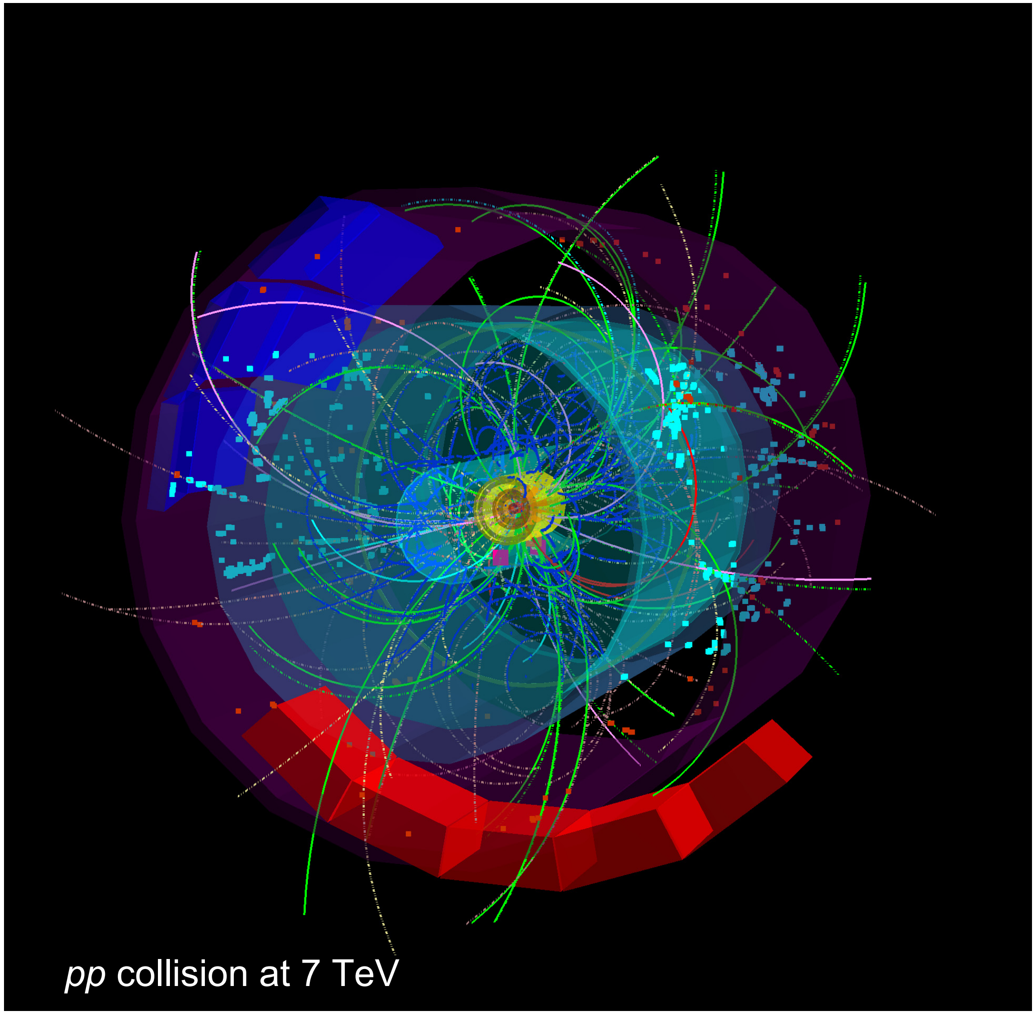


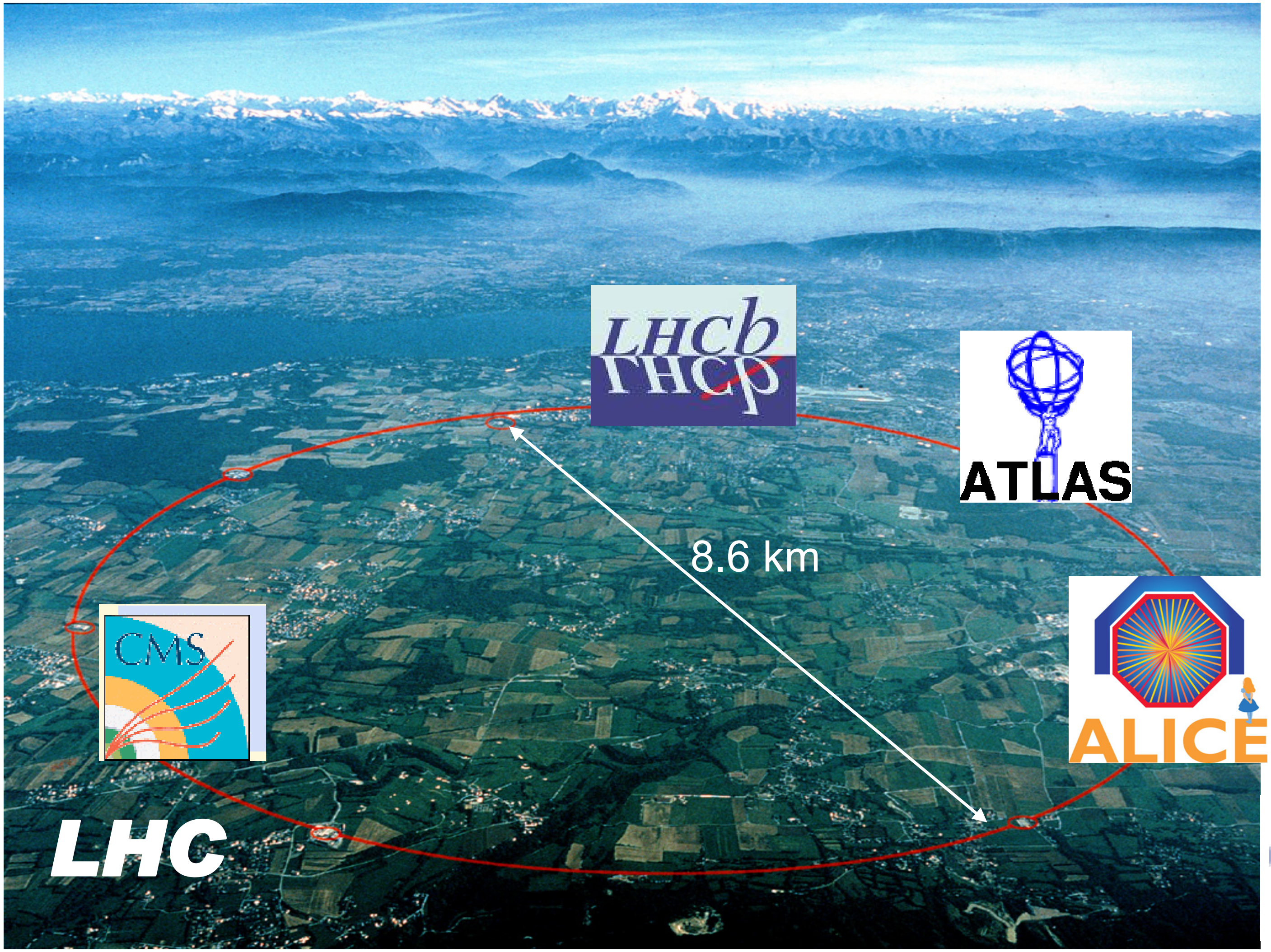
pp collision at 7 TeV

First Physics with ALICE

Harald Appelshäuser
for the
ALICE Collaboration

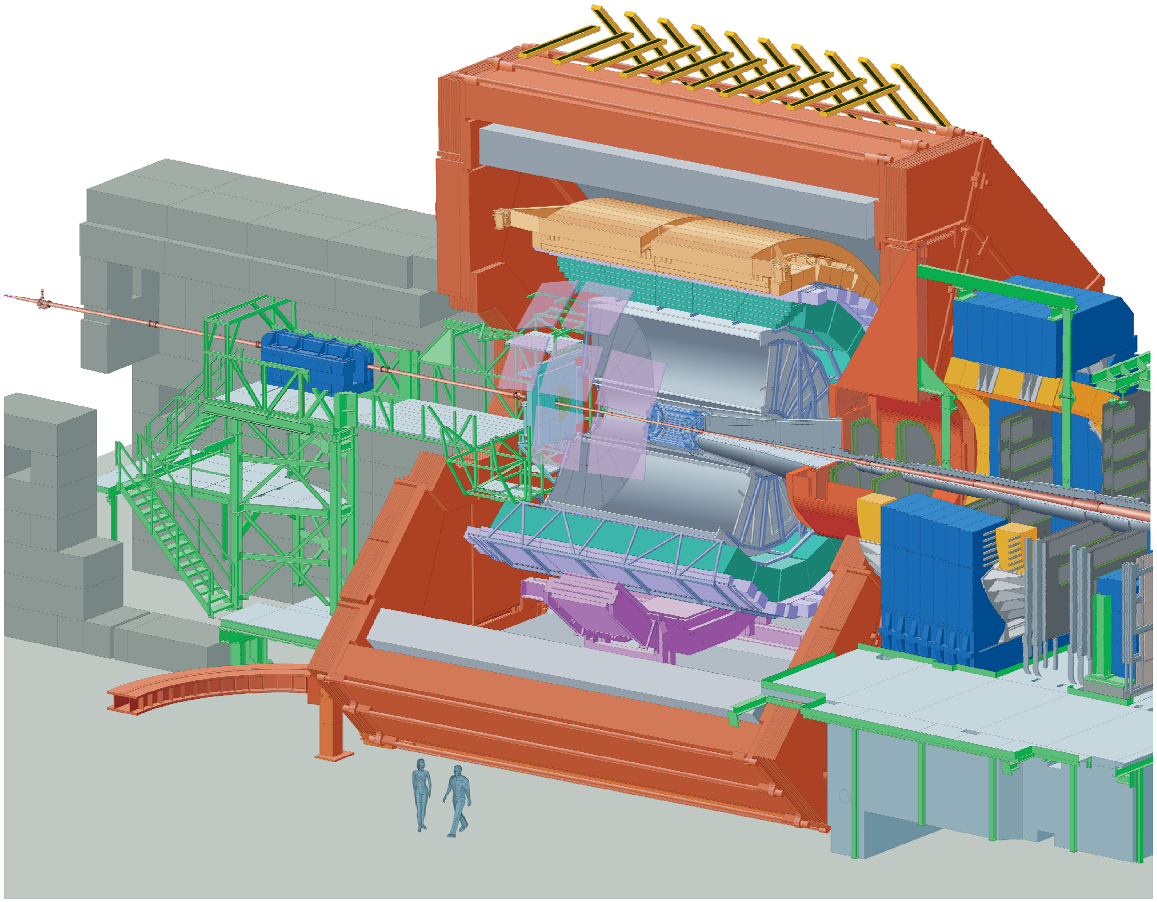
Institut für Kernphysik
Goethe-Universität Frankfurt

CERN Large Hadron Collider



- 4 large experiments
- ALICE dedicated to heavy-ion physics

ALICE



Central Detectors:

Inner Tracking System	100%
Time Projection Chamber	100%
Time-of-Flight	100%
Transition Radiation Detector*	39%

Spectrometers:

RICH	100%
Photon Multiplicity	100%
Forward Multiplicity	100%
Photon Spectrometer	60%
Muon Spectrometer	100%

Calorimeters:

Zero Degree Calorimeter	100%
EM Calorimeter*	36%

Trigger:

Trigger Detectors	100%
pp High-Level-Trigger	100%

*upgrade to the original setup

commissioning and calibration

2008 | 2009

2008: 01 02 03 04 05 06 07 08 09 10 11 12 | 2009: 01 02 03 04 05 06 07 08 09 10 11 12

detector installation → calibration (24/7 cosmics DAQ) → detector installation → calibration (24/7 cosmics DAQ, ~500 M events) → pp

