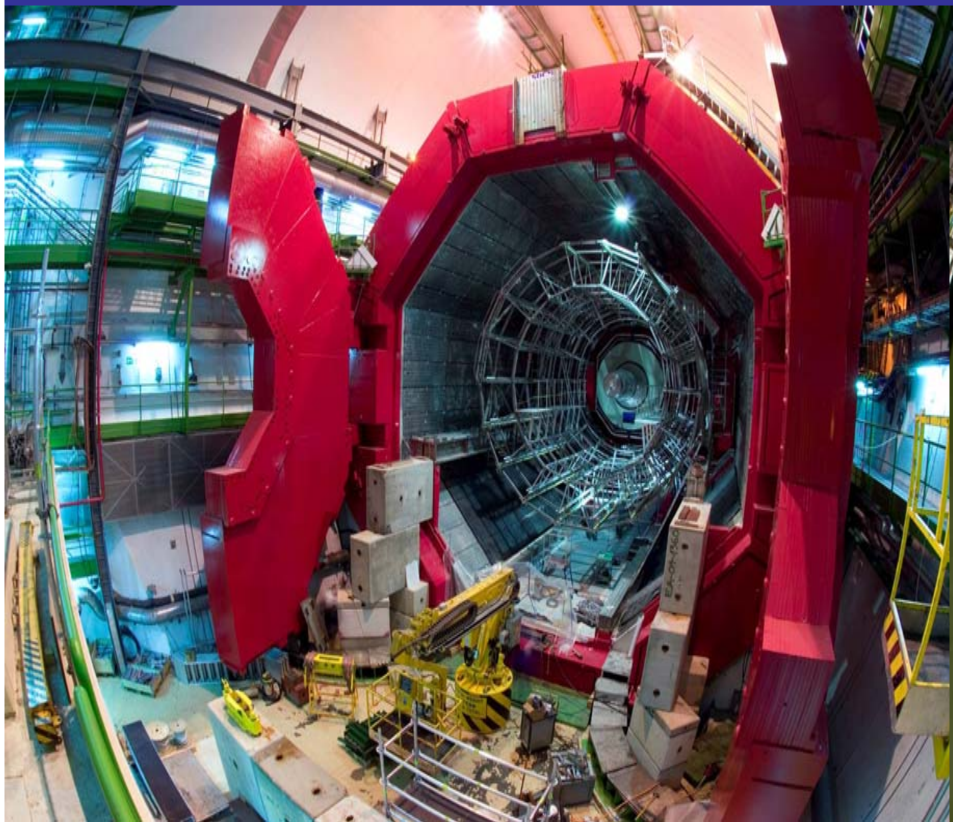
$2.4 < \eta < 4$

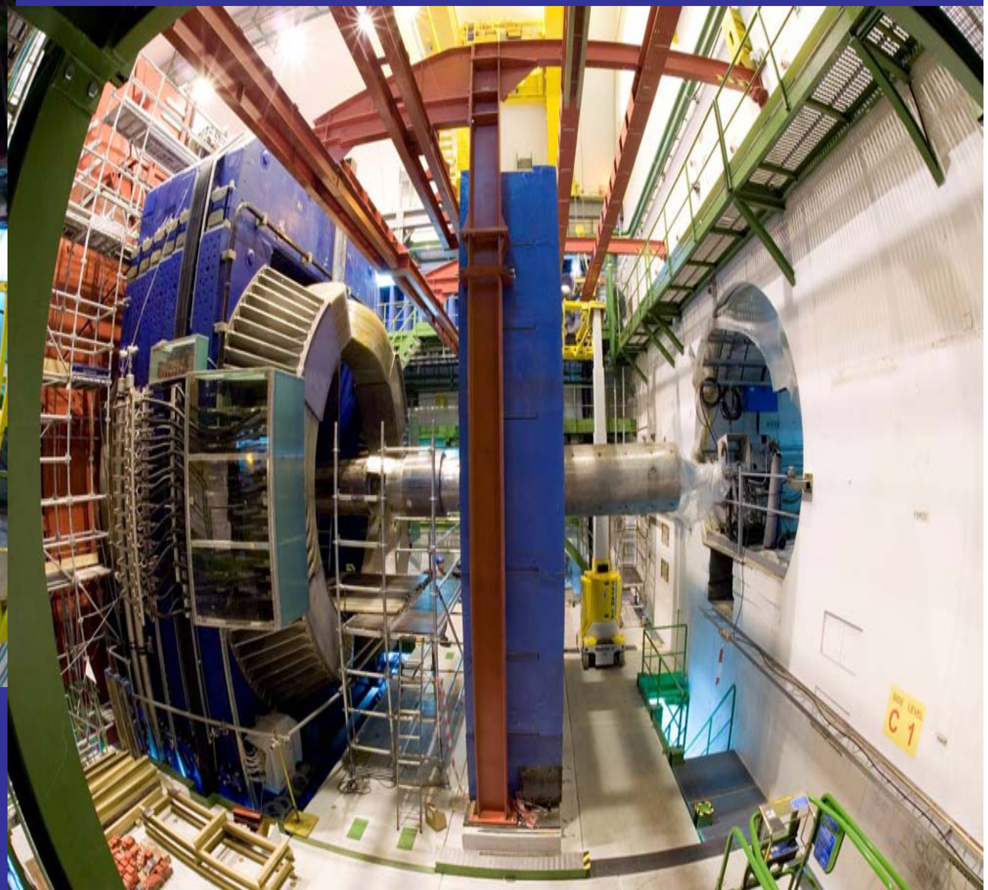
Total weight : 9,800 tons
Overall diameter : 16 m
Overall length : 26 m
130 MCHF CORE

ALICE now

Installation of Services (cables, cooling & gas pipes) ongoing

Space frame, Muon Filter and Absorber: installation completed

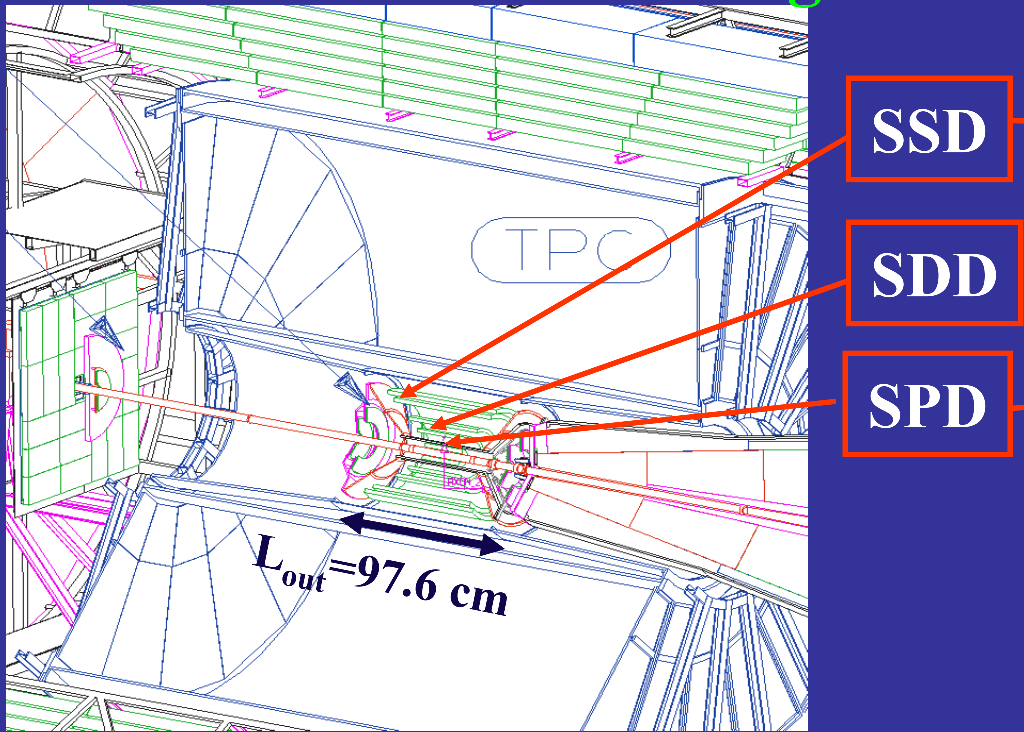


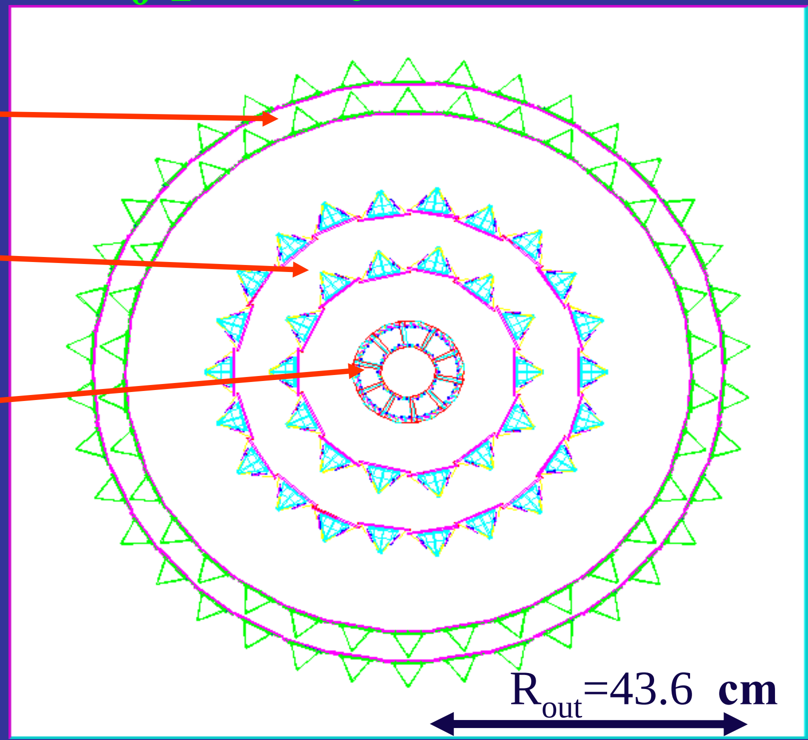


Solenoid ('L3') and Muon Dipole:
assembled and commissioned
field mapping done

Inner Tracking System

Material Budget: ≤ 1% X_0 per layer !



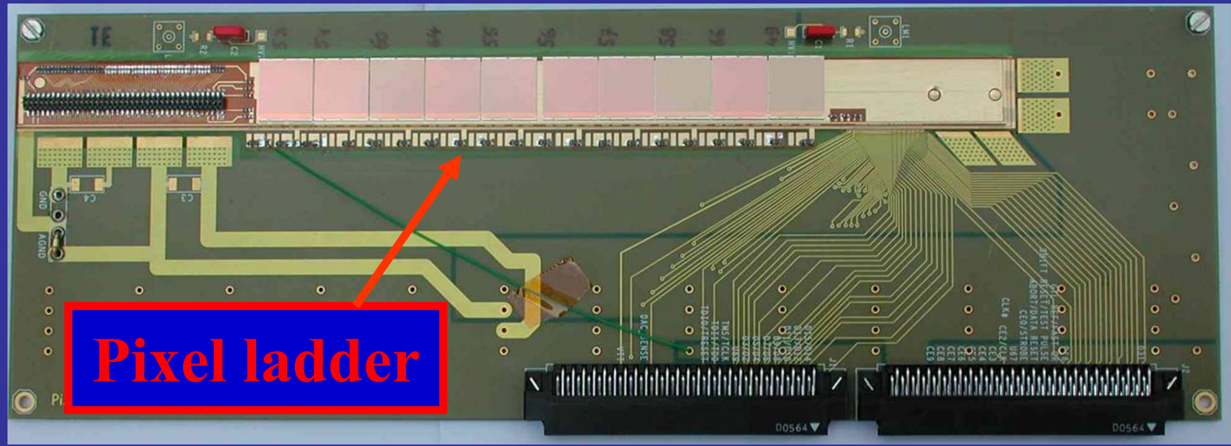


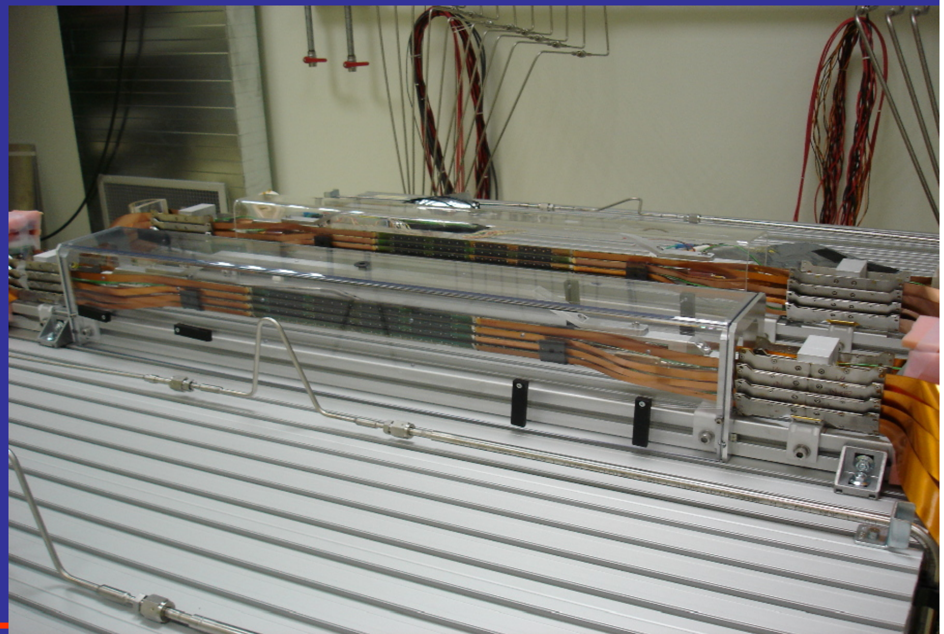
- 6 layers, three technologies (keep occupancy **at a few %** for max multiplicity)
  - SPD: silicon pixels (0.2 m^2, two layers, 9.8 M channels)
  - SDD: silicon drift (1.3 m^2, two layers, 133 k channels)
  - SSD: double-sided silicon strips (4.9 m^2, two layers, 2.6 M channels)