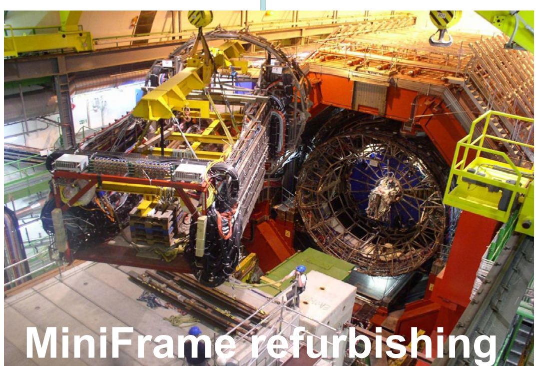
First particles from machine
15.6.08

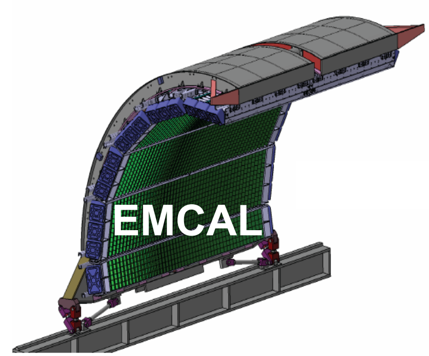
1st Circulating beam
10.9.08

LHC „incident"
11.9.08

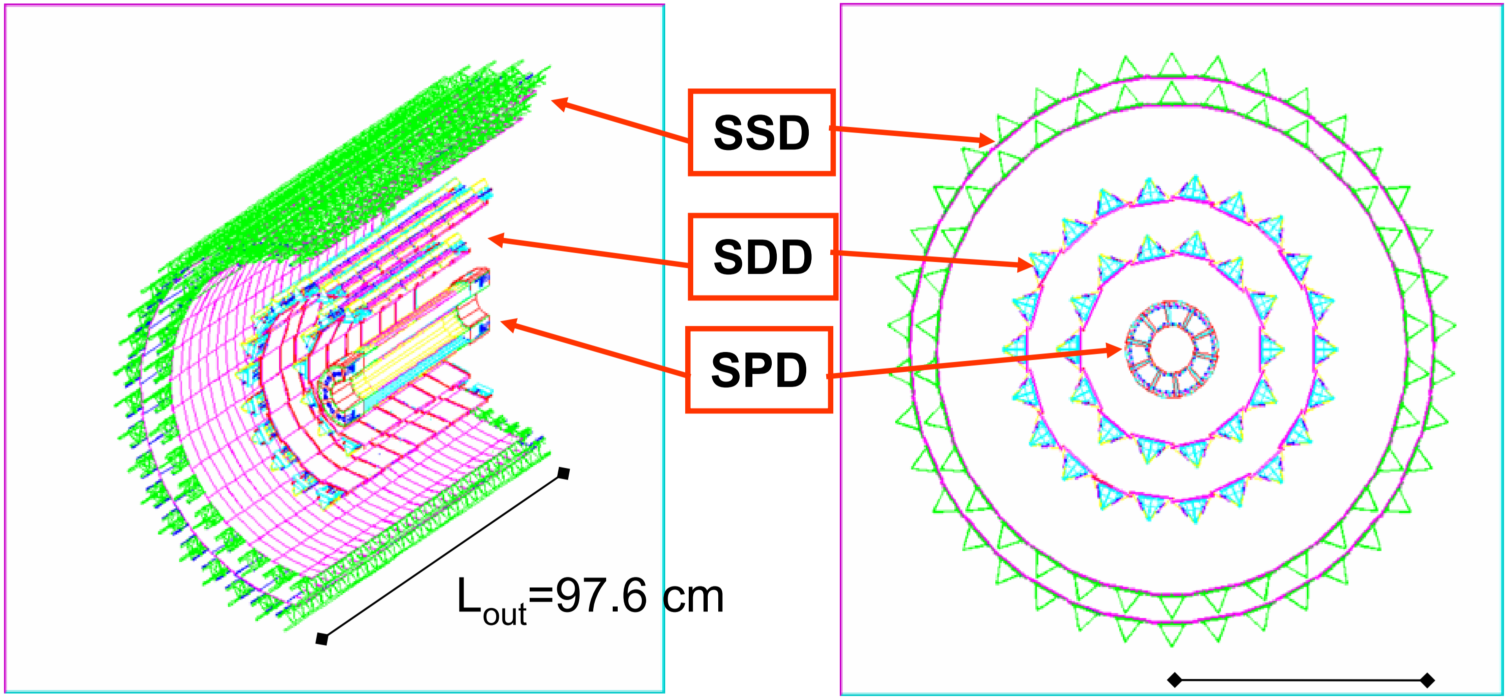
LHC back
15.7.09

first collisions
23.11.09



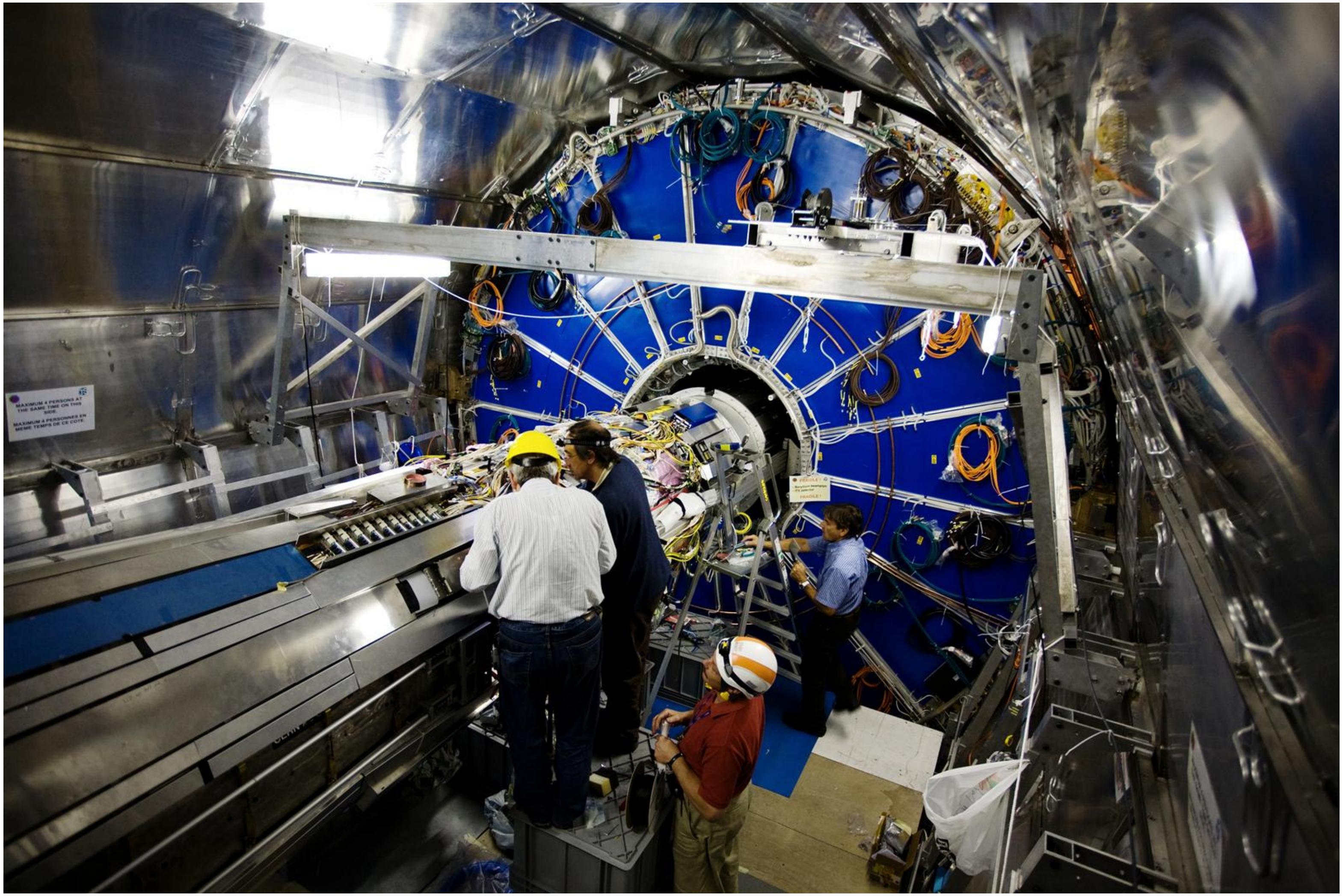


Inner Tracking System ITS



6 Layers, three technologies (keep occupancy ~constant ~2% for max mult)
- Silicon Pixels (0.2 m^2, 9.8 M channels, starting at r = 3.9 cm))
- Silicon Drift (1.3 m^2, 133 k channels)
- Silicon Strip (4.75 m^2, 2.6 M channels)
- Material Budget ~ 1% X/X_0 per layer

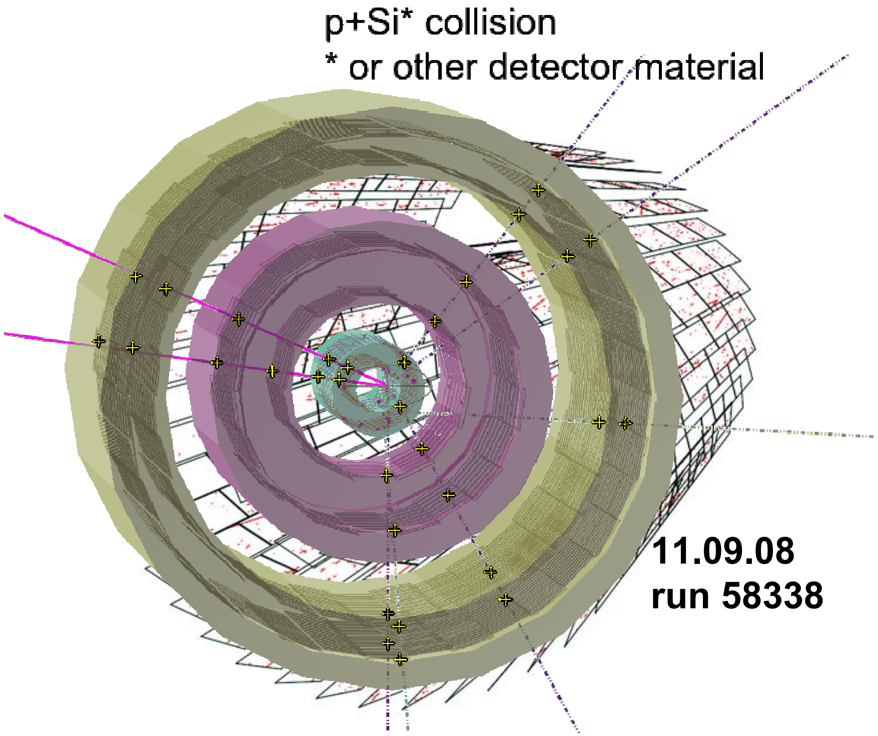
Inner Tracking System ITS



Inner Tracking System ITS

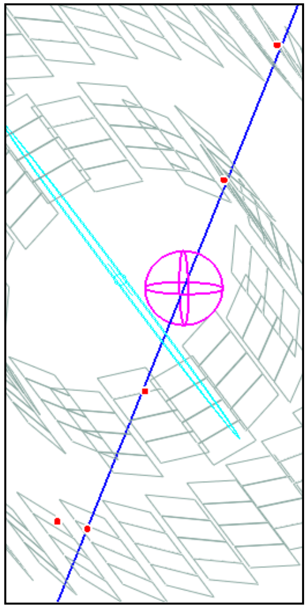
on June 15, 2008 the SPD has seen the first sign of life during the beam injection test…

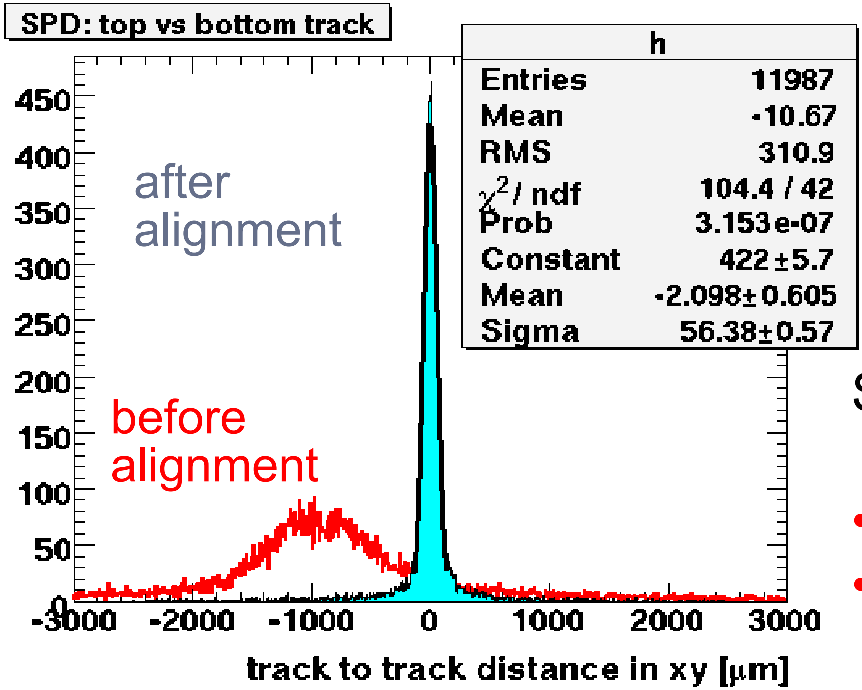
…and the first collision on Sept. 11, 2008!



ITS calibration

alignment with cosmic tracks



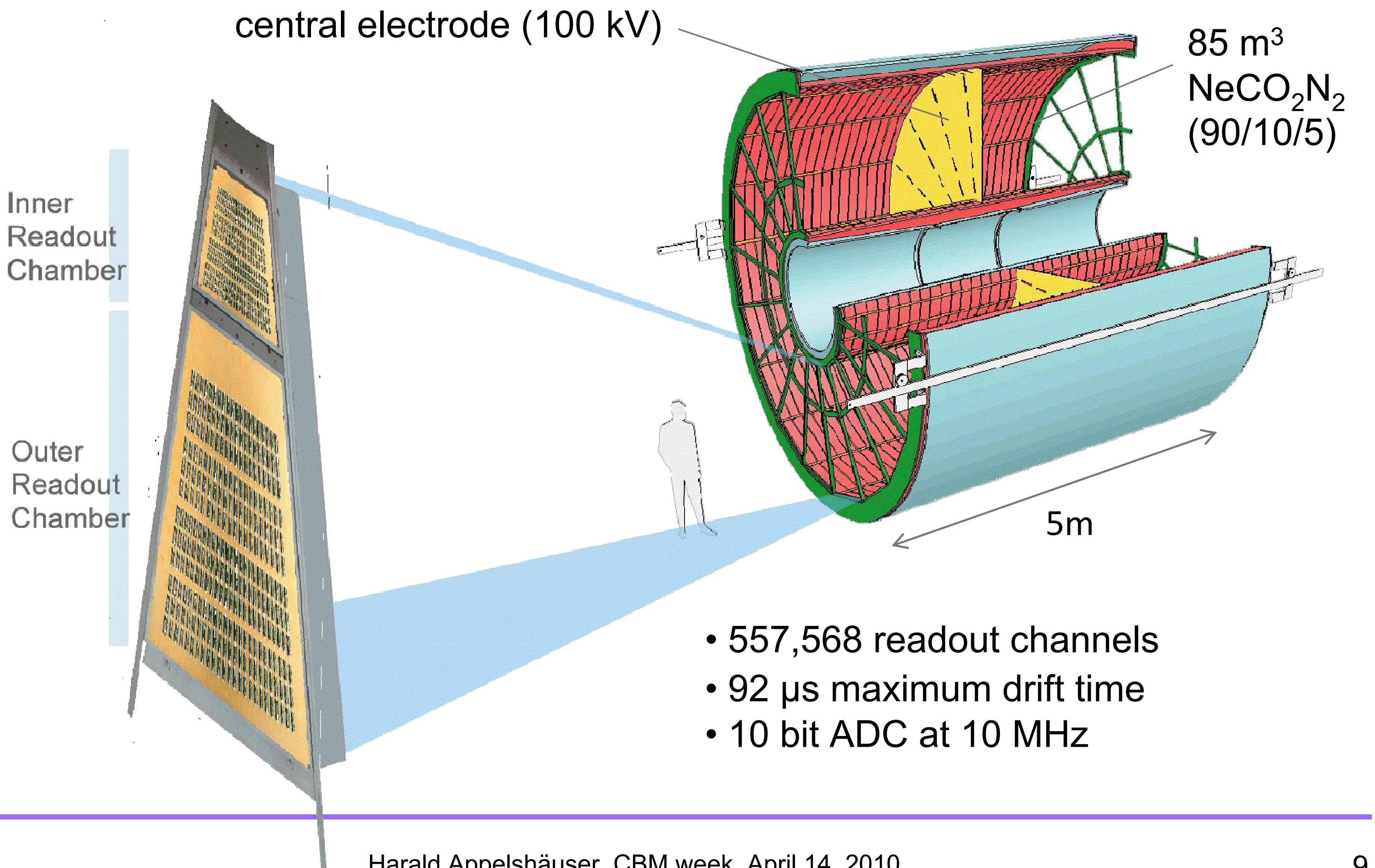


SPD alignment:

- $\sigma_{r\varphi} \approx 12\ \mu m$
- impact parameter resolution $\sigma \sim 56\ \mu m$
- misalignment < 10 μm

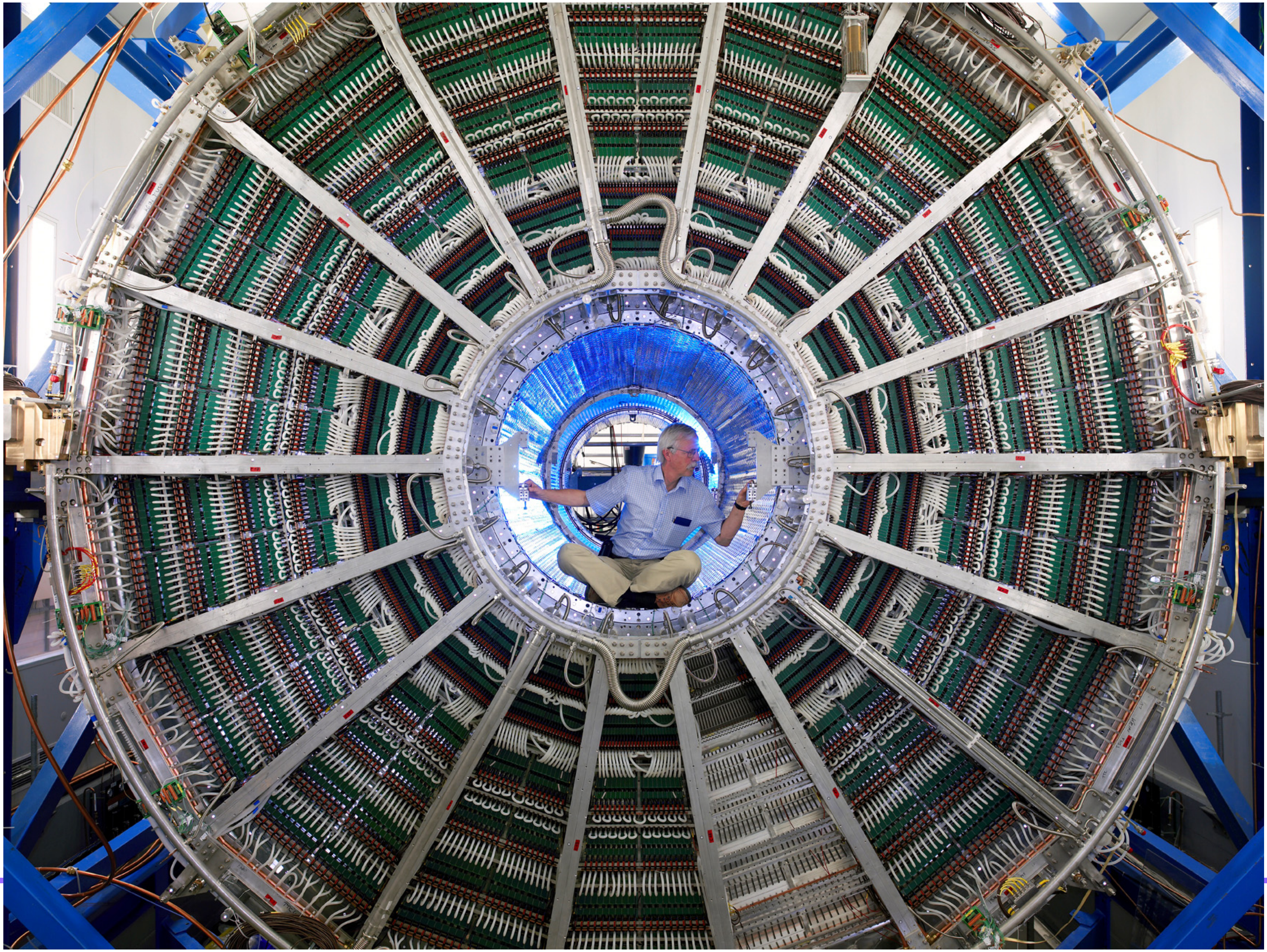
→ close to design values

Time Projection Chamber TPC



- 557,568 readout channels
- 92 µs maximum drift time
- 10 bit ADC at 10 MHz

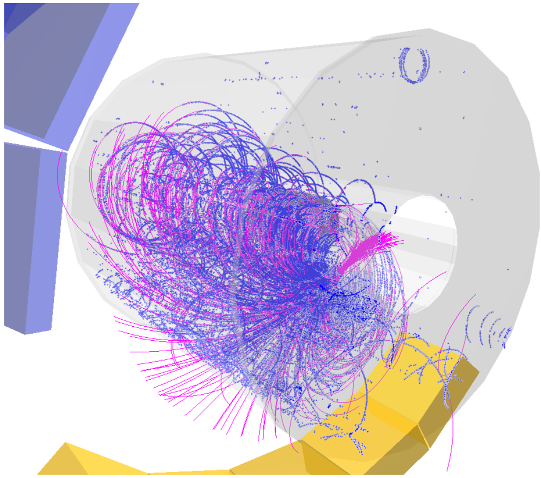
Time Projection Chamber TPC



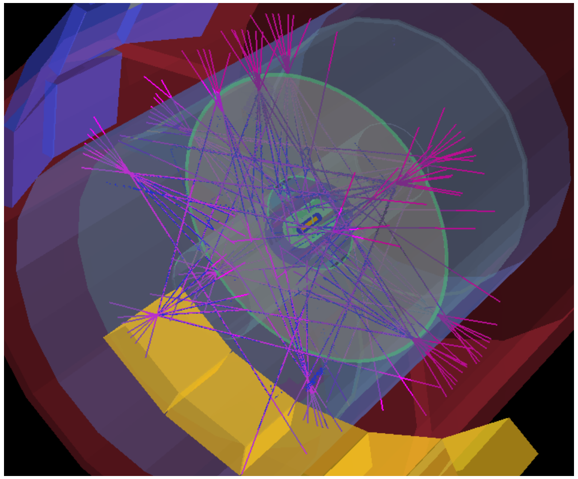
TPC calibration

- TPC installed in ALICE since 2007, running continuously from May to October 2008 and August to December 2009
- >750 million events (cosmics, krypton, and laser) recorded, with and without B
- first round of calibrations (dE/dx, momentum, alignment, gain) completed before collisions

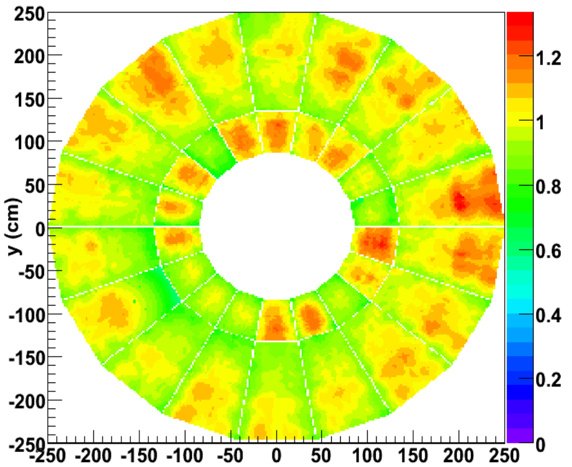
cosmic shower event



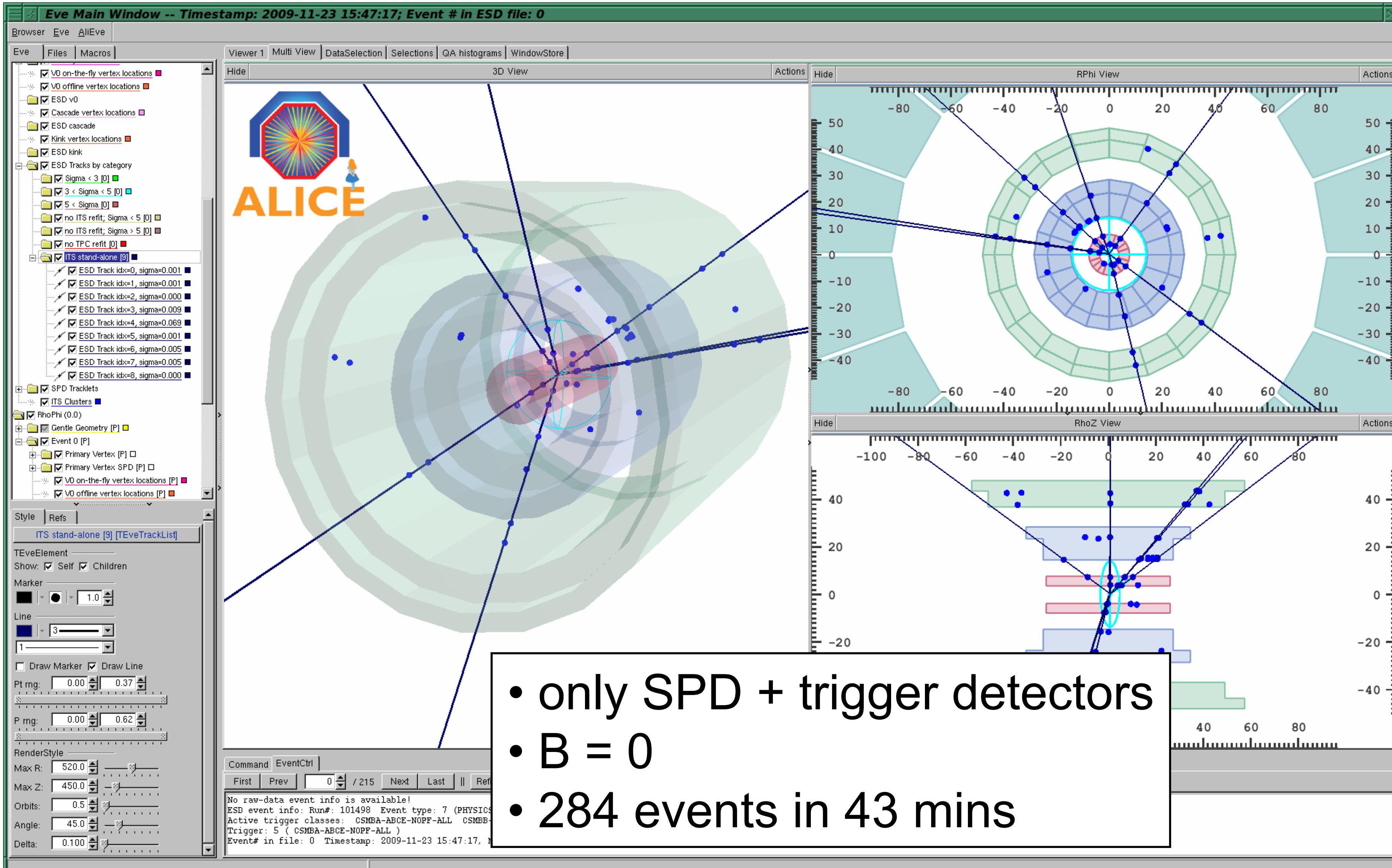
laser event



^{83}Kr gain map



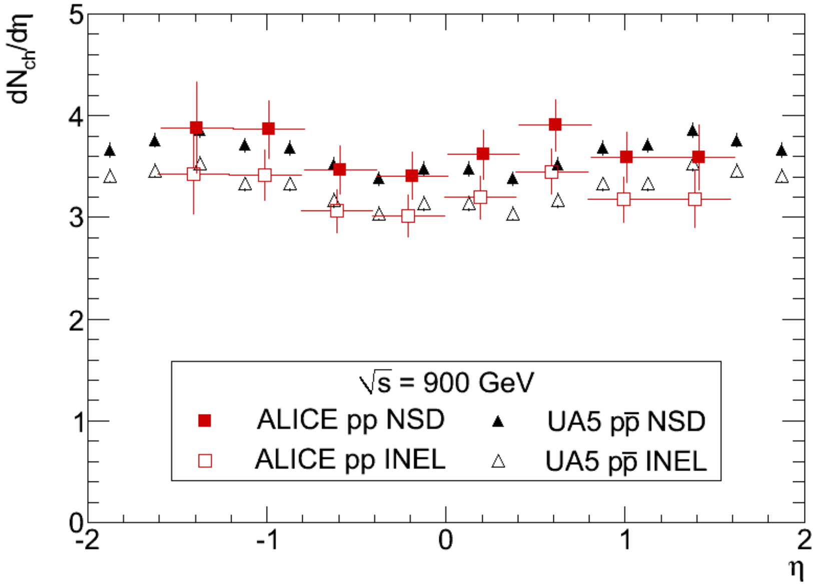
first collision on Nov. 23 2009



- only SPD + trigger detectors
- B = 0
- 284 events in 43 mins

first LHC physics paper Nov. 28 2009

…sufficient to measure $dN_{ch}/d\eta$

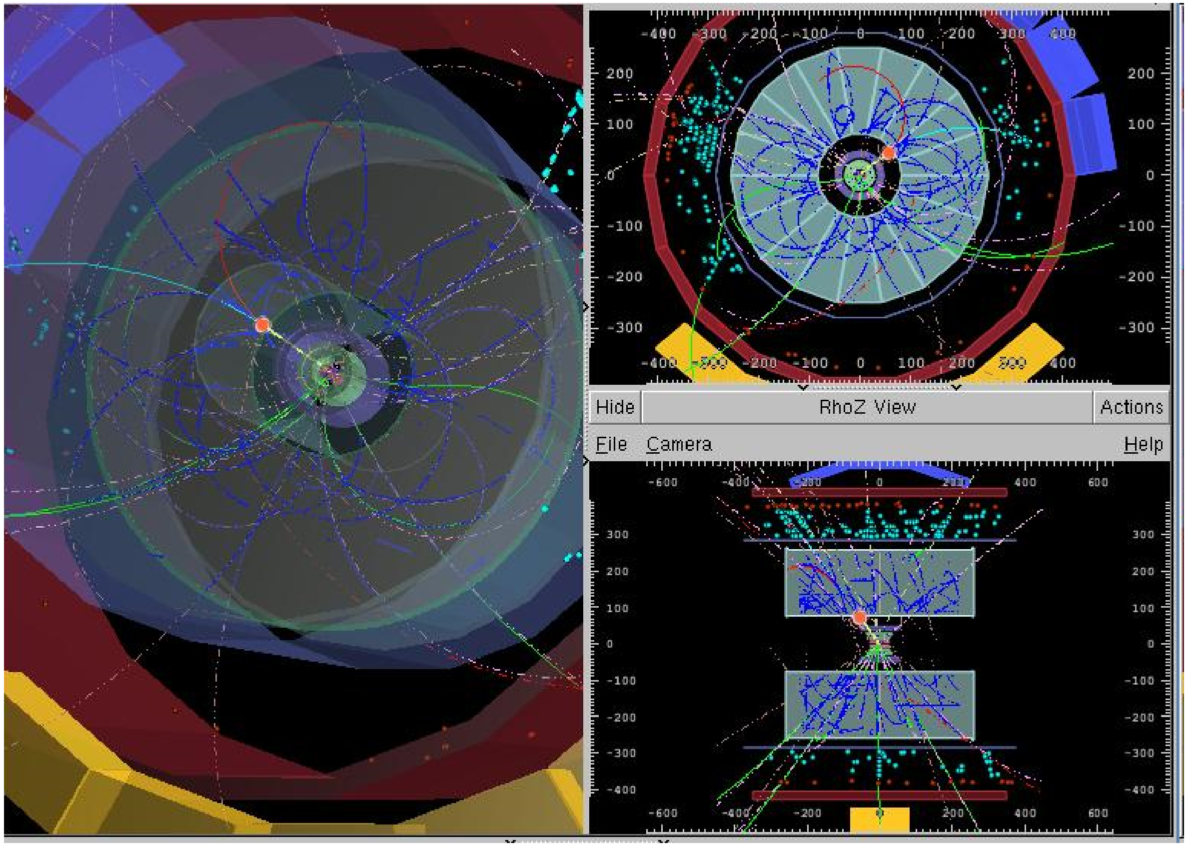


→ first LHC physics paper
submitted on Nov. 28 2009

ALICE Collaboration
Eur.Phys.J.C65:111-125,2010

ALICE in full glory

- on Dec. 6 2009, *stable beams* declared
  → switch on all ALICE detectors



until Dec. 14:

- ~300k pp events at 900 GeV recorded with B=0.5 T and all ALICE detectors included!
- ~40k pp events at 2.36 TeV SPD only

→ detailed detector validation and first physics analysis

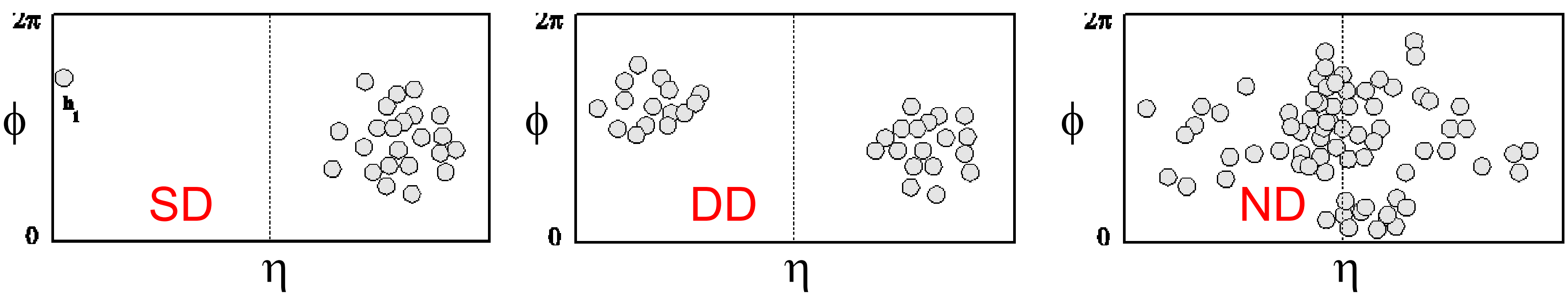
ALICE First Physics

- charged particle density $dN_{ch}/d\eta$ in pp at 0.9 and 2.36 TeV
- multiplicity distributions $P(N_{ch})$ in pp at 0.9 and 2.36 TeV
- transverse momentum dN_{ch}/dp_T distributions in pp at 0.9 TeV

→ characterize underlying event for rare observables
→ reference for PbPb

pp process fractions

$$\sigma_{total} = \sigma_{elastic} + \sigma_{single\text{-}diffractive} + \sigma_{double\text{-}diffractive} + \sigma_{non\text{-}diffractive}$$



- one of the protons remains intact
$\sigma_{SD}/\sigma_{INEL} = O(10\%)$

-„rapidity gap"
$\sigma_{DD}/\sigma_{INEL} = O(10\%)$

- central production
$\sigma_{ND}/\sigma_{INEL} = O(80\%)$

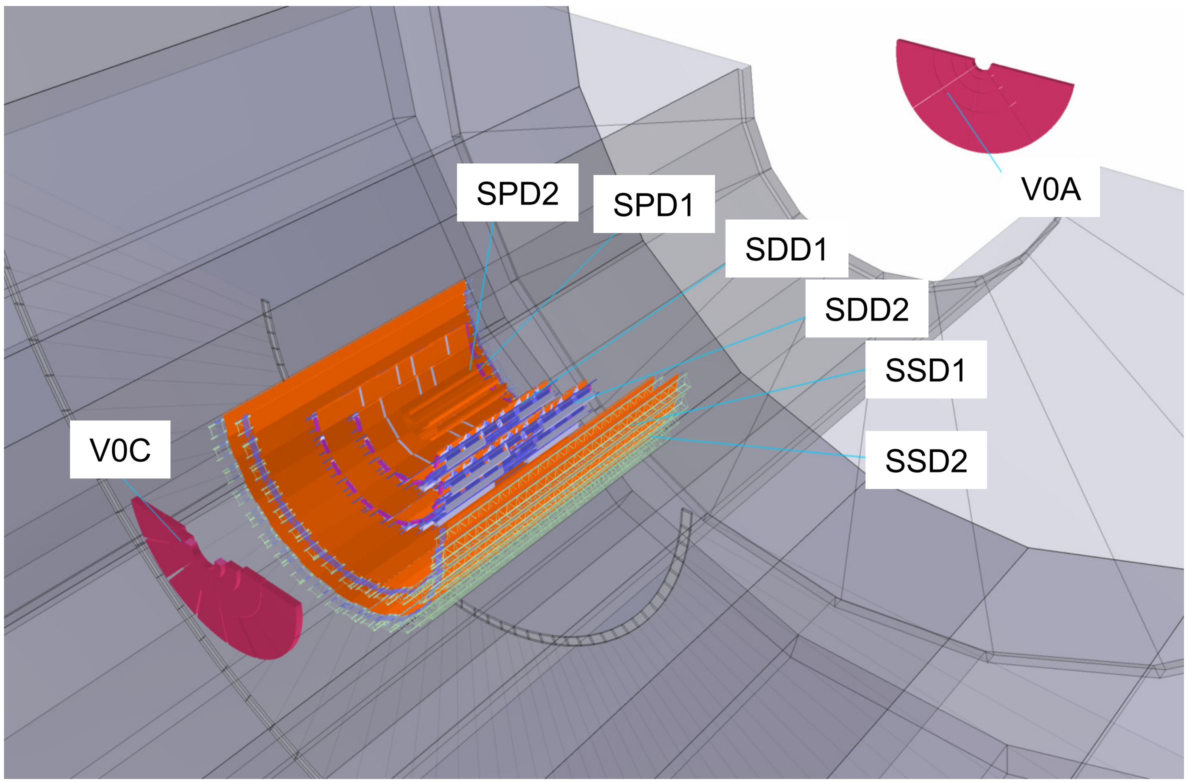
INEL

NSD

→ diffractive contribution is not well known

running conditions and trigger

LHC: up to 4x4 counterrotating bunches (~few 10^9 p each)
at injection energy (900 GeV)



- online trigger:
  coincidence of beam
  and MB_{OR}=SPD || V0A || V0C
  (coverage: 8 units in η!)

- interaction rate: few Hz

- offline event selection:
  INEL: MB_{OR}
  NSD: MB_{AND} = V0A && V0A

- no V0 in the 2.36 TeV run:
  → separate analysis,
  larger systematic errors

event selection efficiency

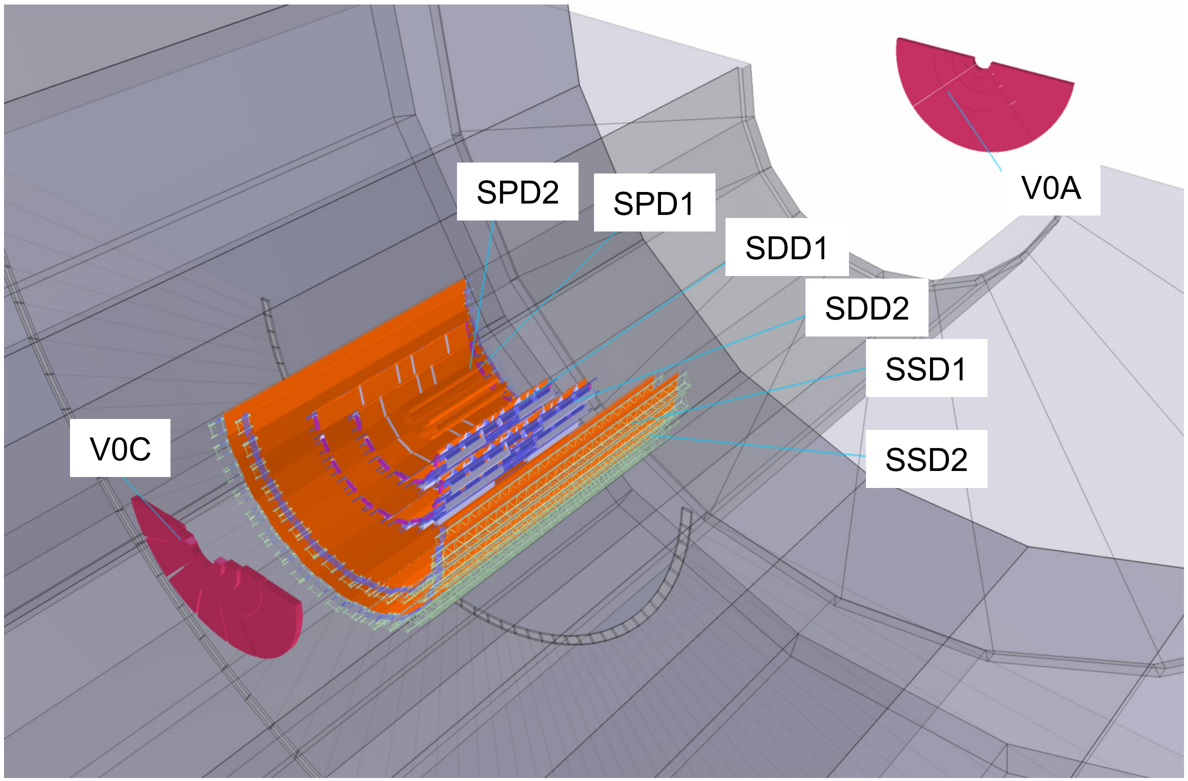
Event selection efficiencies determined from Monte Carlo:
(PYTHIA 6.4.14 (tune D6T) and PHOJET, folded with detector response)

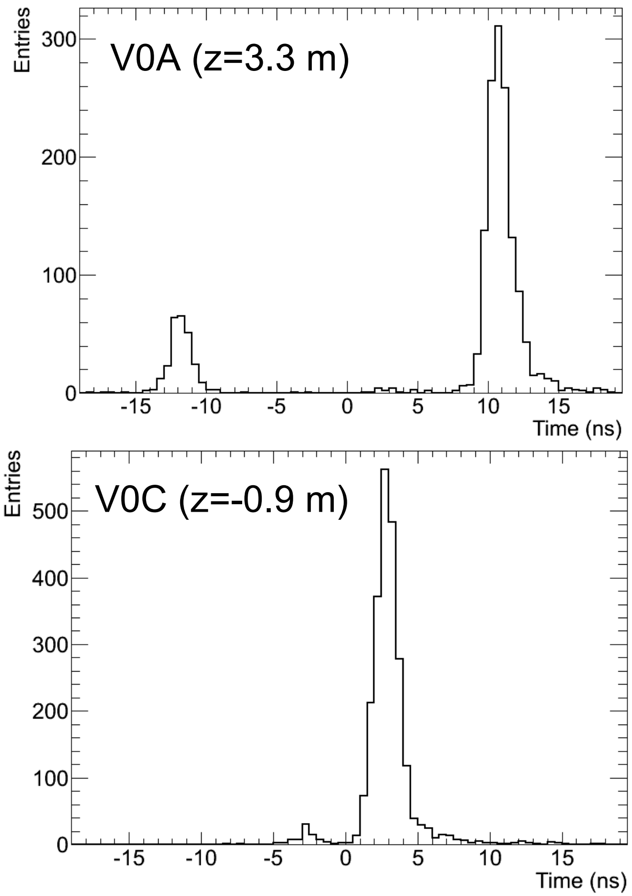
	SD	DD	ND	INEL	NSD
MB_{OR}:	77-86%	92-98%	100%		
MB_{AND}:	29-34%	49-77%	96-98%		