Silicon Pixel Detector

Challenge: track densities at r = 4 cm (1st layer): up to 100 / cm^2

50 μm (ρϕ) x 425 μm
(z) pixel cell
spatial resolution
(rφ, z) : 12 μm, 100 μm

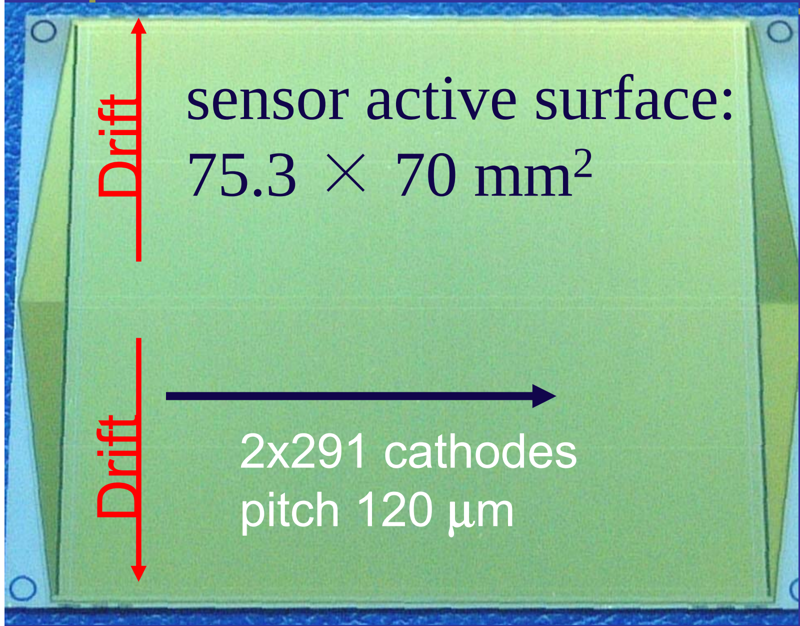




STATUS

- **Production is progressing well**
- **Four sectors (~4 M channels) out of ten are under test in the DSF at CERN**
- **1st half-barrel service integration successfully completed**
- **Ready for installation: Nov '06**

Silicon drift detector



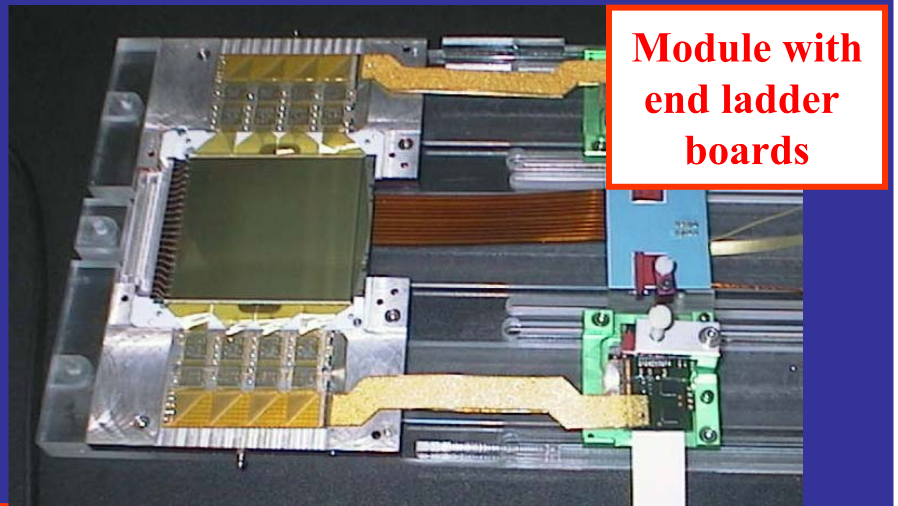
cell size (rφ,z):
294 x 150 μm^2

spatial resolution
(rφ, z) :
35 µm, 23 µm

analogue R/O
(dE/dx)

STATUS

- **Sensor production completed**
- **Module (260 in total) assembly accomplished**
- **Ladder assembly in progress**
- **Ready for installation: Dec. 06**

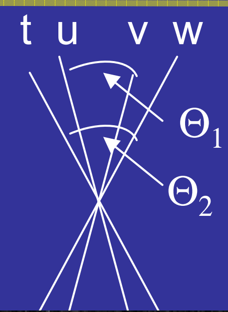


Silicon Strip Detector

– 42 mm long strip (pitch 95 μm), double sided silicon detectors

– amplitude readout, charge matching & dE/dx

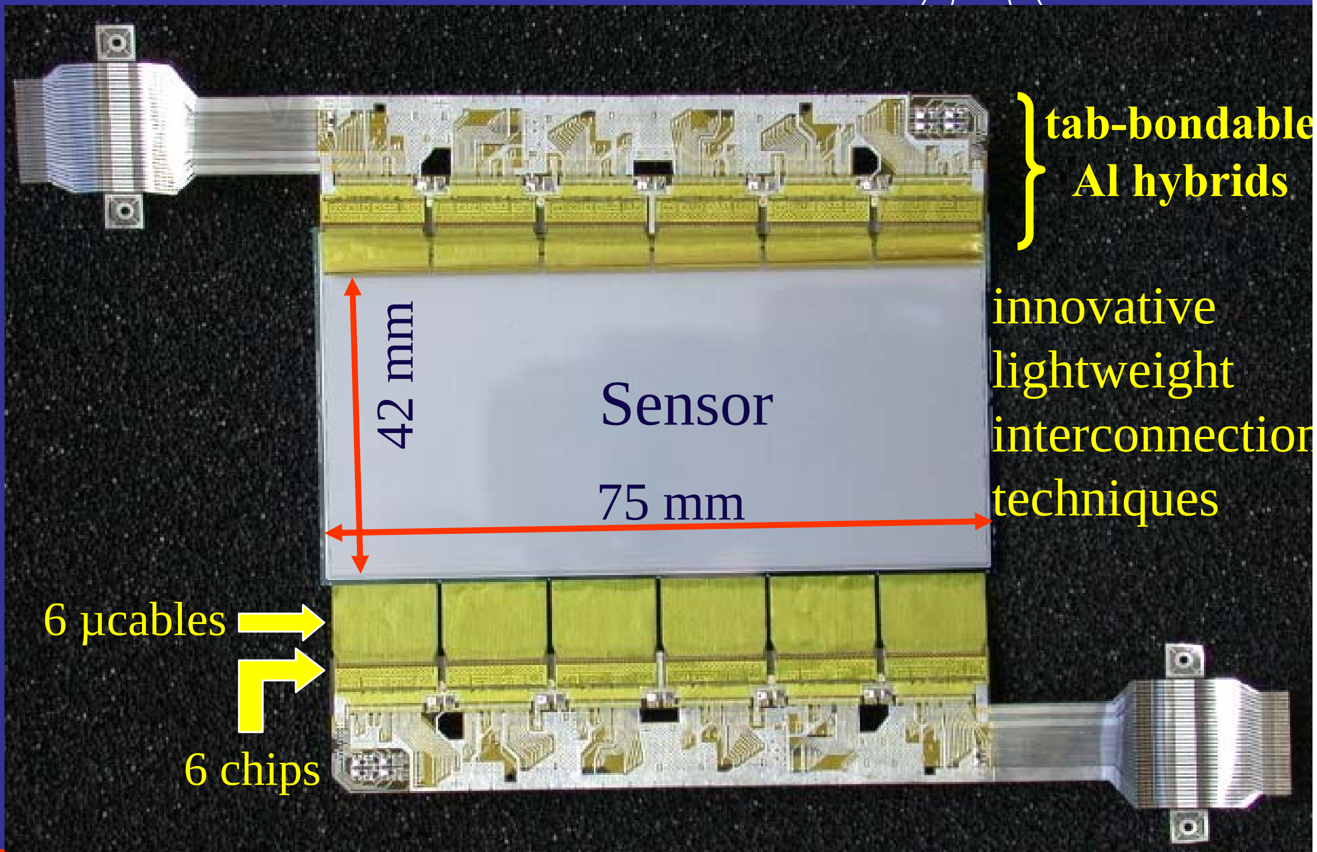
– t u v w arrangement (Θ_1 = 18 mrad, Θ_2 = 36 mrad)



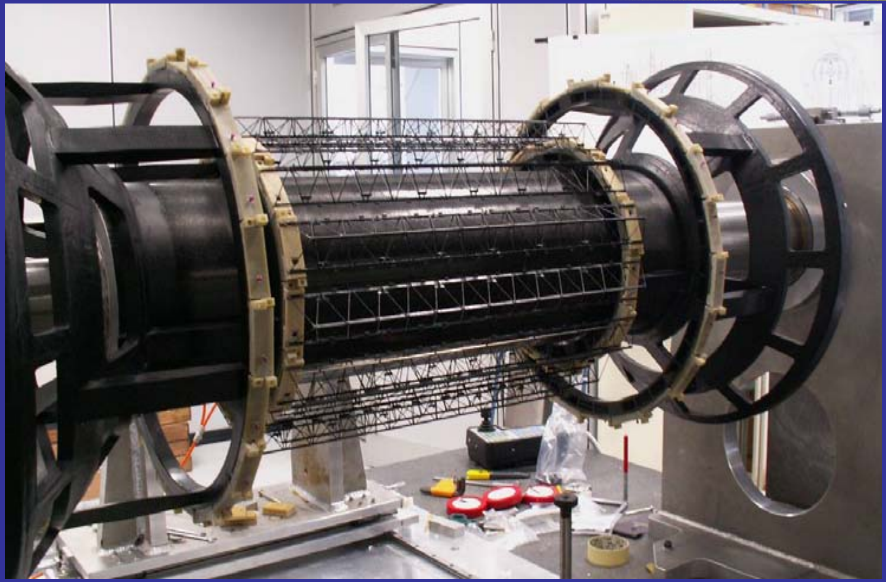
cell size (rφ,z): 95 x 4200 μm^2
spatial resolution (rφ) 20 μm
spatial resolution (z) 830 μm

STATUS

- **Module production completed**
- **50% of the ladders assembled and tested**
- **Service integration in progress**
- **Ready for installation: December 06**