→ dominates final systematic uncertainties

beam-induced background

- timing information from V0A and V0C



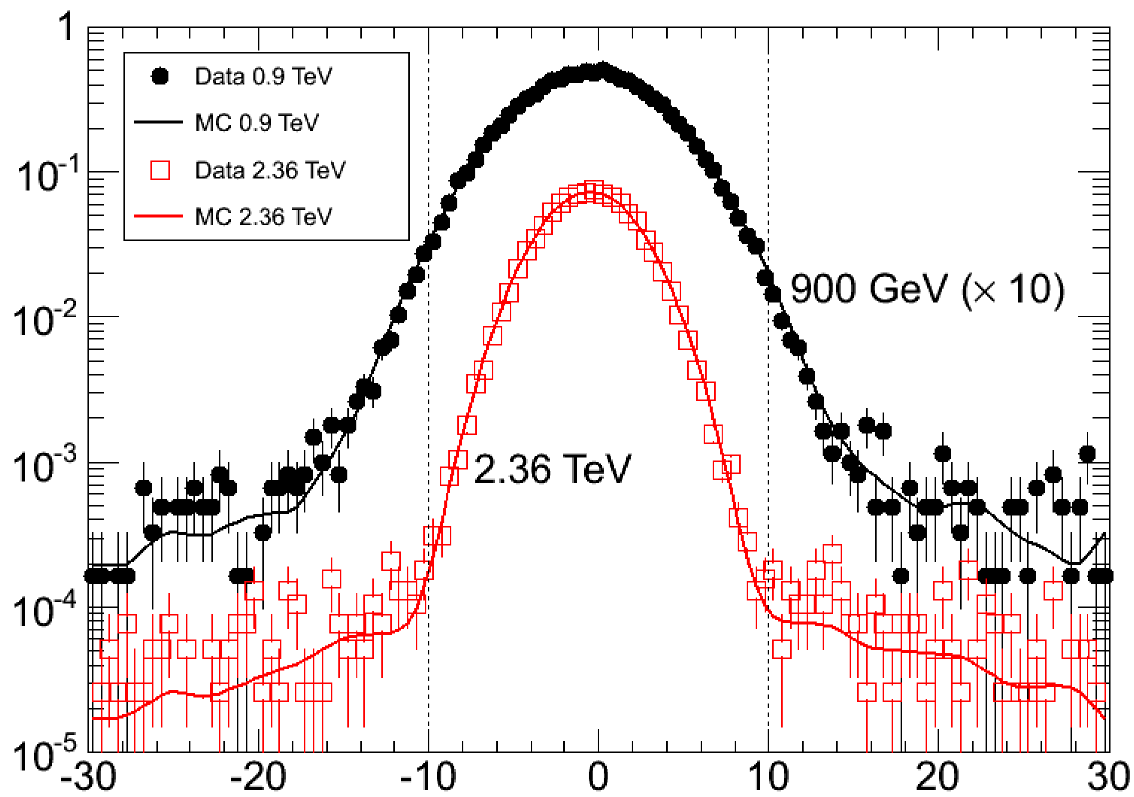


ALICE Collaboration Eur.Phys.J.C65:111-125 (2010)

vertex reconstruction

tracklets are formed from hits in SPD1 and SPD2

→ common vertex is reconstructed in 83% (MB_{OR}) resp. 93% (MB_{AND}) of the events.

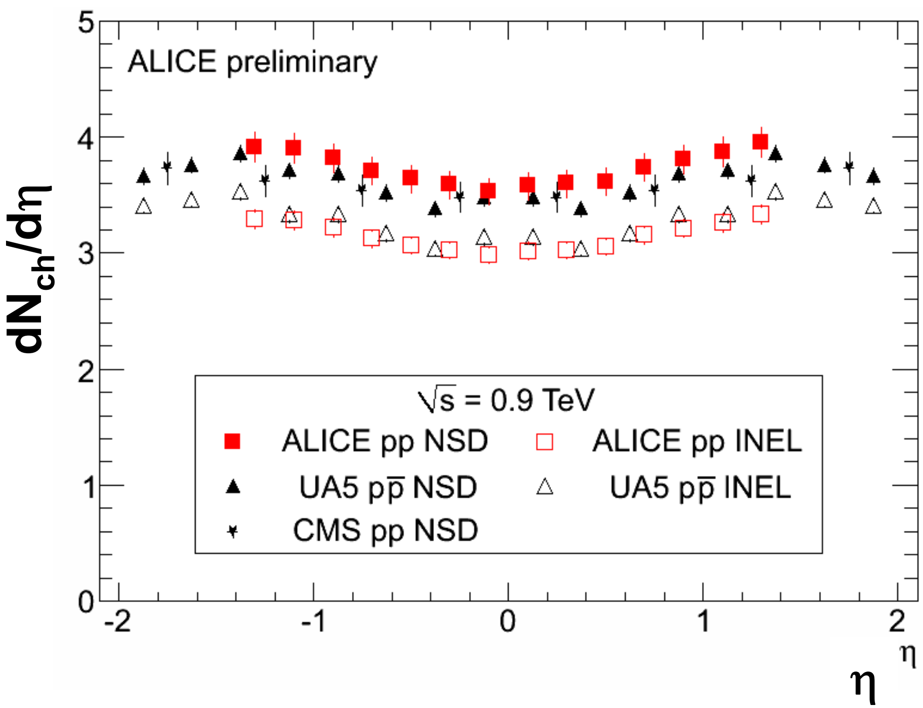


Resolution: 0.1-0.3 mm (longitudinal), 0.2-0.5 mm (transverse)

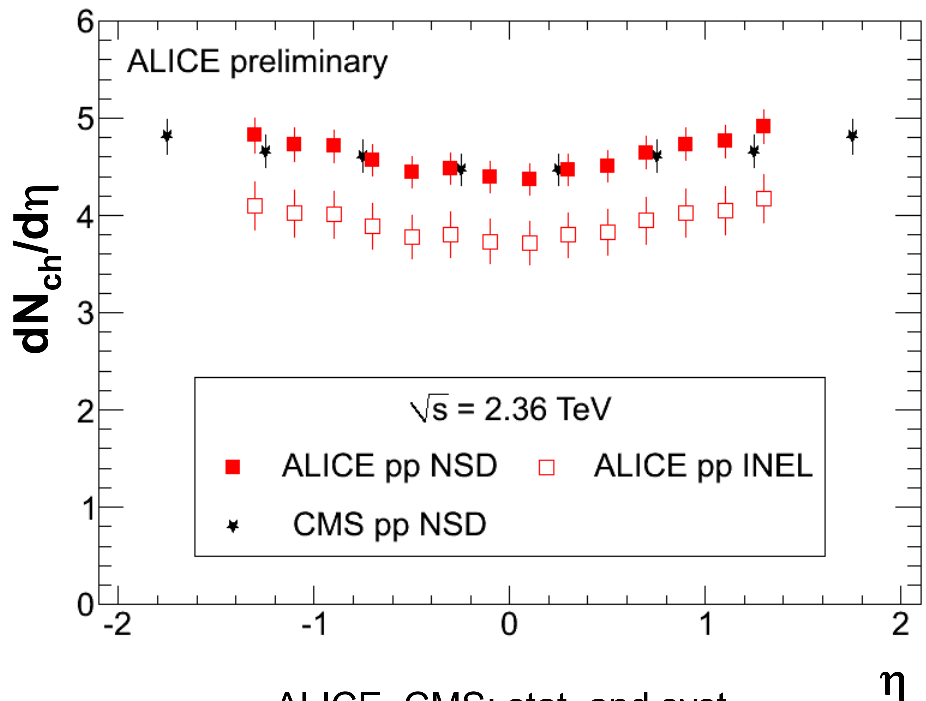
$dN_{ch}/d\eta$

Jan Fiete Grosse Oetringhaus (CERN), Rencontres de Moriond 2010

$\sqrt{s}$ = 900 GeV



$\sqrt{s}$ = 2.36 TeV



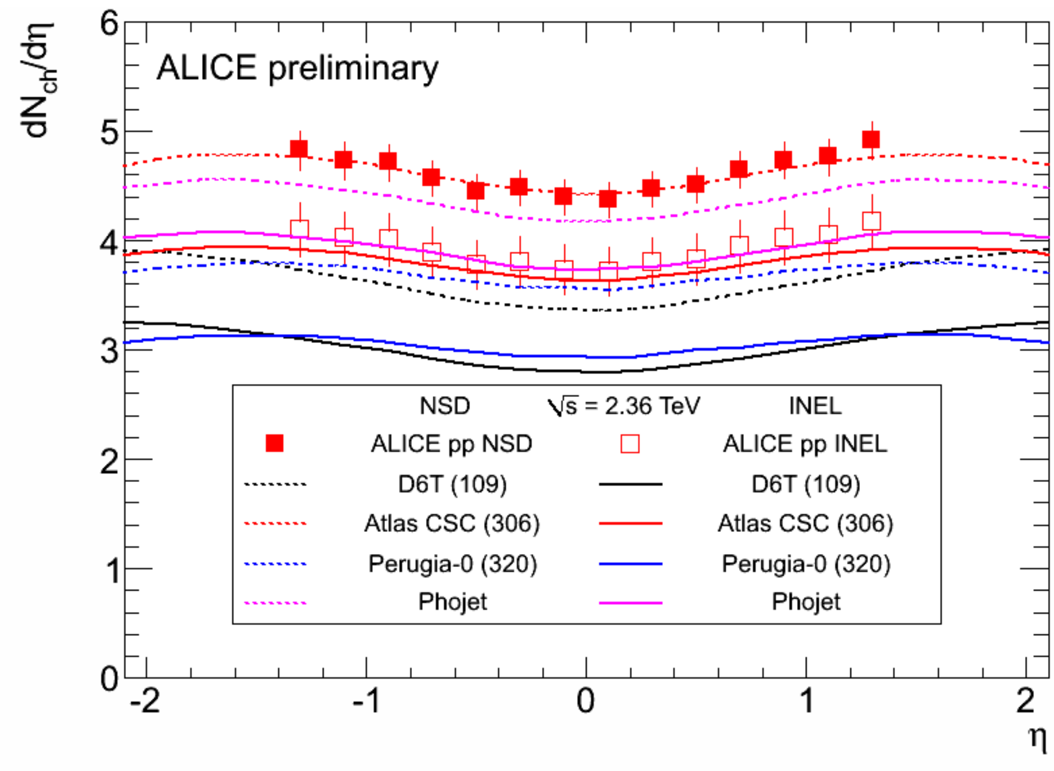
- ALICE, CMS: stat. and syst. uncertainty added quadratically

- good agreement between ALICE, CMS, UA5

- CMS data points do not include charged leptons → ~1.5 % difference

$dN_{ch}/d\eta$

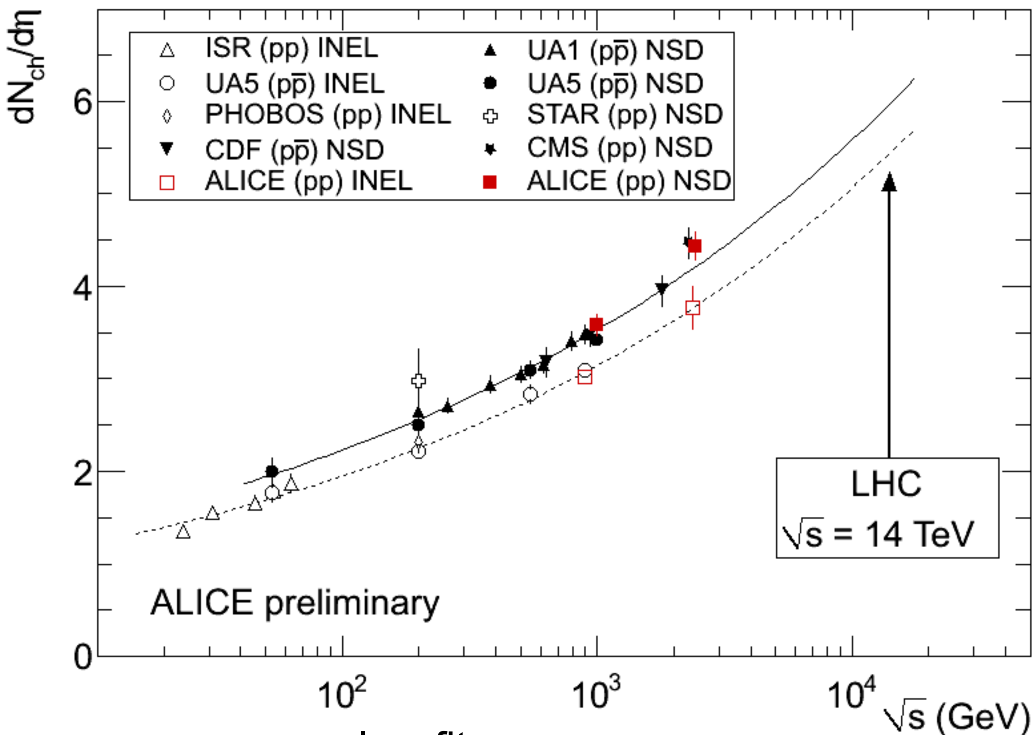
√s = 2.36 TeV



- some of the models (tunes) fail considerably to describe the data

$dN_{ch}/d\eta$

Jan Fiete Grosse Oetringhaus (CERN), Rencontres de Moriond 2010



curve: power law fit

→ stronger-than-expected increase with $\sqrt{s}$ as reported by CMS

Increase from 0.9 to 2.36 TeV

	in %	INEL	NSD
	ALICE prel.	**24.8 $^{+6.1}_{-3.0}$**	**24.0 $^{+3.9}_{-1.3}$**
	CMS		**28.4 ± 3.0**
Pythia	**D6T**	**19.7**	**18.7**
	ATLAS CSC	**19.2**	**18.3**
	Perugia-0	**19.6**	**18.5**
	Phojet	**17.5**	**14.5**