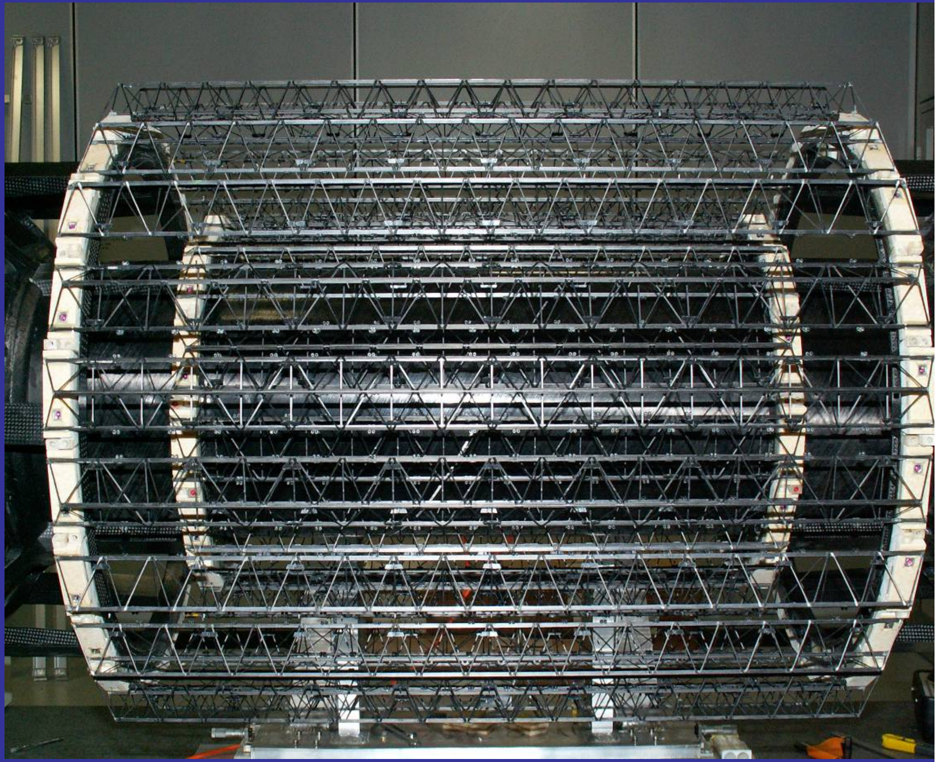


Status of ITS support structures



Assembly of the ladder positioning elements completed for both SDD and SSD

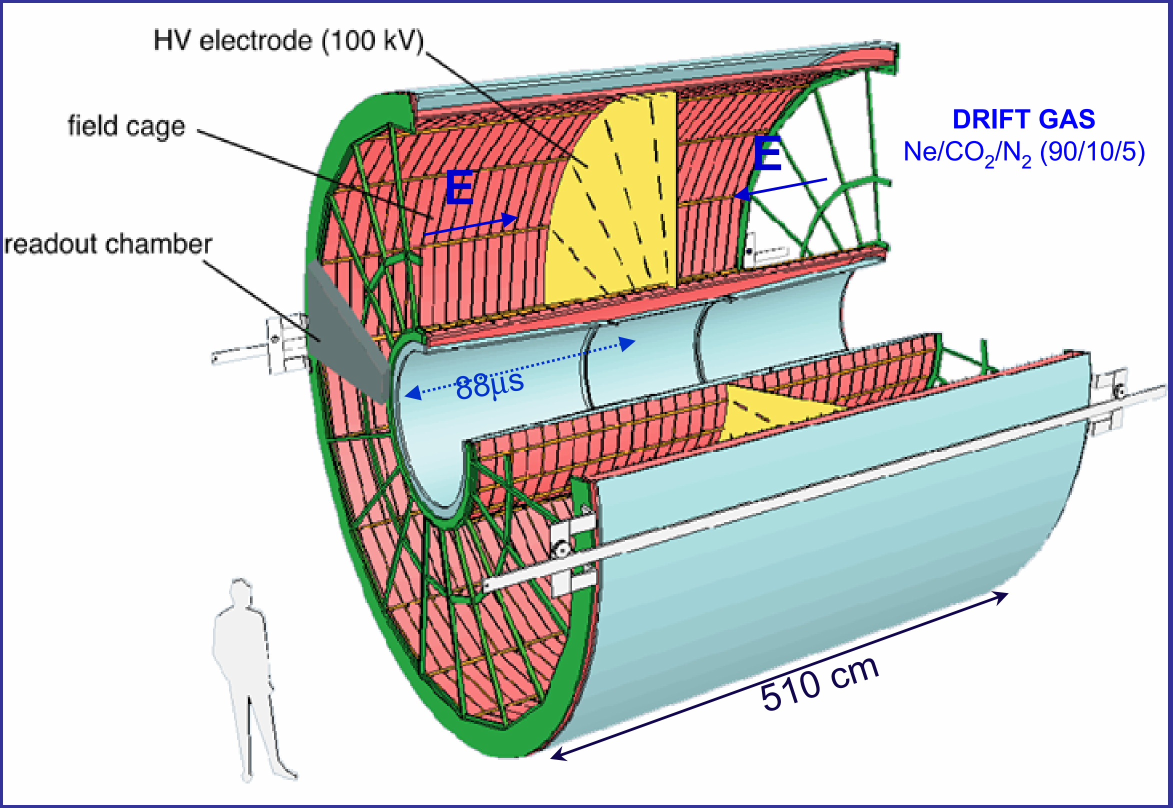
SPD Half-Barrel final assembly



Time Projection Chamber

the largest gaseous detector ever built (95 m^3)

# of Pixels:570,132 pads x 500 time bins corresponding to ~$3x10^8$ pixels in space

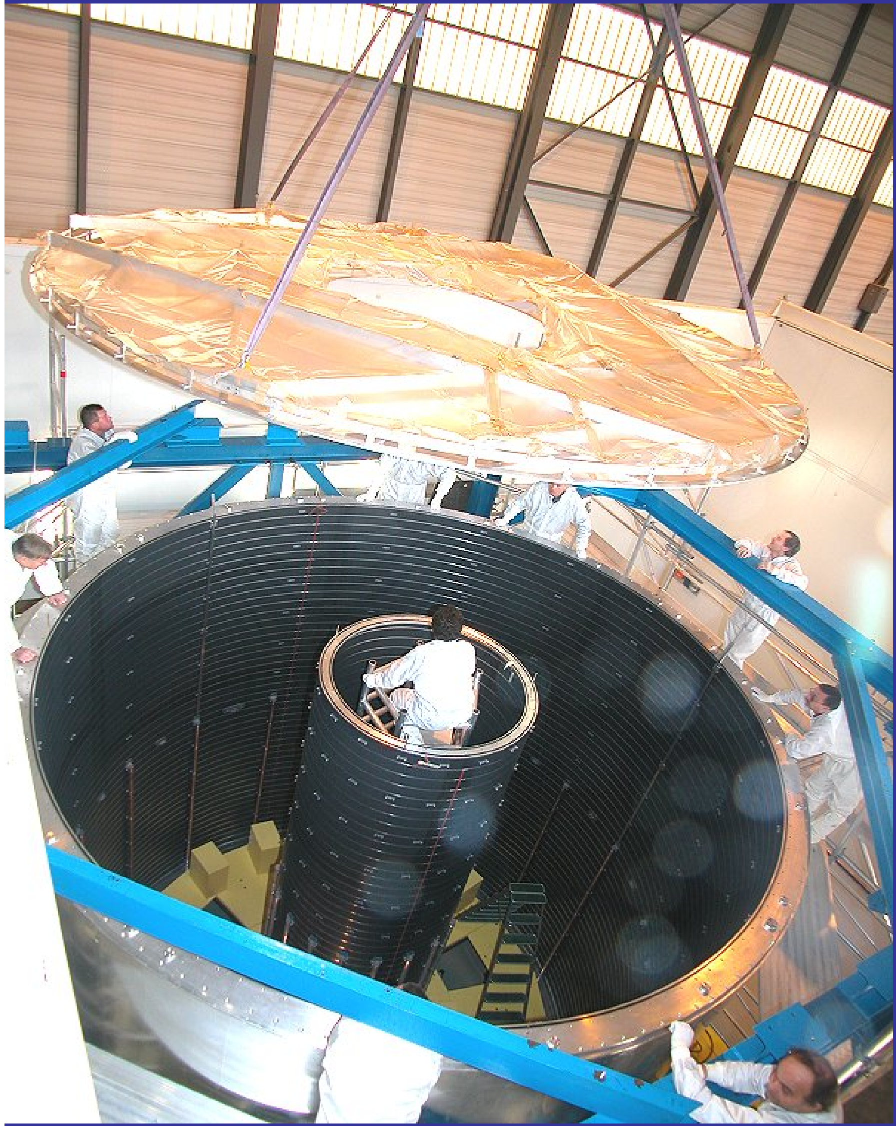


Readout plane segmentation

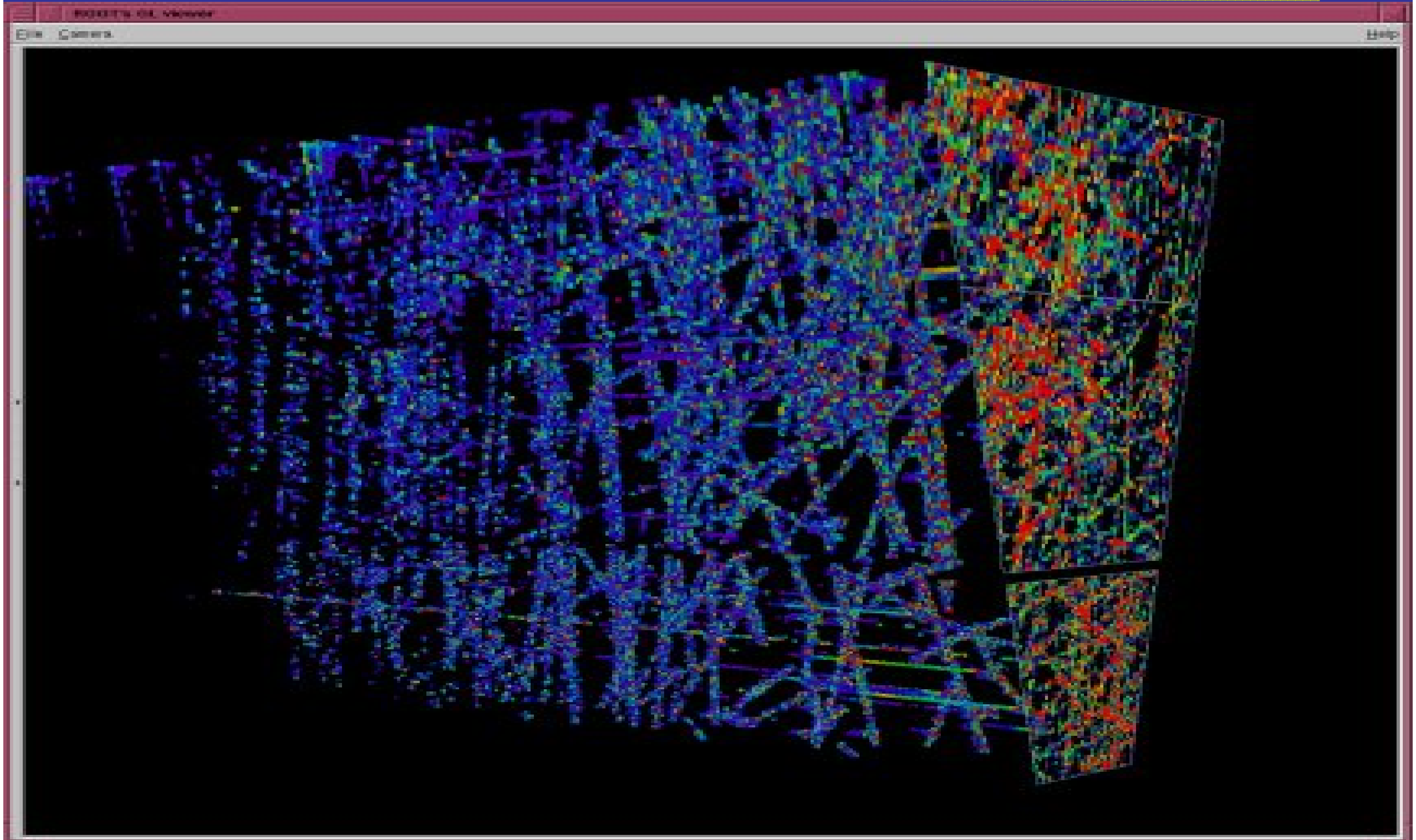
18 trapezoidal sectors each covering 20 degrees in azimuth

High structural integrity with low-mass and low-Z material (composite structures: Nomex, Tedlar, fiber matrices) X/X0~3%

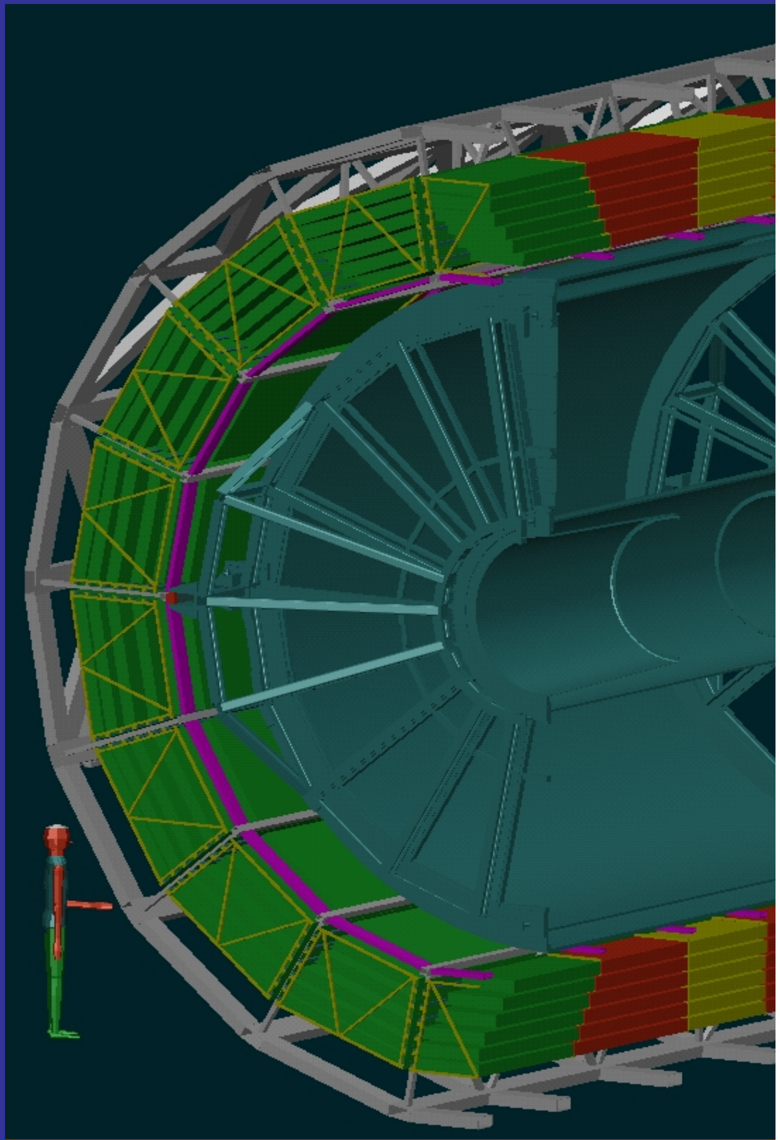
TPC Field Cage and RO Chamber Installation

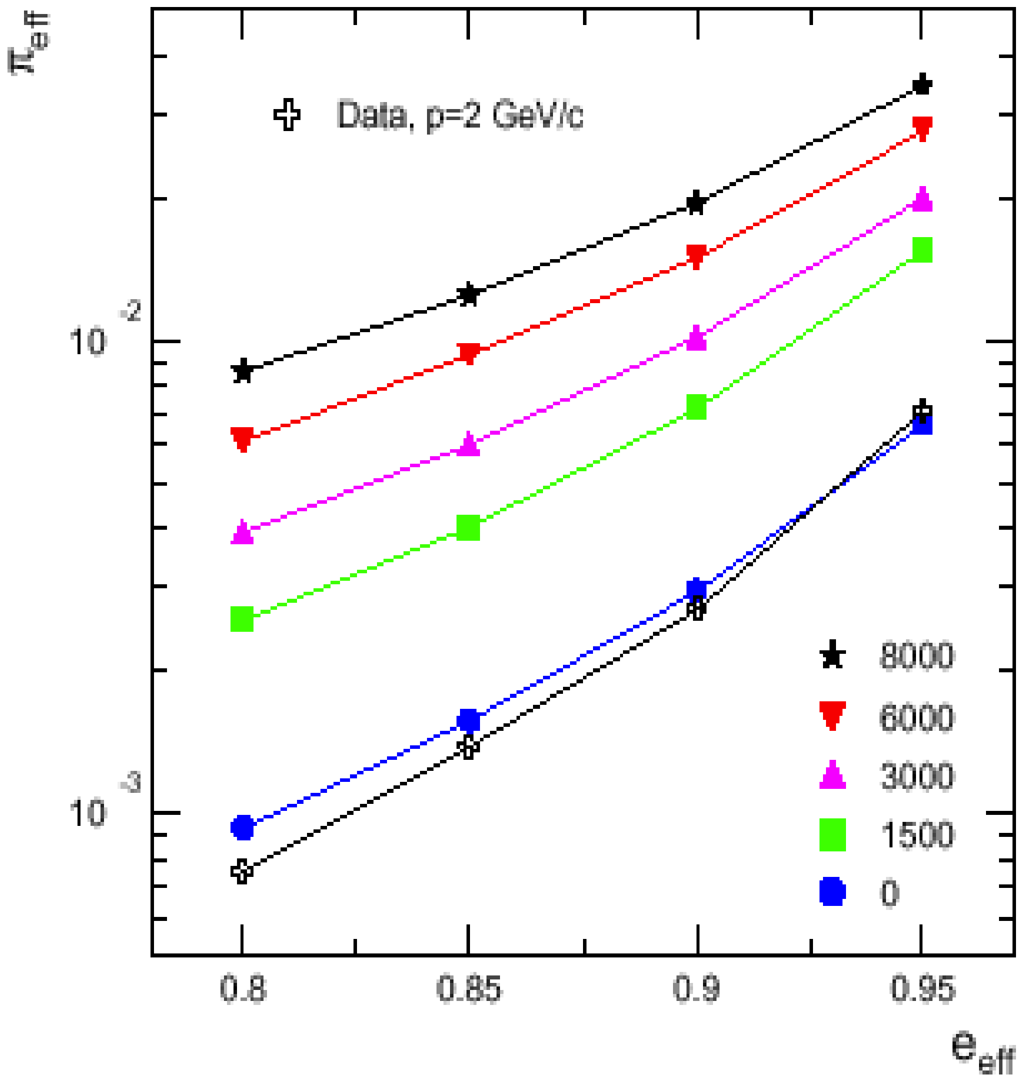


TPC commissioning with cosmics and laser beams



Transition Radiation Detector





Transition Radiation Detector Status

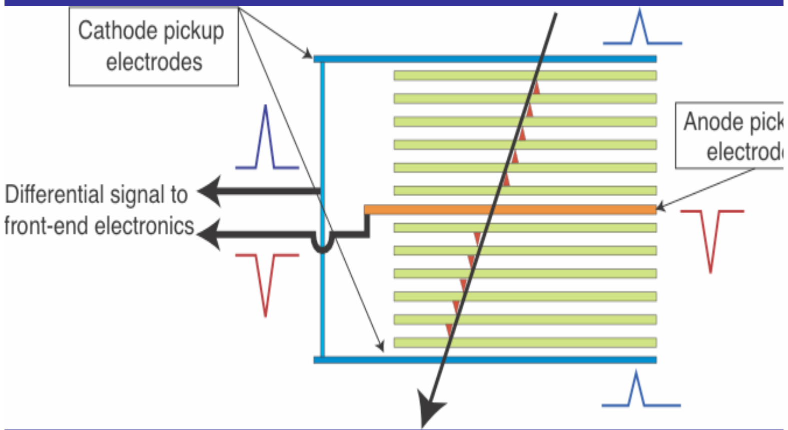
Reached 50 % of the chamber production

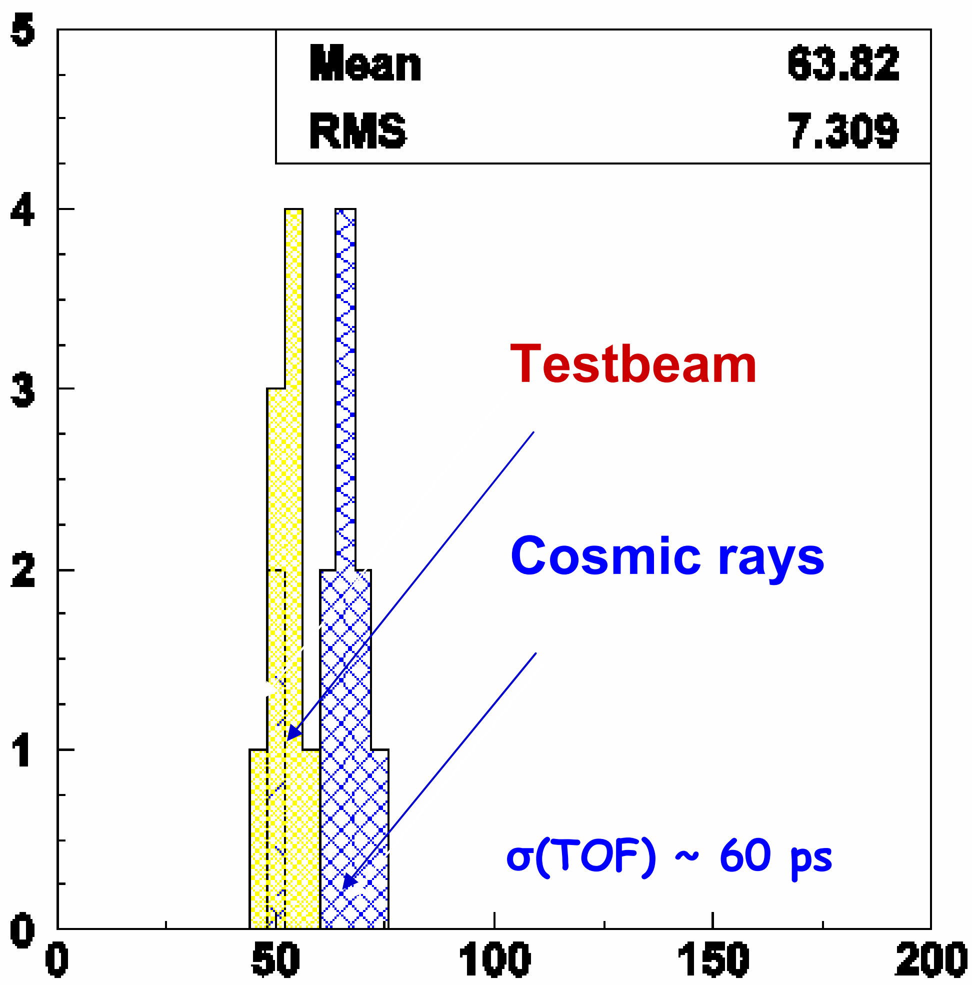
Start installation in April 2007

Time of Flight

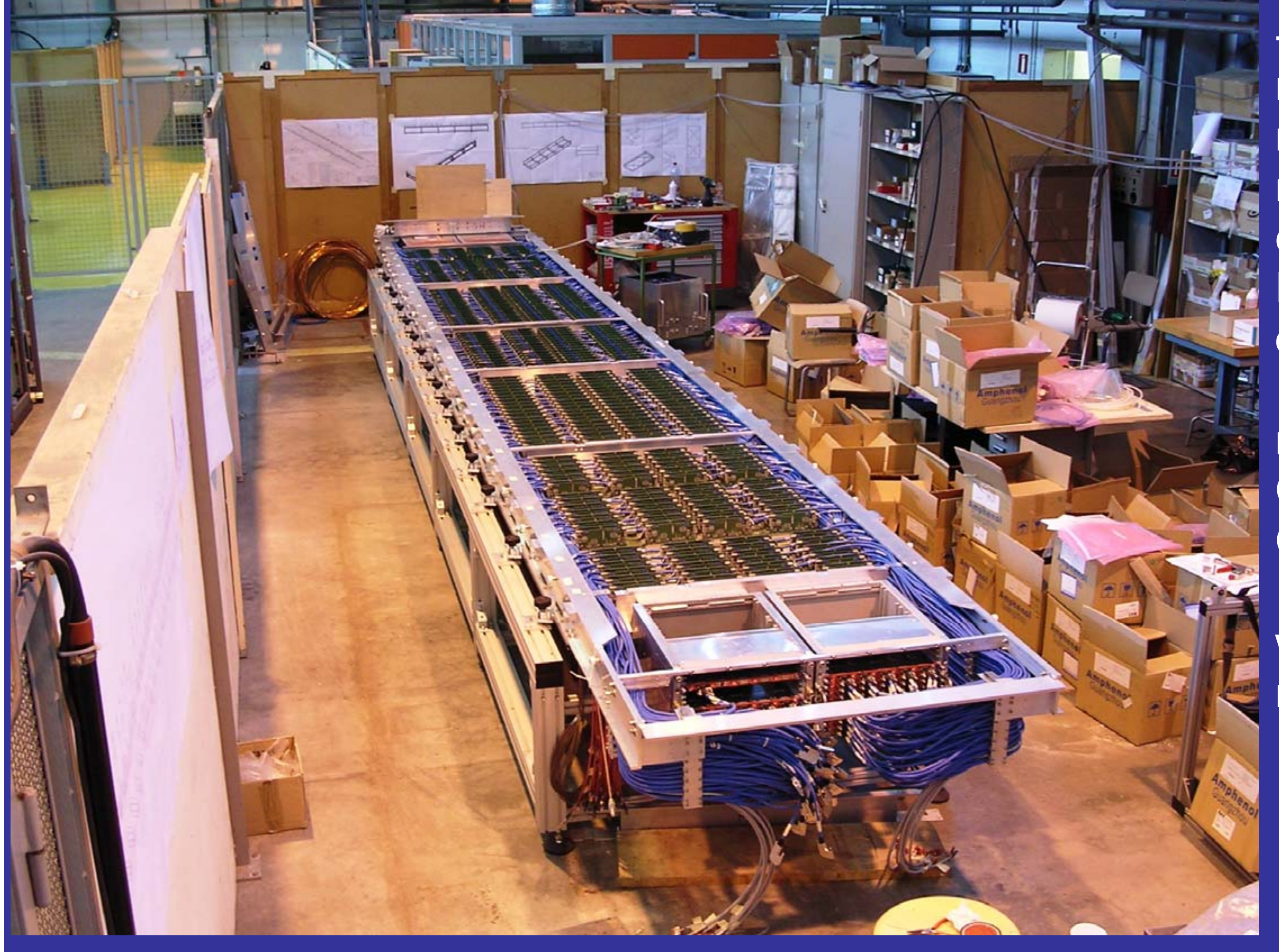
A revolution in technology: a standard TOF system built of fast scintillators + photomultipliers would cost > 100 MCHF