→ stronger energy dependence of particle production than expected from models!

multiplicity distributions

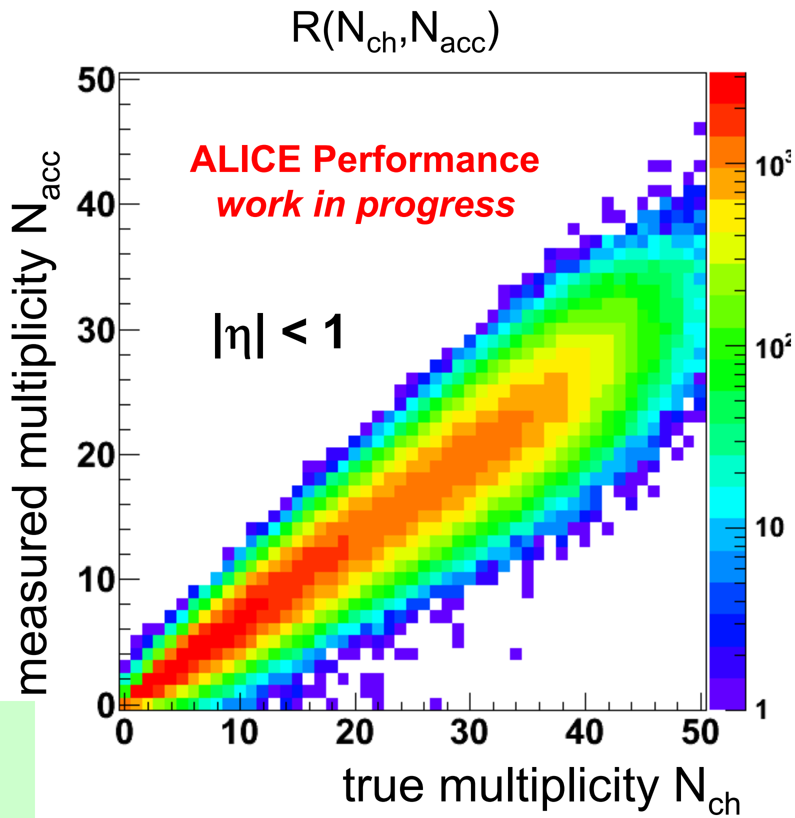
$$P(N_{ch}) = \frac{\#\text{ events with multiplicity } N_{ch}}{\text{all events}}$$

BUT: measured distribution $P(N_{acc})$ does not correspond to $P(N_{ch})$, rather

$$P(N_{acc}) = \Sigma_{Nch}\, R(N_{ch},N_{acc}) \cdot P(N_{ch})$$

→ unfolding procedure:

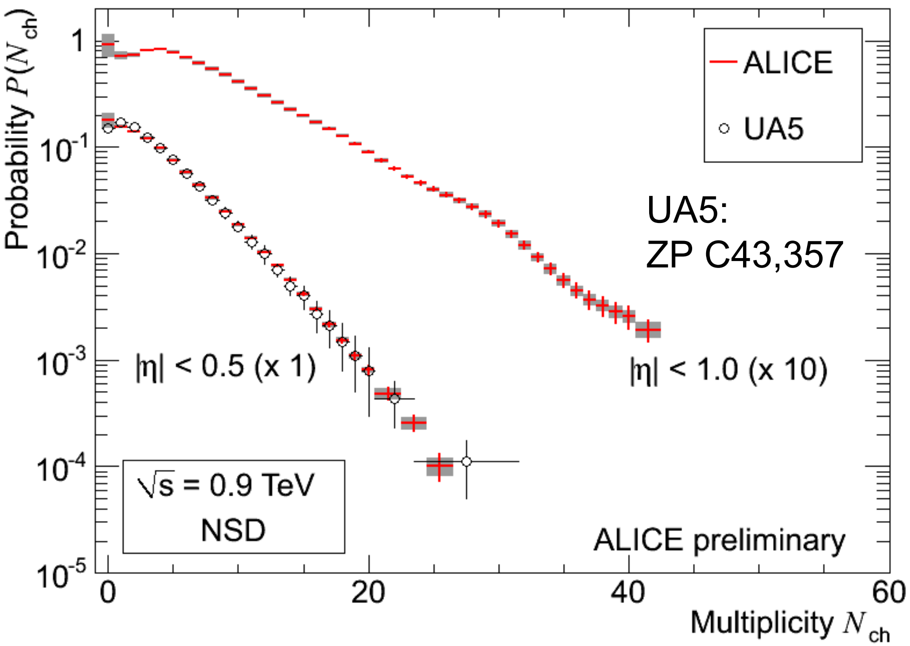
$$\chi^2(P(N_{ch})) = \sum_{N_{acc}} \left(\frac{P(N_{acc}) - \sum_{N_{ch}} R(N_{ch},N_{acc}) \cdot P(N_{ch})}{e(N_{acc})} \right)^2 + \beta R(P(N_{ch}))$$



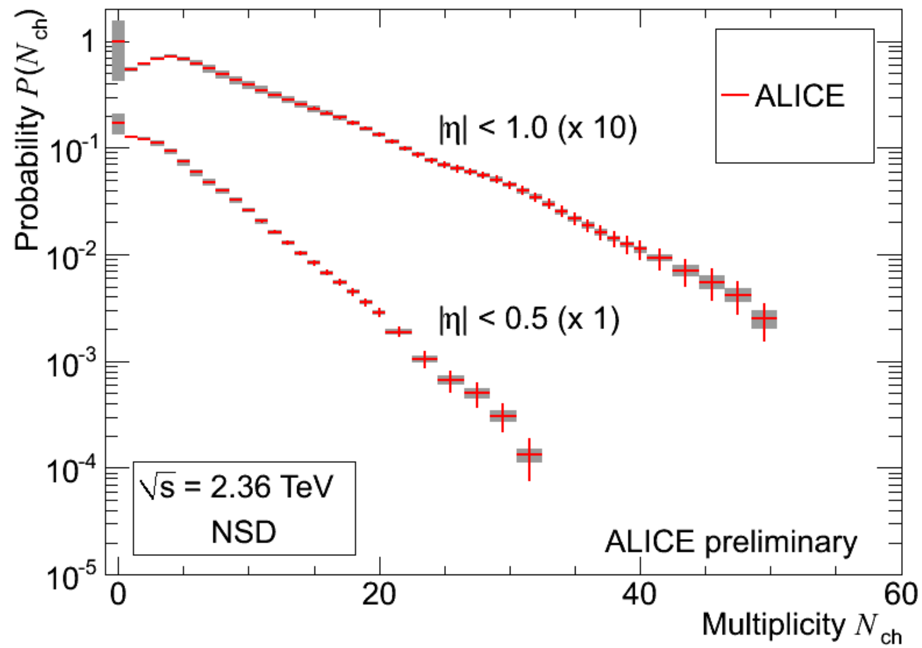
multiplicity distributions

Jan Fiete Grosse Oetringhaus (CERN), Rencontres de Moriond 2010

$\sqrt{s}$ = 900 GeV



$\sqrt{s}$ = 2.36 TeV

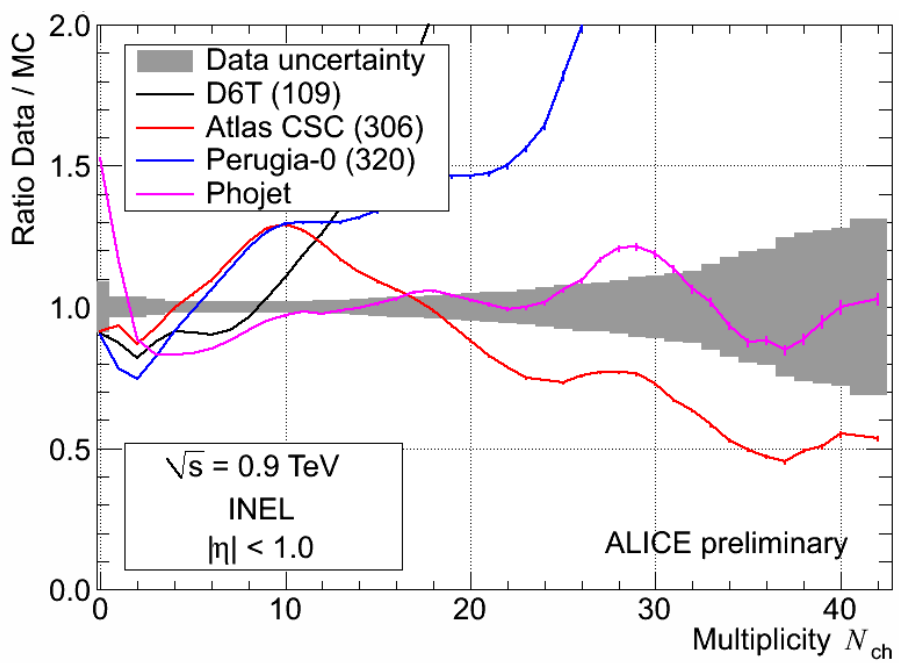


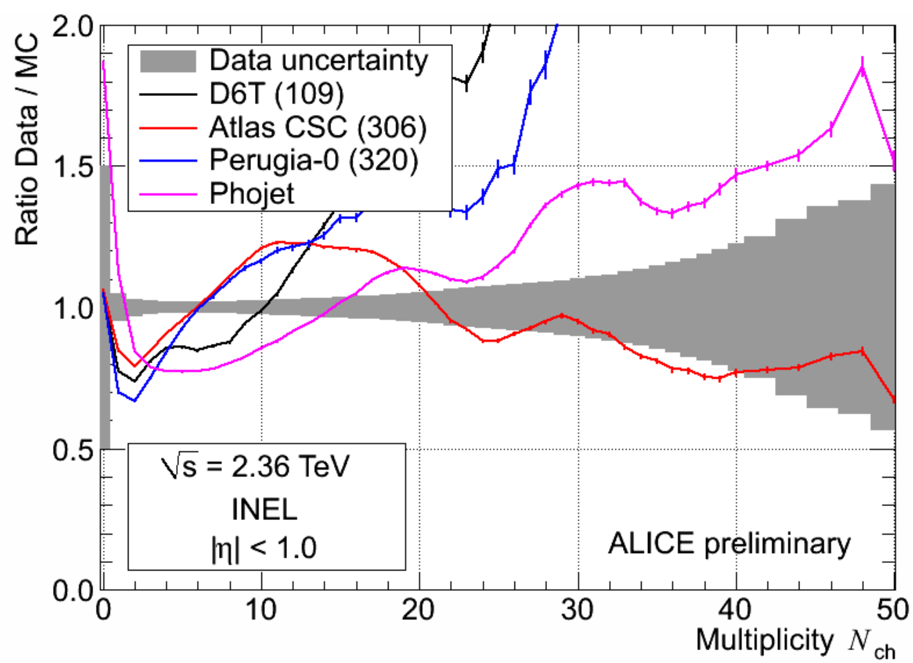
- good agreement with UA5 at 900 GeV
- first measurement at 2.36 TeV

multiplicity distributions

Jan Fiete Grosse Oetringhaus (CERN), Rencontres de Moriond 2010

$\sqrt{s}$ = 900 GeV $\sqrt{s}$ = 2.36 TeV

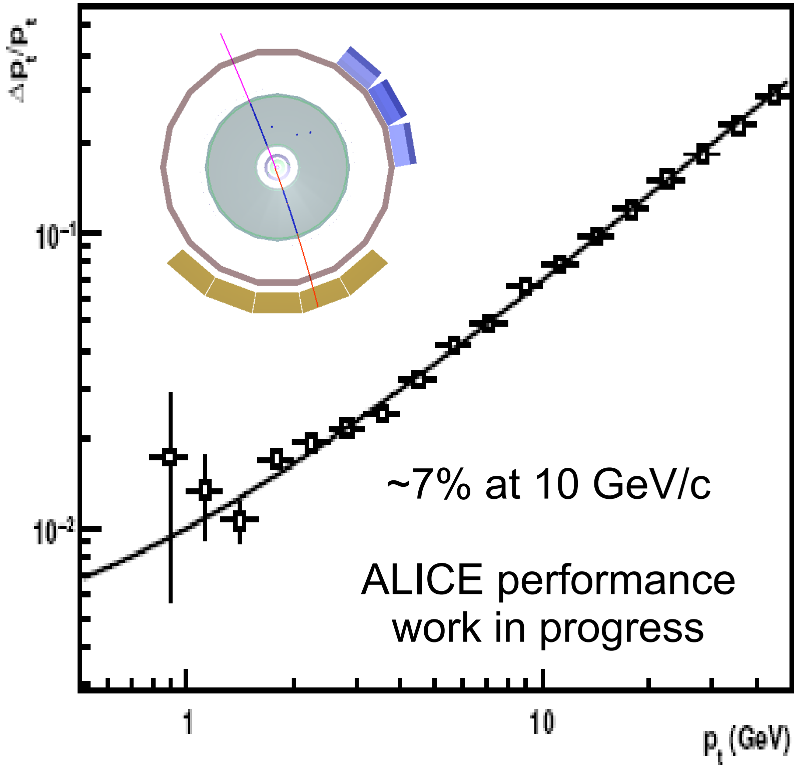


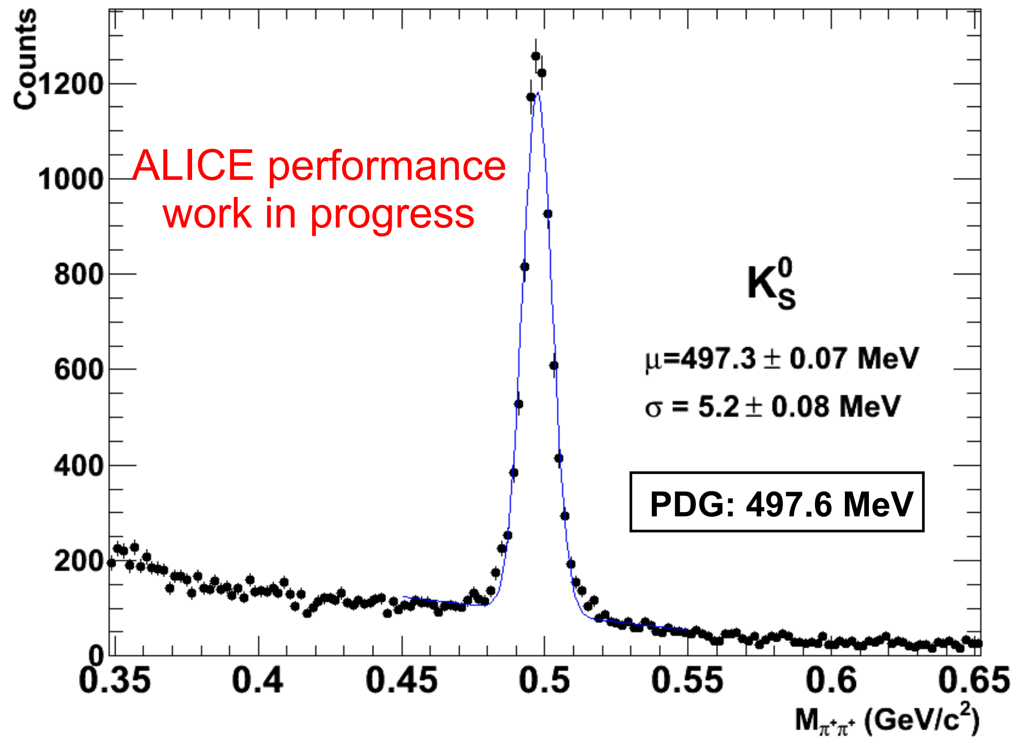


- MC generators do not describe the energy dependence of the high multiplicity tail correctly