157,248 channels
total sensitive area: ~150 m^2





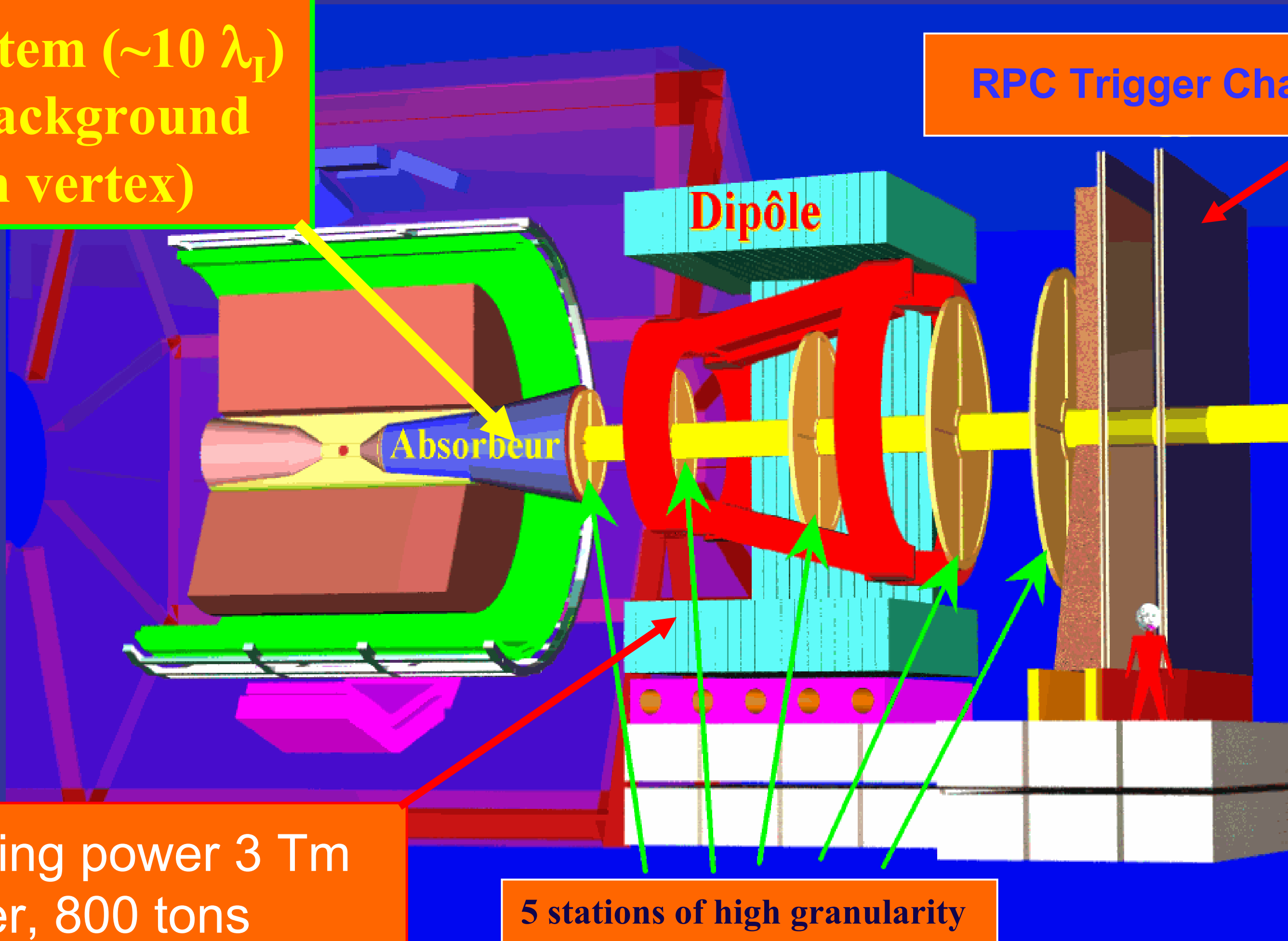
Time of Flight Status



- 1st Supermodule: modules tested, mechanical structure mounted, cabling completed. Installation trial ongoing
- 2nd Supermodule: modules in the Cosmic test facility at CERN
- 3rd Supermodule: working on the module assembly
- **Start installation in the cavern in April 07**

MUON spectrometer set-up

Complex absorber/small angle shield system (~10 λ_I) to minimize background (90 cm from vertex)

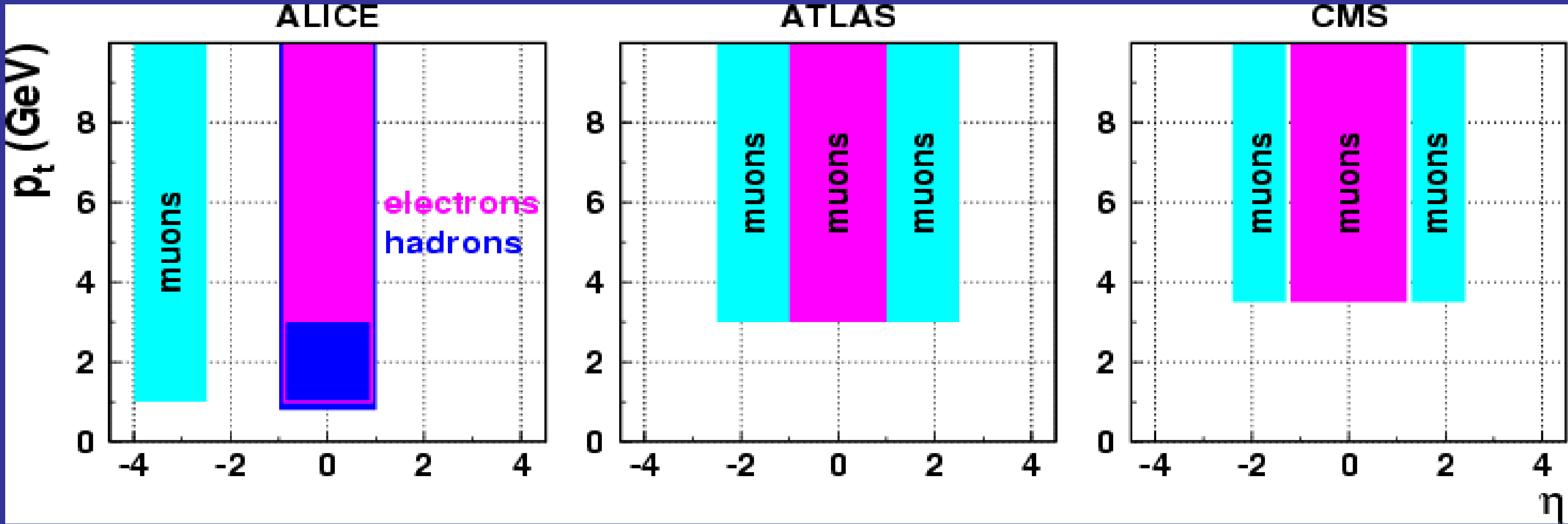


RPC Trigger Chambers

- 0.7 T, bending power 3 Tm
- 4 MW power, 800 tons
- World's largest warm dipole

5 stations of high granularity pad tracking chambers, over 1 million channels

Lepton Acceptance



ATLAS & CMS present a large lepton acceptance $|\eta|<2.4$

ALICE combines muonic and electronic channels

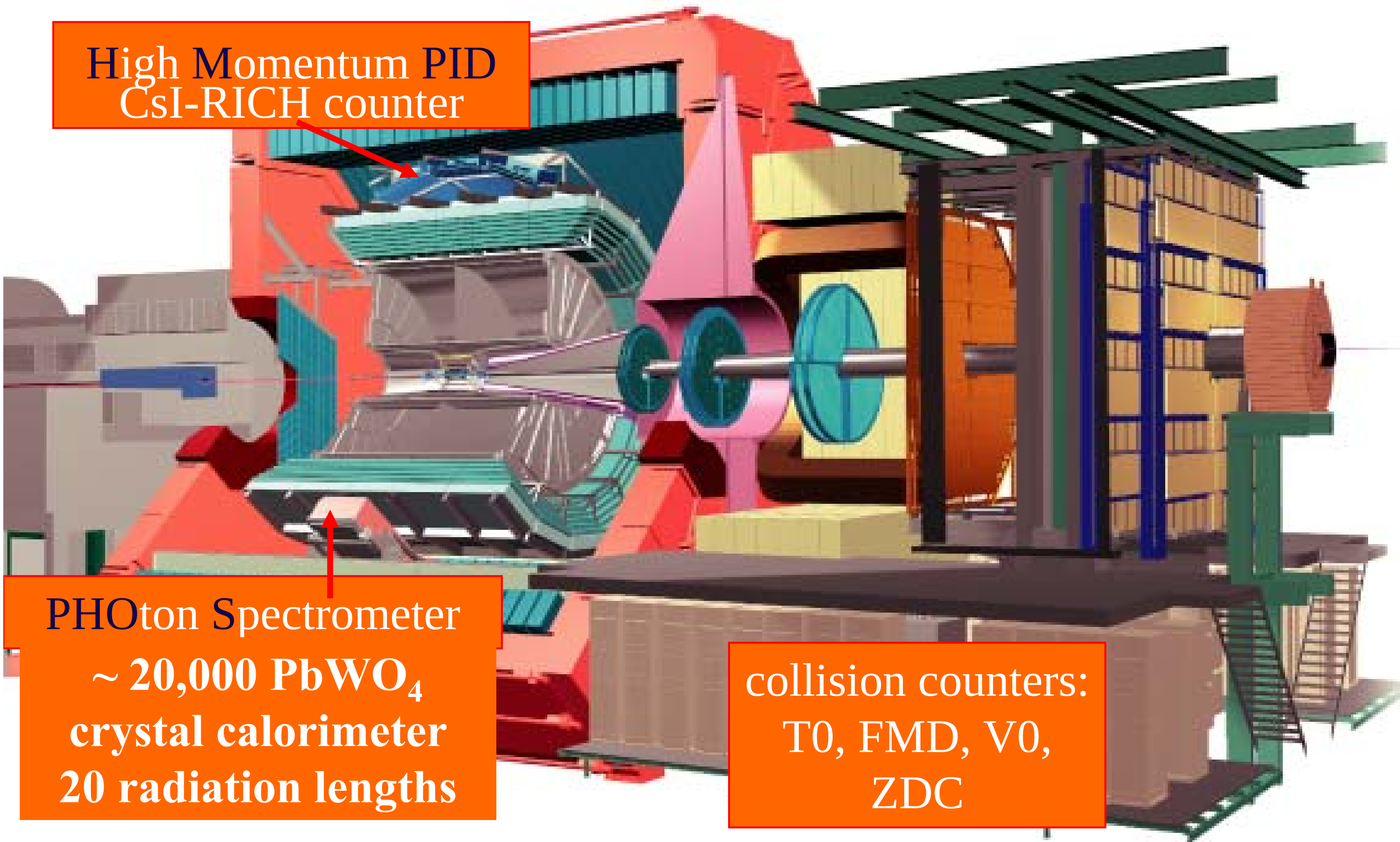
- covers the low p_T region (quarkonia)

- covers the forward region $2.5<\eta<4.0$

MUON Spectrometer Status

All chambers (tracking and trigger) are produced
Trigger electronics in production
Installation of first tracking chamber under way

Single arm sub-systems and forward detectors

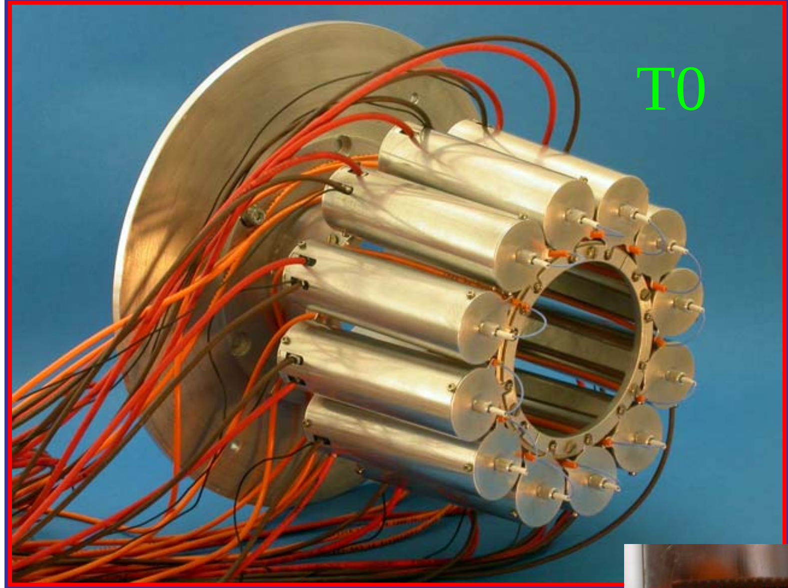


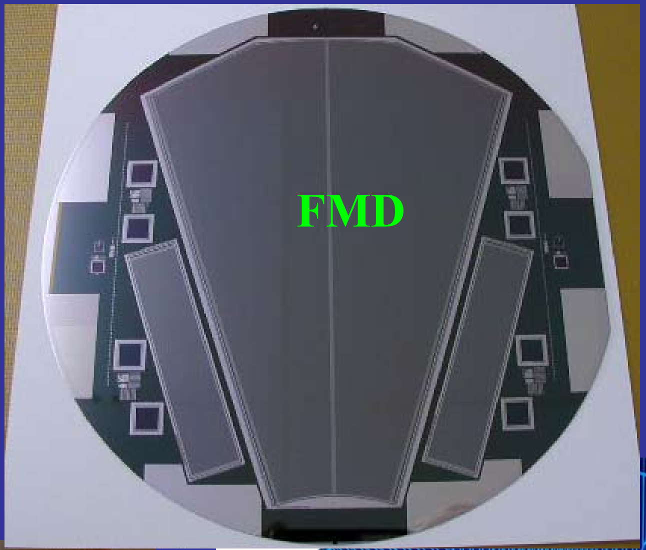
HMPID & PHOS Status

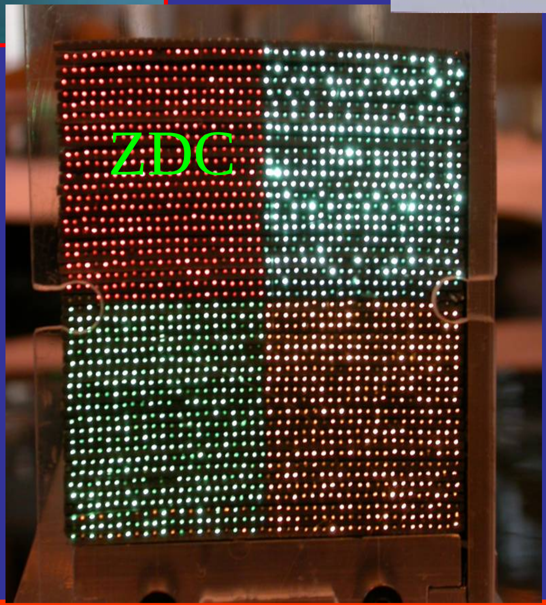
PHOS: Crystal production:
~11,000 (of 18,000) accepted
1st module completed

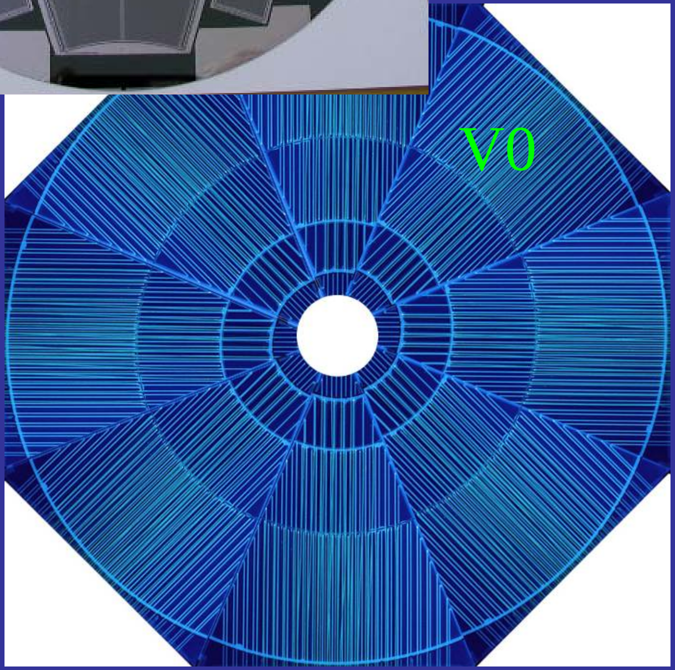
HMPID: module assembly completed. Installation in L3 in August 2006

Beam-beam counters





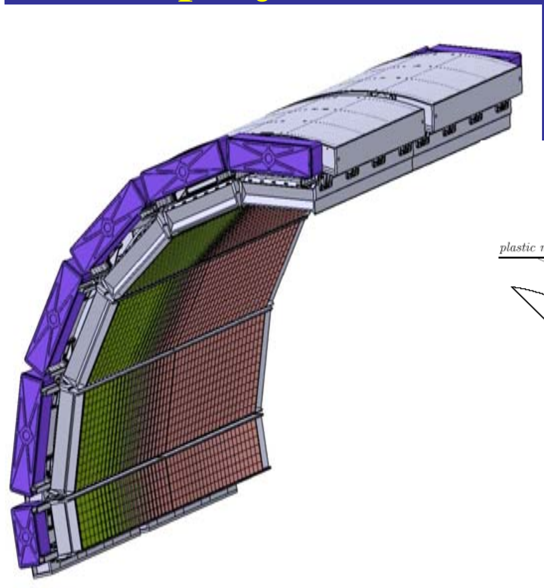


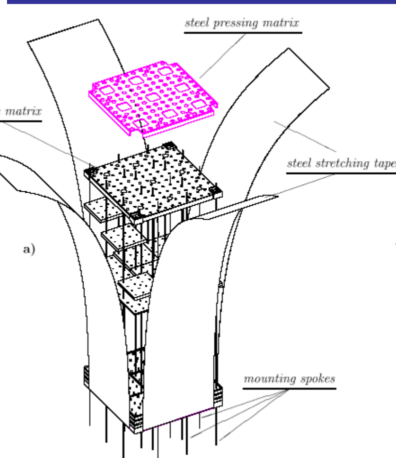


Production on schedule
Installation of first set in November 06
Installation of second set in April 07

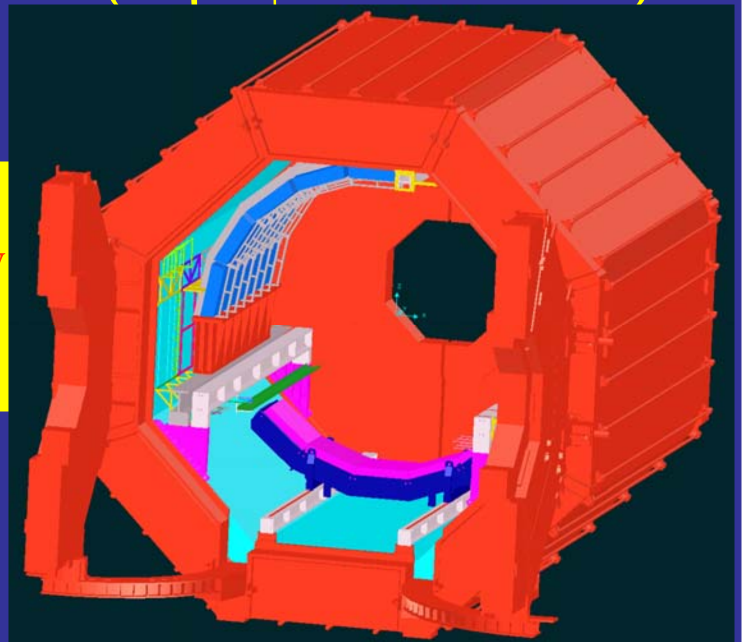
EMCAL

Joint project between US and Europe (Italy and France)





- Lead-scintillator sampling calorimeter
- $|\eta|<0.7$, $\Delta\phi=110^{o}$ (Total Pb depth = 124 mm = 22.1 X0)
- Shashlik geometry, APD photosensor
- PHOS Readout electronics
- ~13k towers ($\Delta\eta\cdot\Delta\phi\sim0.014\cdot0.014$)



It will enhance the ALICE capabilities for jet measurement. It enables triggering on high energy jets (enhancement factor 10-15), reduces the bias for jet studies and improves the jet energy resolution.

first SM under construction as 'pre-production prototype'

schedule: ~ 50% for 2009 run, 100% for 2010 run

EMCAL Potentiality

- Essential jet measurements: modification of fragmentation in dense matter + response of the medium to the jet
  - cross sections are huge: rate is not a primary issue
  - calorimetry alone insufficient: physics lies in detailed changes of fragmentation patterns and correlations, including low pT
- Requirements for jet measurements:
  - precise tracking over very broad kinematic range (TPC+ITS)
  - PID
  - detailed correlations of soft and hard physics
  - jet trigger (EMCAL)

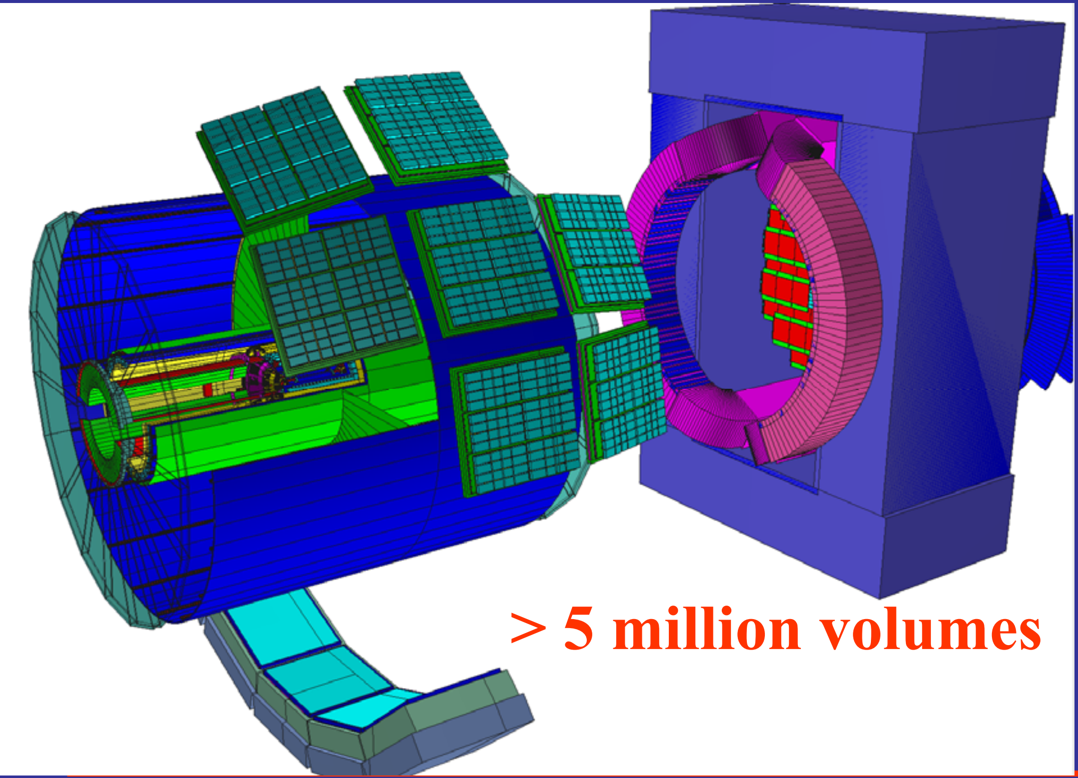
EMCAL brings unique capabilities to LHC heavy ion program

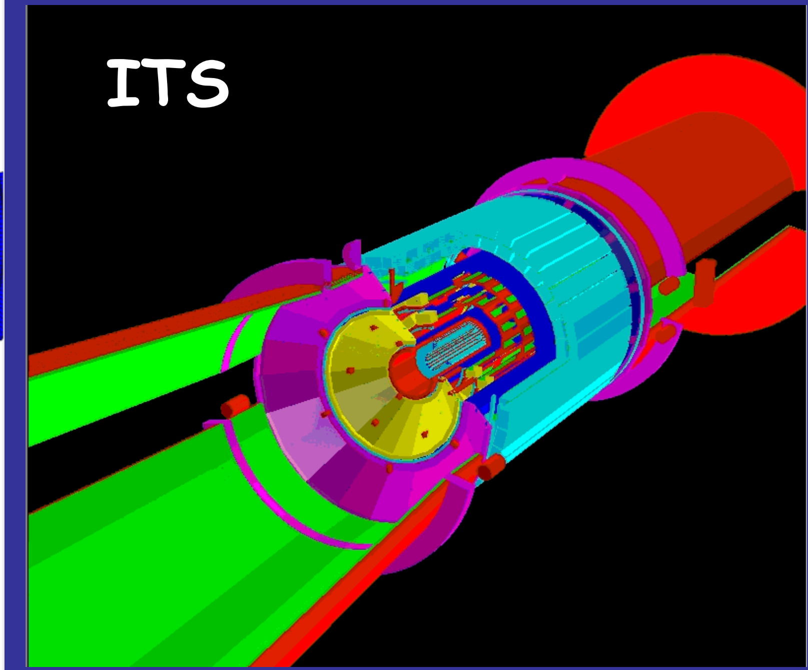
Alice Simulation Model

ALIROOT maps, visualizes and performs tracking from GEANT3 geometry setup

Big challenge: particle multiplicity in Pb-Pb collisions

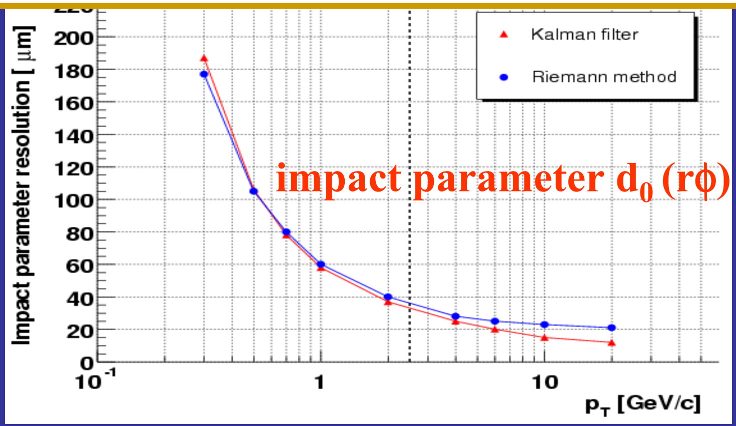
- Simple scaling from RHIC data: safe guess $dN_{ch}/d\eta \sim 1500 - 6000$
- ALICE optimized for $dN_{ch}/d\eta = 4000$, operational up to 8000 (safety factor 2)