TPC momentum reconstruction

momentum resolution (from matching of two segments of cosmic track)



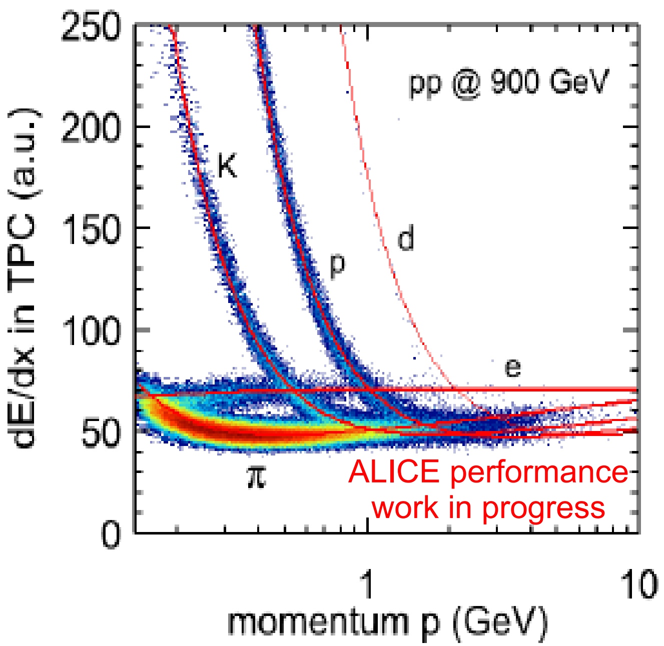


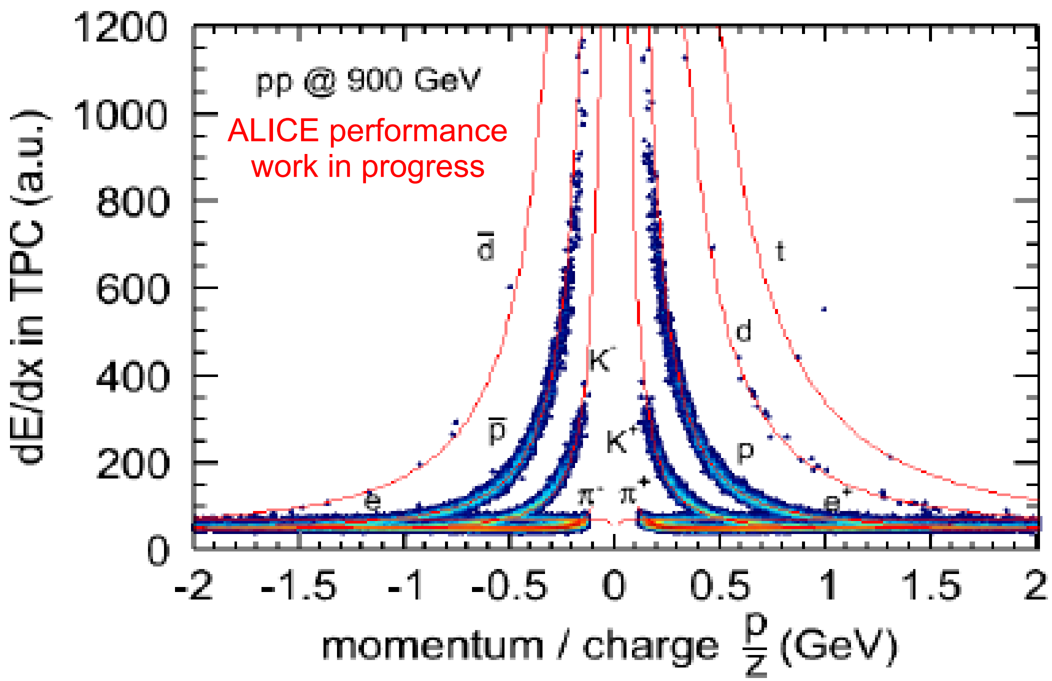
→ present p_T resolution

- 7% at 10 GeV/c
- below 1% at p_T<1 GeV/c

confirmed by K^0_s measurements

TPC dE/dx

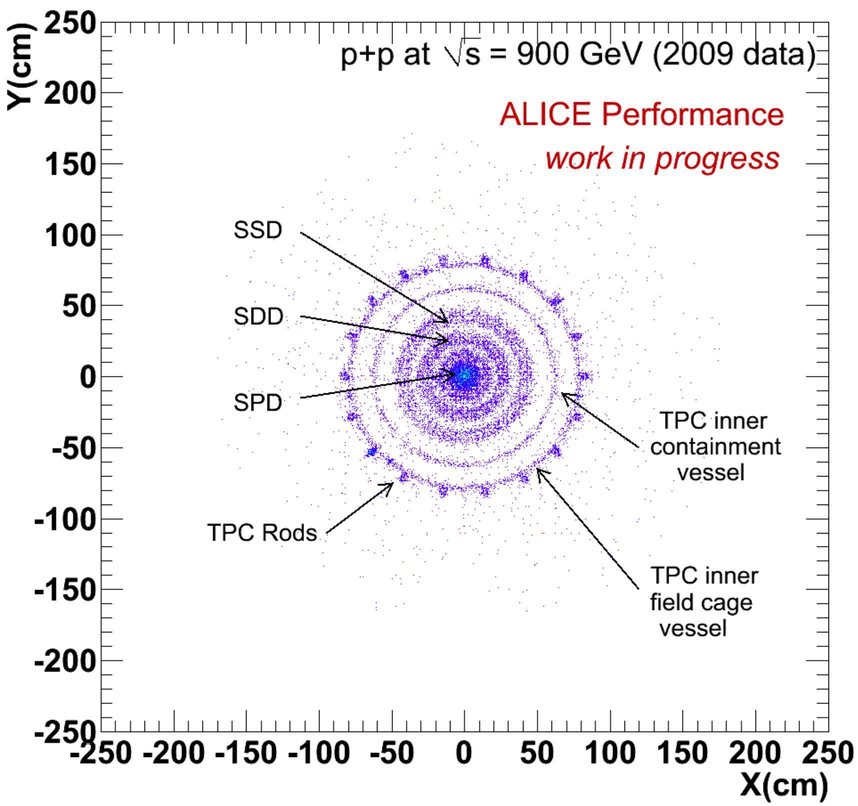


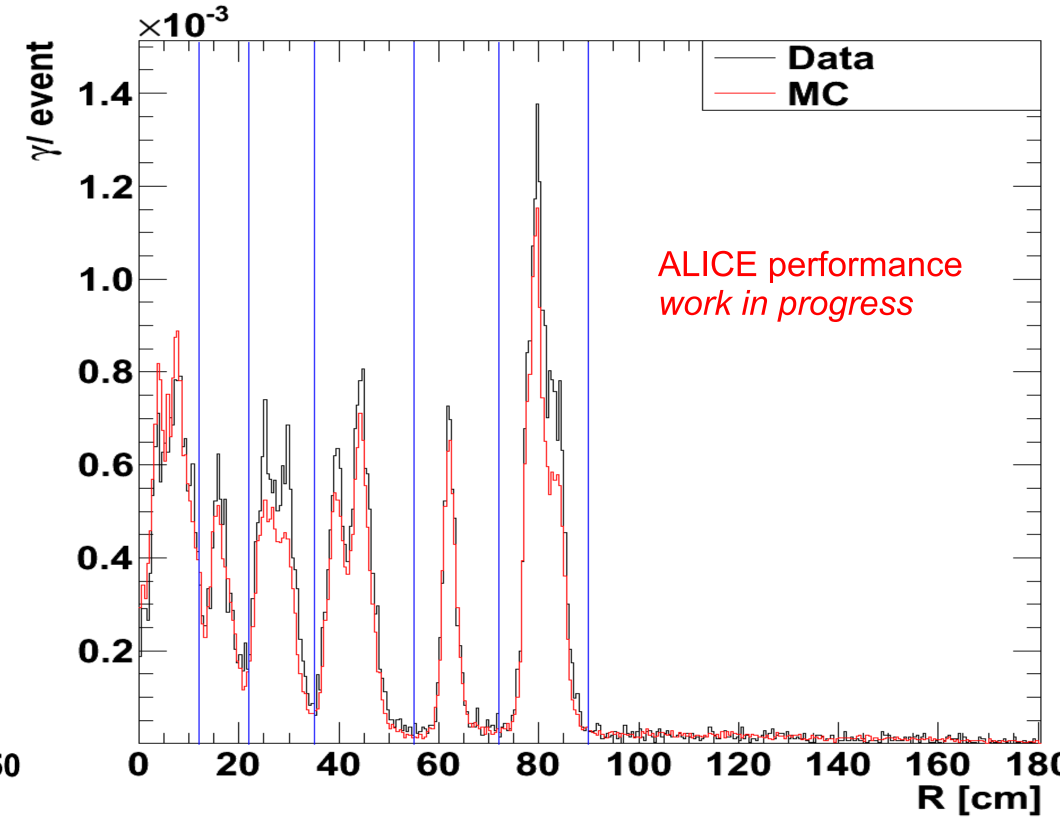


- TPC dE/dx resolution: 5.5% (= design value!)
- TPC particle ID used for track propagation through material and p_T reconstruction.

material budget

- reconstructed photon conversion distribution

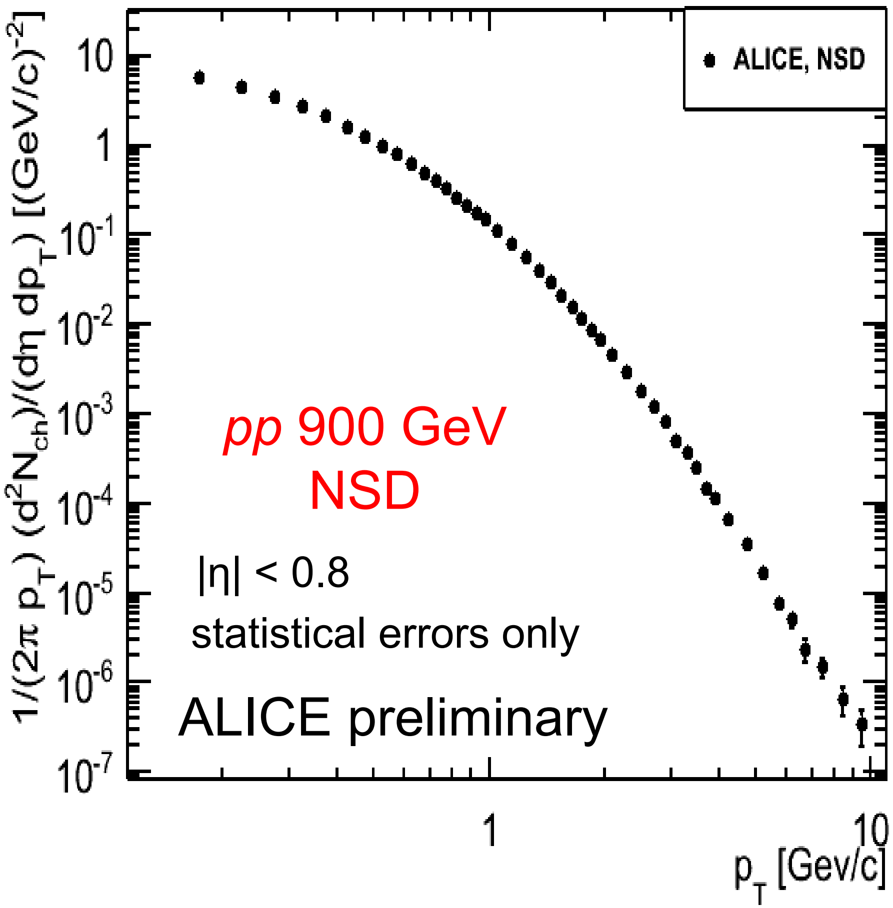




- agreement between MC and data within 10%.