Impact Parameter Resolution and Vertex resolution

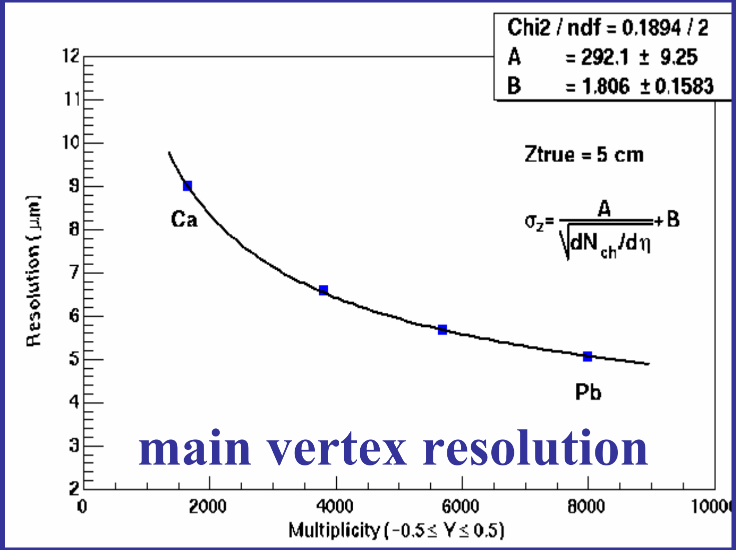
Impact parameter resolution is crucial for the detection of short-lived particles: charm and beauty mesons and baryons
Determined by pixel detectors:
at least one component has to be better than 100 μm (cτ for D^0 meson is 123 μm)



better than 40 μm for p_T > 2.3 GeV/*c*
~20 μm at high p_T

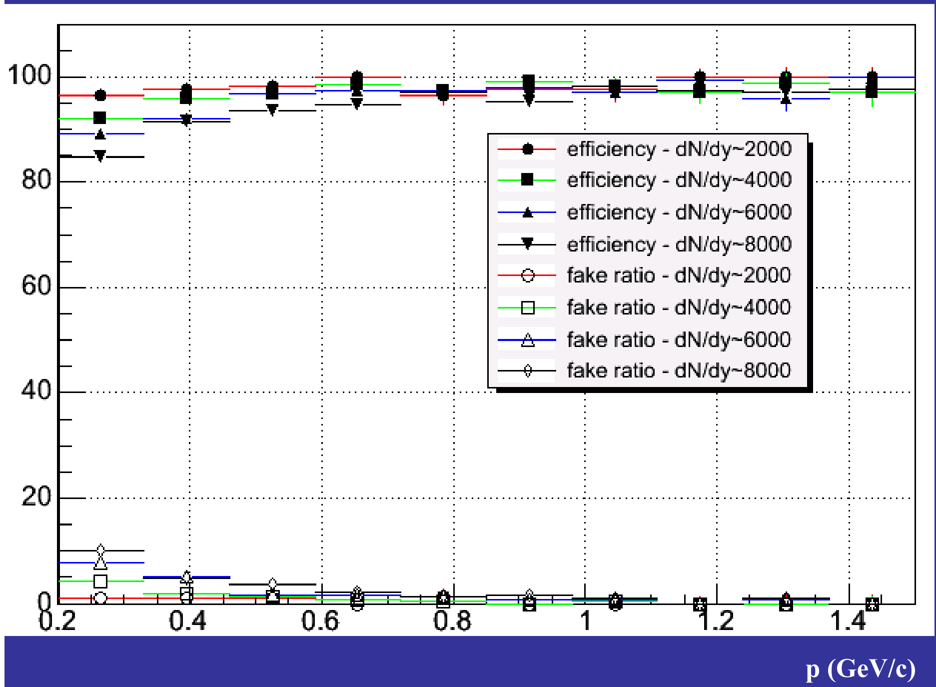
Correlation of two innermost pixel layers (without tracking)

At beam axis	1cm off beam axis
σx = 15 μm	σx = 25 μm
σy = 15 μm	σy = 25 μm
σz = 5 μm	σz = 5 μm



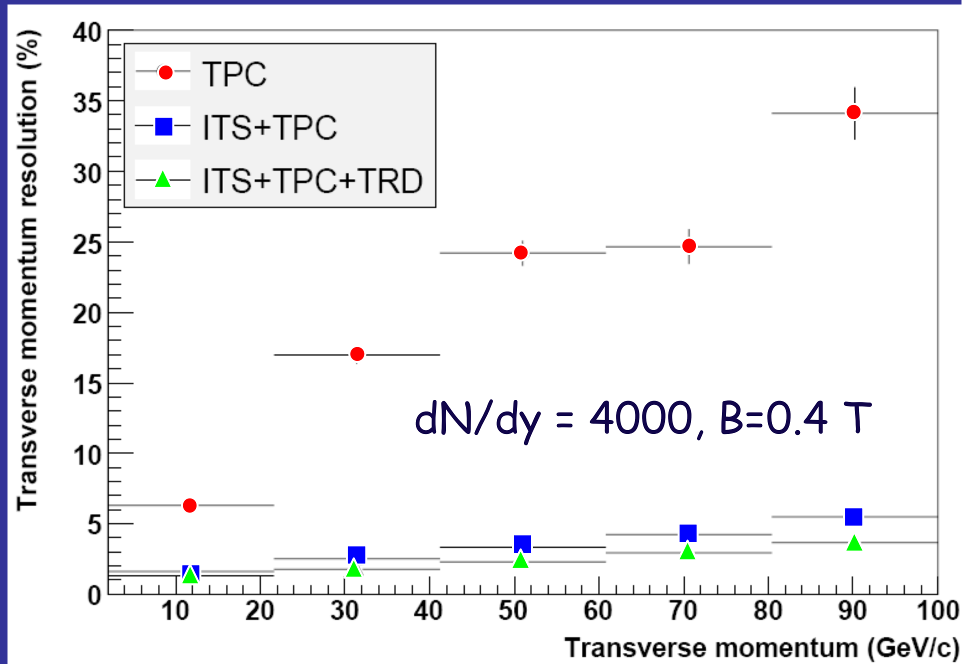
	Position resolution	Mass resolution	Momentum resolution	Efficiency
K^0_s	200÷300 μm	6÷8 MeV	1.5÷1.8%	21÷25%
Λ	~500 μm	3÷4 MeV	1.3%	15%

Tracking Performance

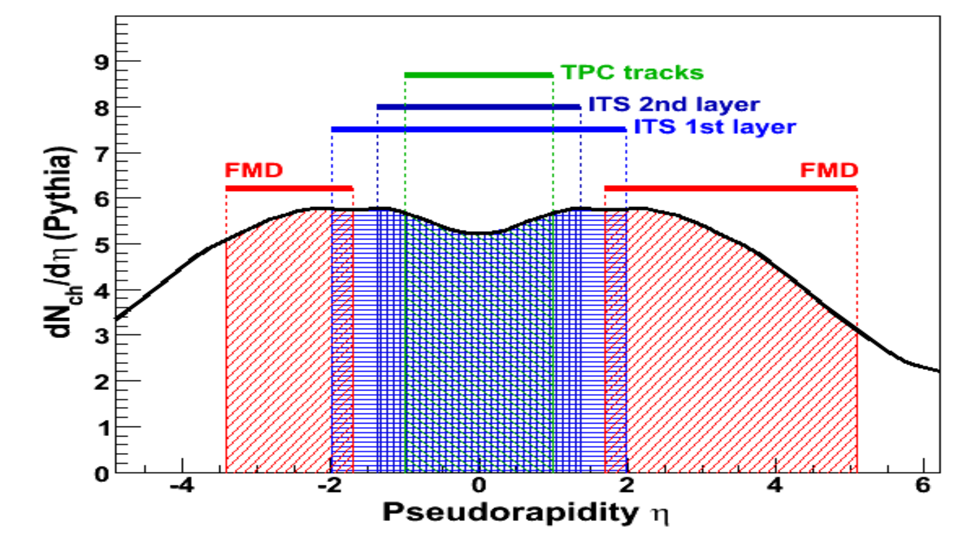


resolution ~ 5% at 100 GeV/c excellent performance in hard region!

For track densities dN/dy = 2000 - 4000, combined tracking efficiency well above 90% with <5% fake track probability



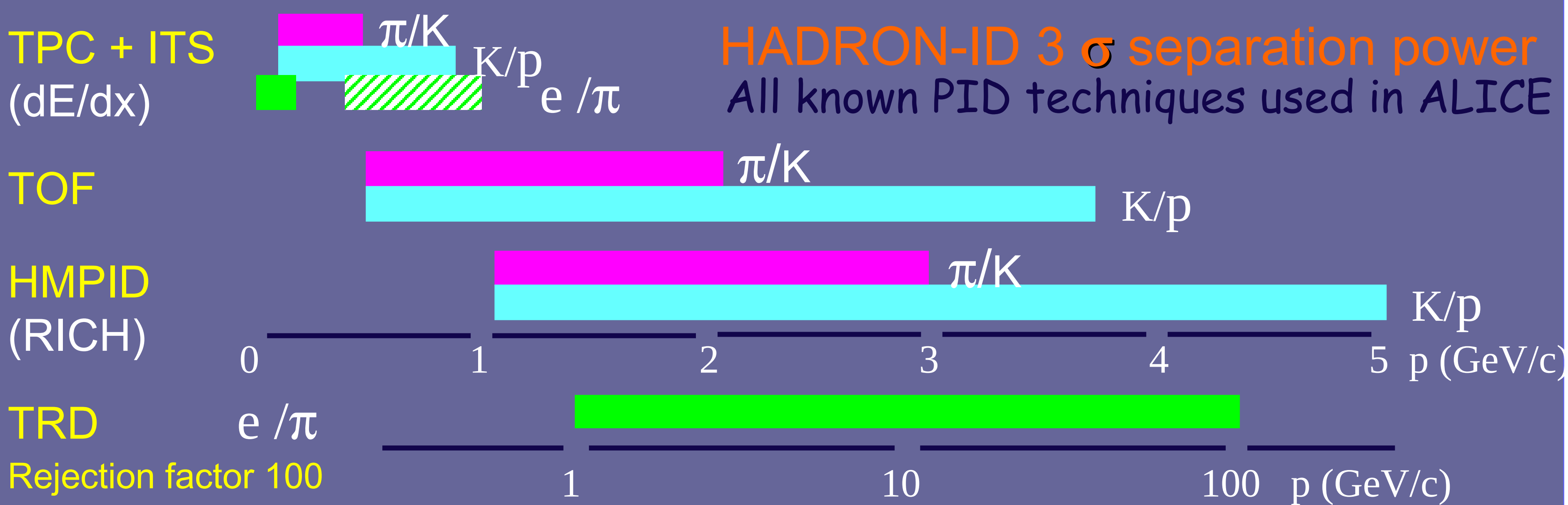
Multiplicity measurement

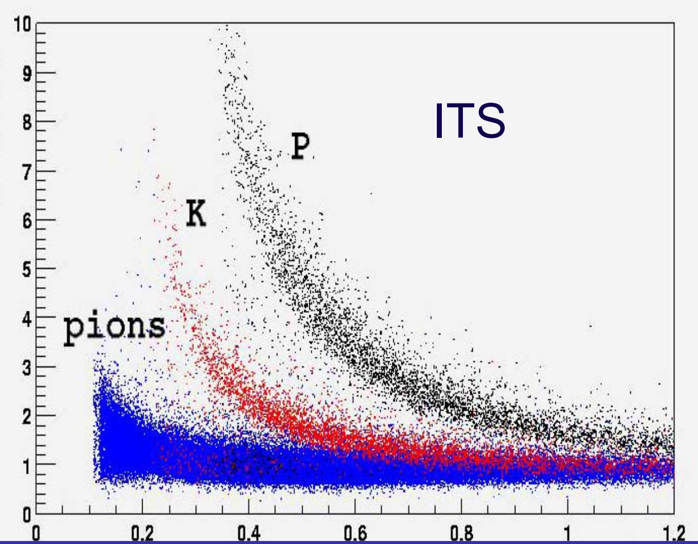


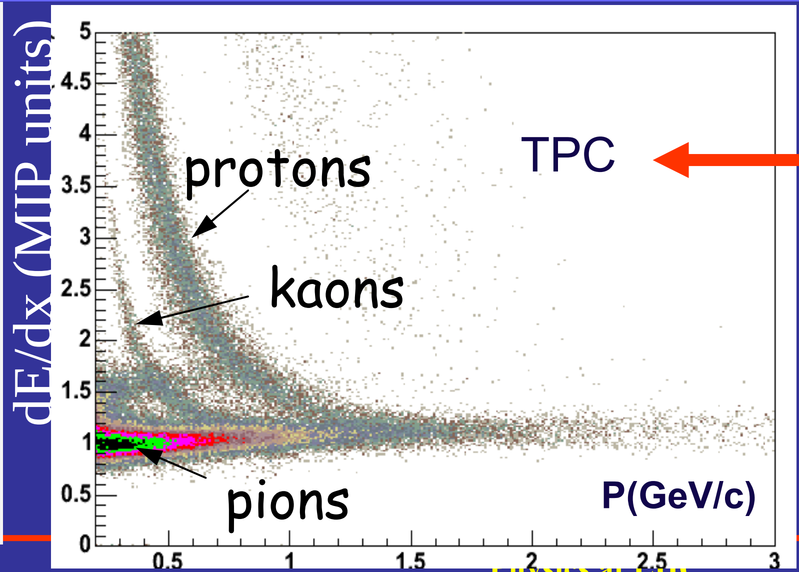
Redundant techniques:

- CLUSTERS on innermost ITS layers (Silicon Pixels)
- TRACKLETS with 2 innemost layers of ITS (Silicon Pixels)
- FULL TRACKING (ITS+TPC)
- ENERGY DEPOSITION in the pads of Forward Multiplicity Detector (FMD)

Charged Particle Identification

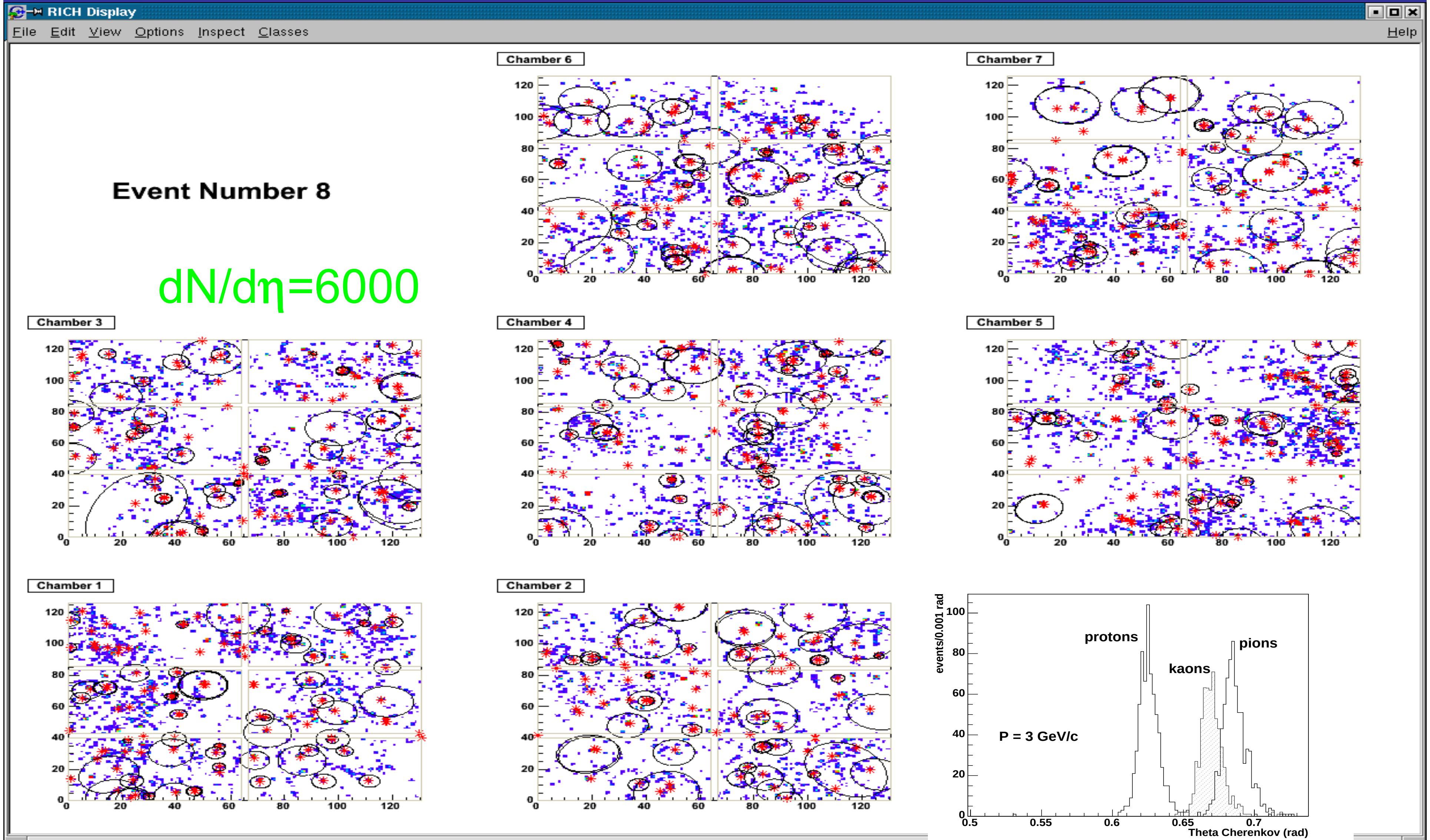




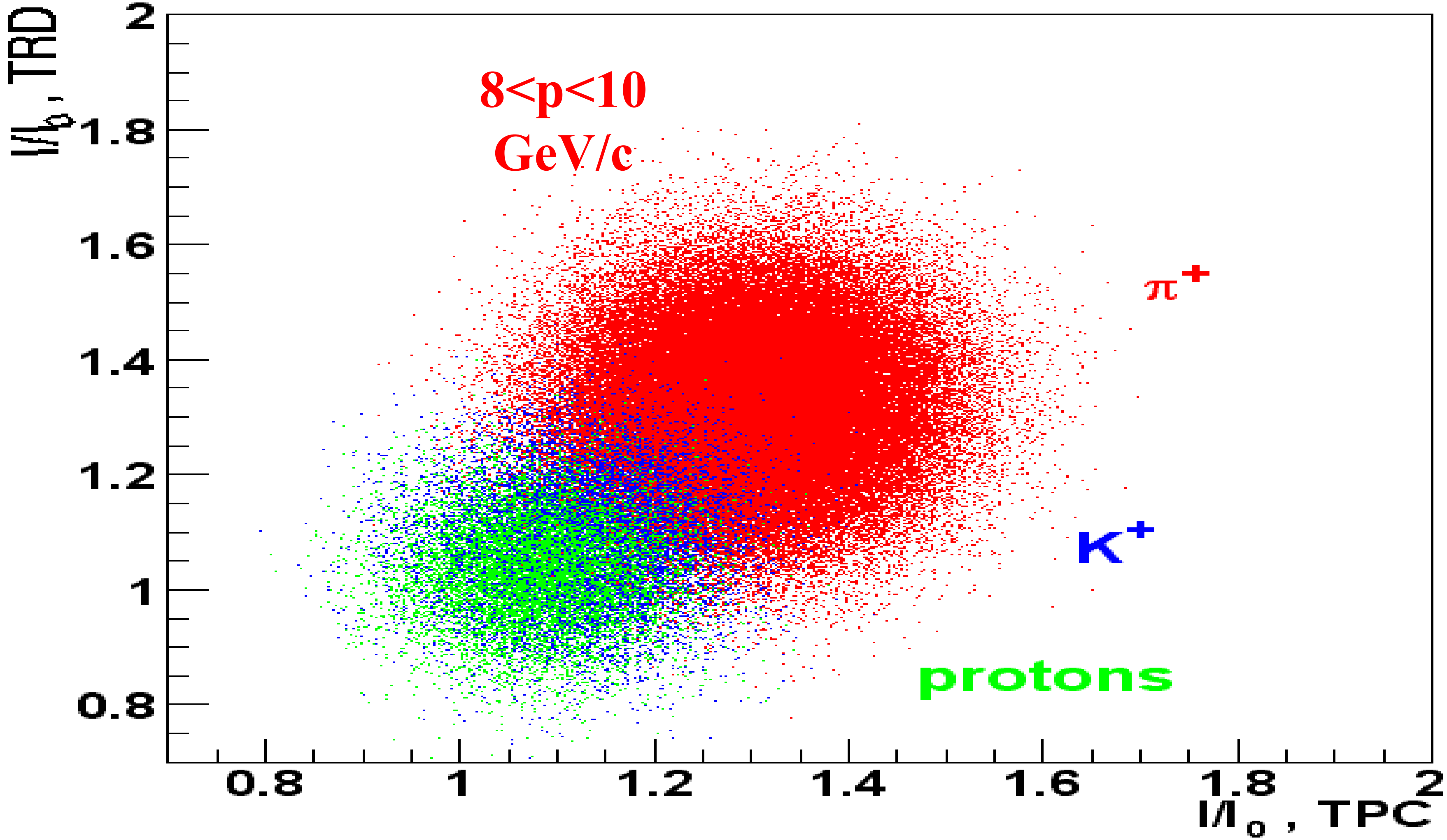


$\sigma_{dE/dx}$ = 6.8% at dN/dy=8000 (5.5% for isolated tracks)

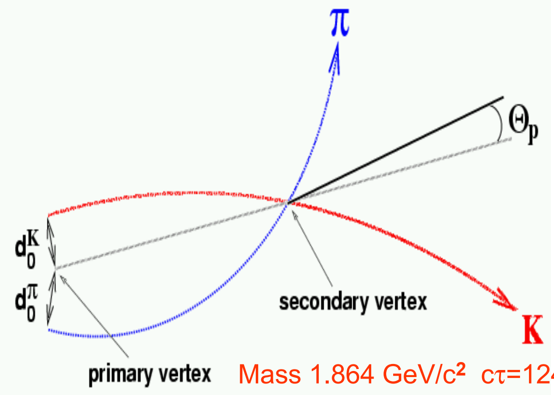
Example of a high multiplicity event as seen by the HMPID

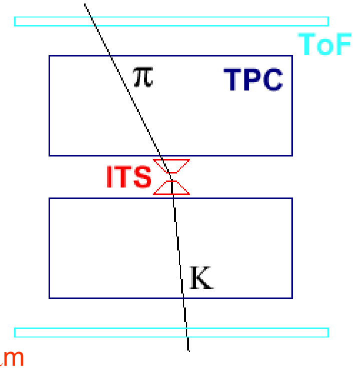


Extension of PID by dE/dx to higher momenta



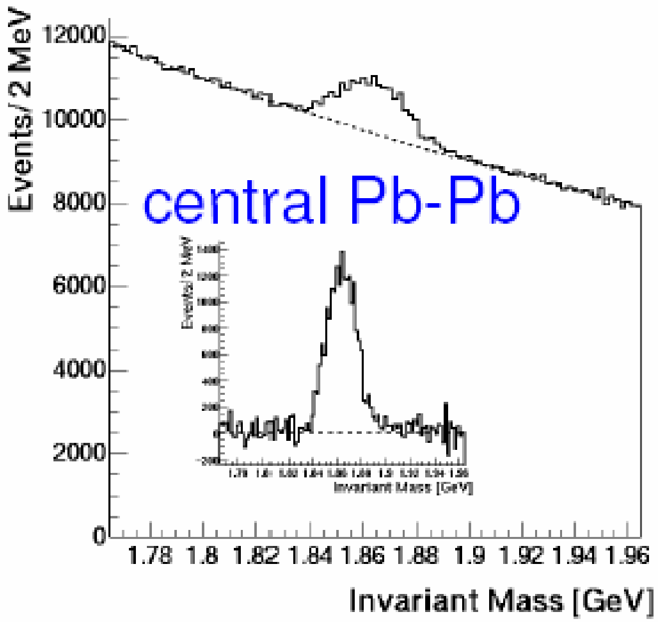
Open Charm Detection in Hadronic Decays





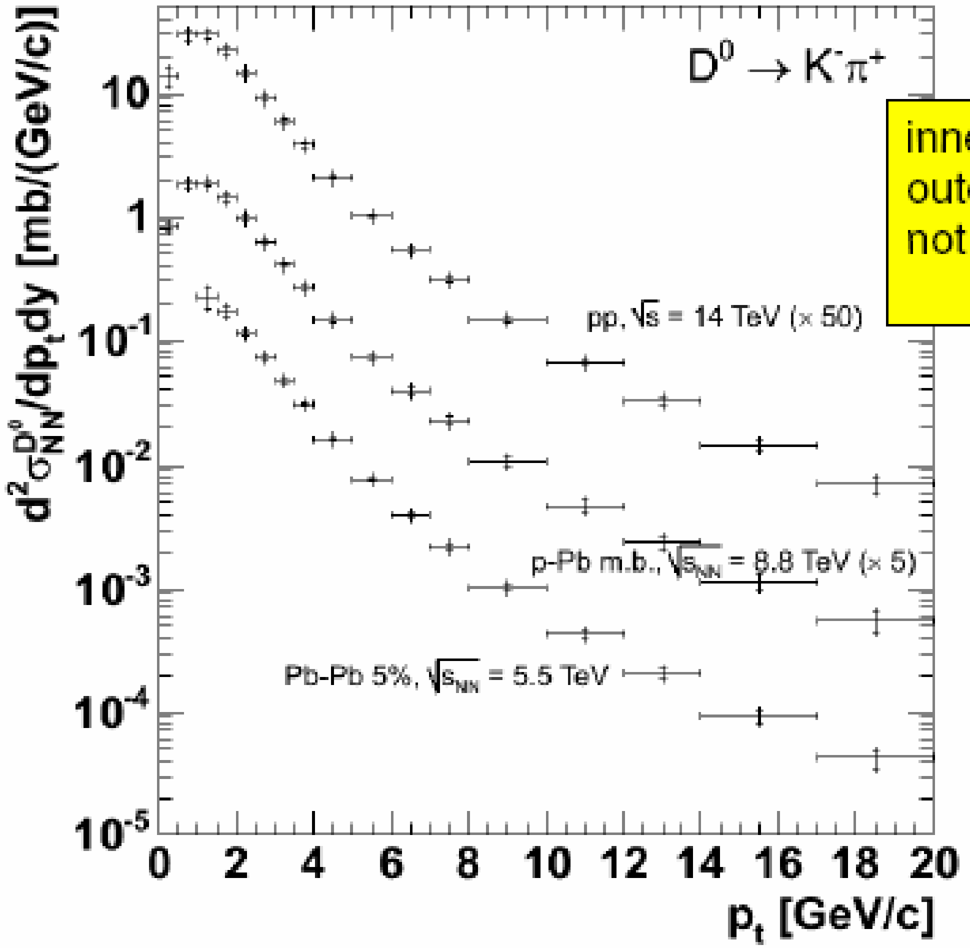
Mass 1.864 GeV/c² cτ=124 μm

~0.55 $D^0 \rightarrow K^-\pi^+$ accepted/event
important also for J/ψ normalization



	S/B initial (M±3σ)	S/B final (M±1σ)	Significance $S/\sqrt{S+B}$ (M±1σ)
Pb-Pb Central (dN_{ch}/dy = 6000)	$5 \cdot 10^{-6}$	10%	~35 (for 10^7 evts, ~1 month)
pPb min. bias	$2 \cdot 10^{-3}$	5%	~30 (for 10^8 evts, ~1 month)
pp	$2 \cdot 10^{-3}$	10%	~40 (for 10^9 evts, ~7 months)

Spectra



inner bars: stat. errors
outer bars: stat. ⊕ p_t-dep. syst.
not shown: 9% (Pb-Pb), 5% (pp, p-Pb) normalization errors

1 year at nominal luminosity
(10^7 central Pb-Pb events,
10^9 pp events)
+ 1 year with 1month of p-Pb running
(10^8 p-Pb events)

Down to p_t ~ 0 in pp and p-Pb (1 GeV/c in Pb-Pb)
→important to go to low p_T for charm cross-section measurement

Conclusion