transverse momentum spectra

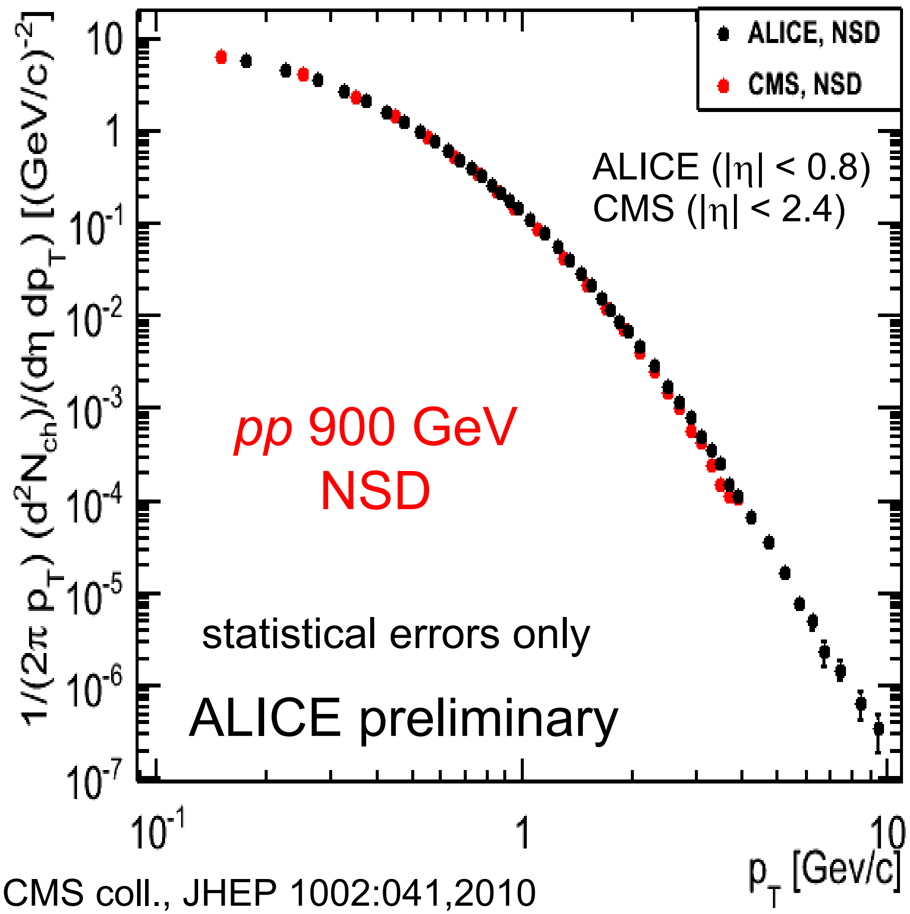
Jacek Otwinowski (GSI), Rencontres de Moriond 2010



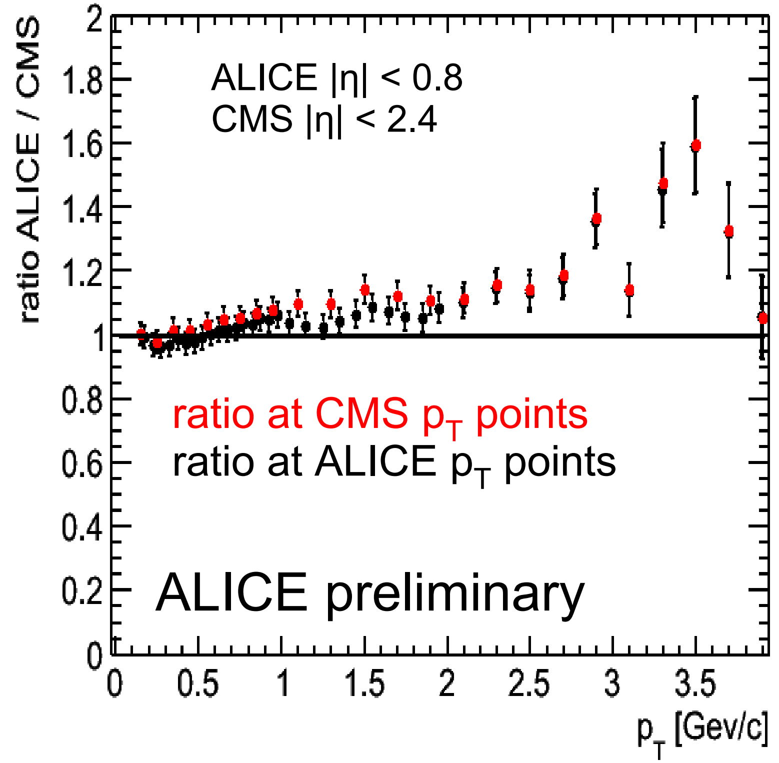
- p_T reach: 0.15 – 10 GeV/c
- power law tail at high p_T

comparison ALICE - CMS

Jacek Otwinowski (GSI), Rencontres de Moriond 2010



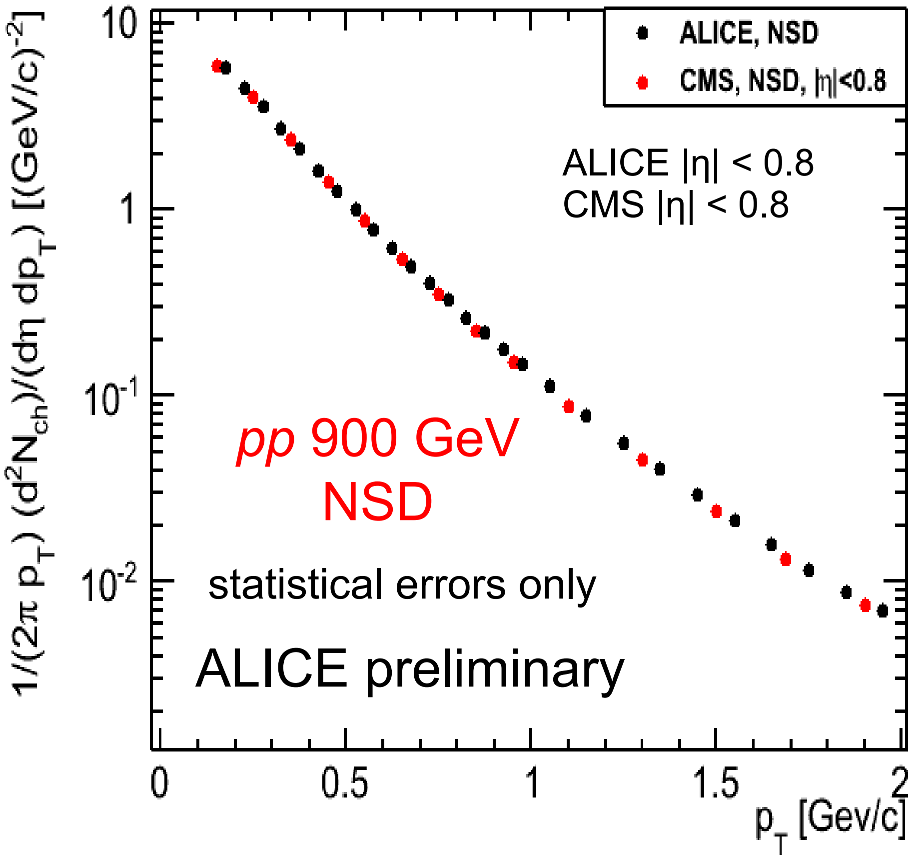
CMS coll., JHEP 1002:041,2010

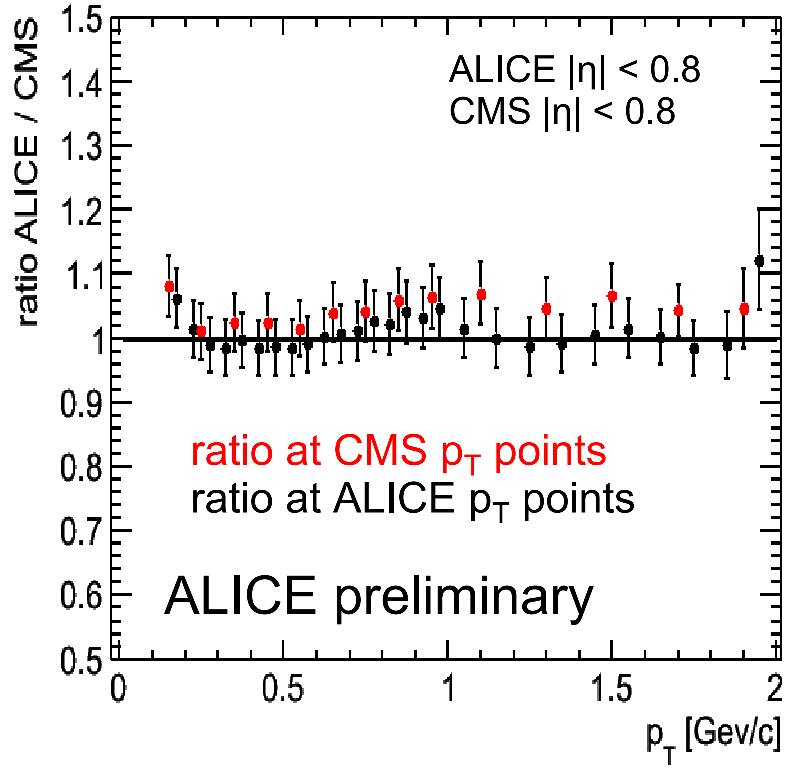


- ALICE p_T spectrum harder than CMS (but different η acceptance!)

comparison ALICE - CMS

Jacek Otwinowski (GSI), Rencontres de Moriond 2010

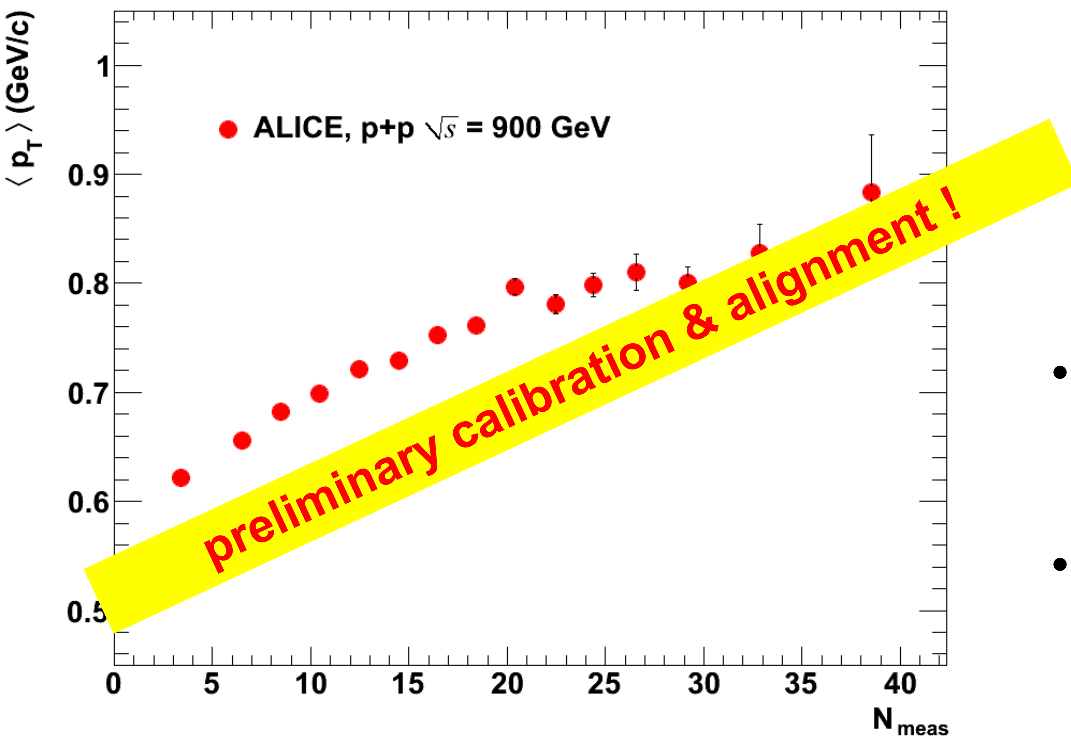




• agreement between ALICE and CMS ($|\eta|<0.8$) within 5%

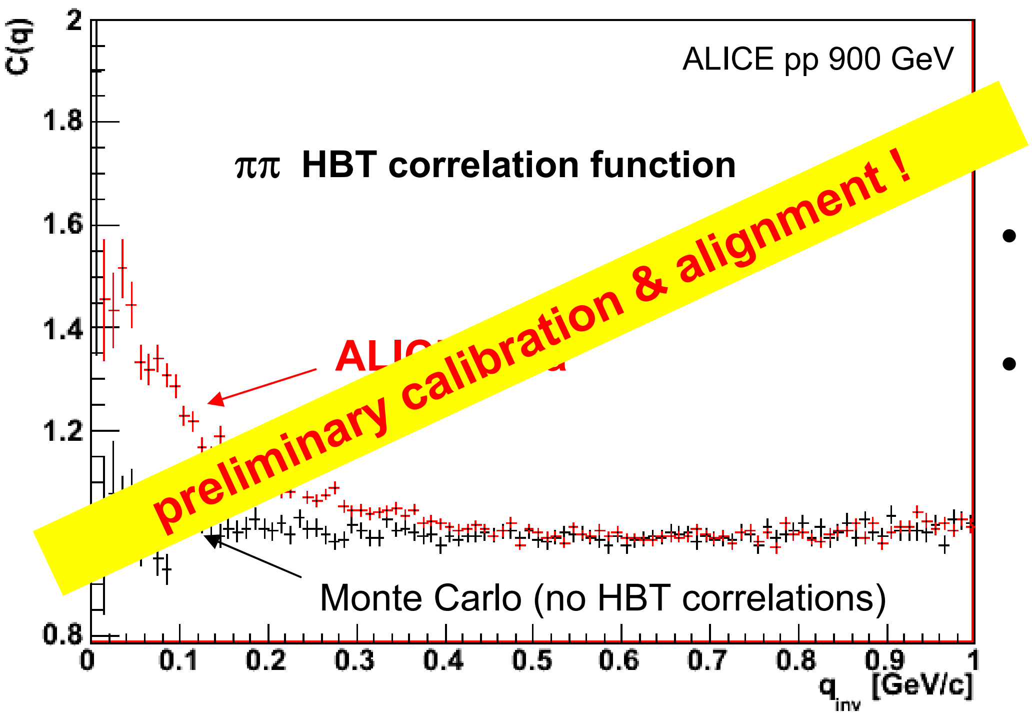
more to come...

$\langle p_t \rangle$ versus multiplicity



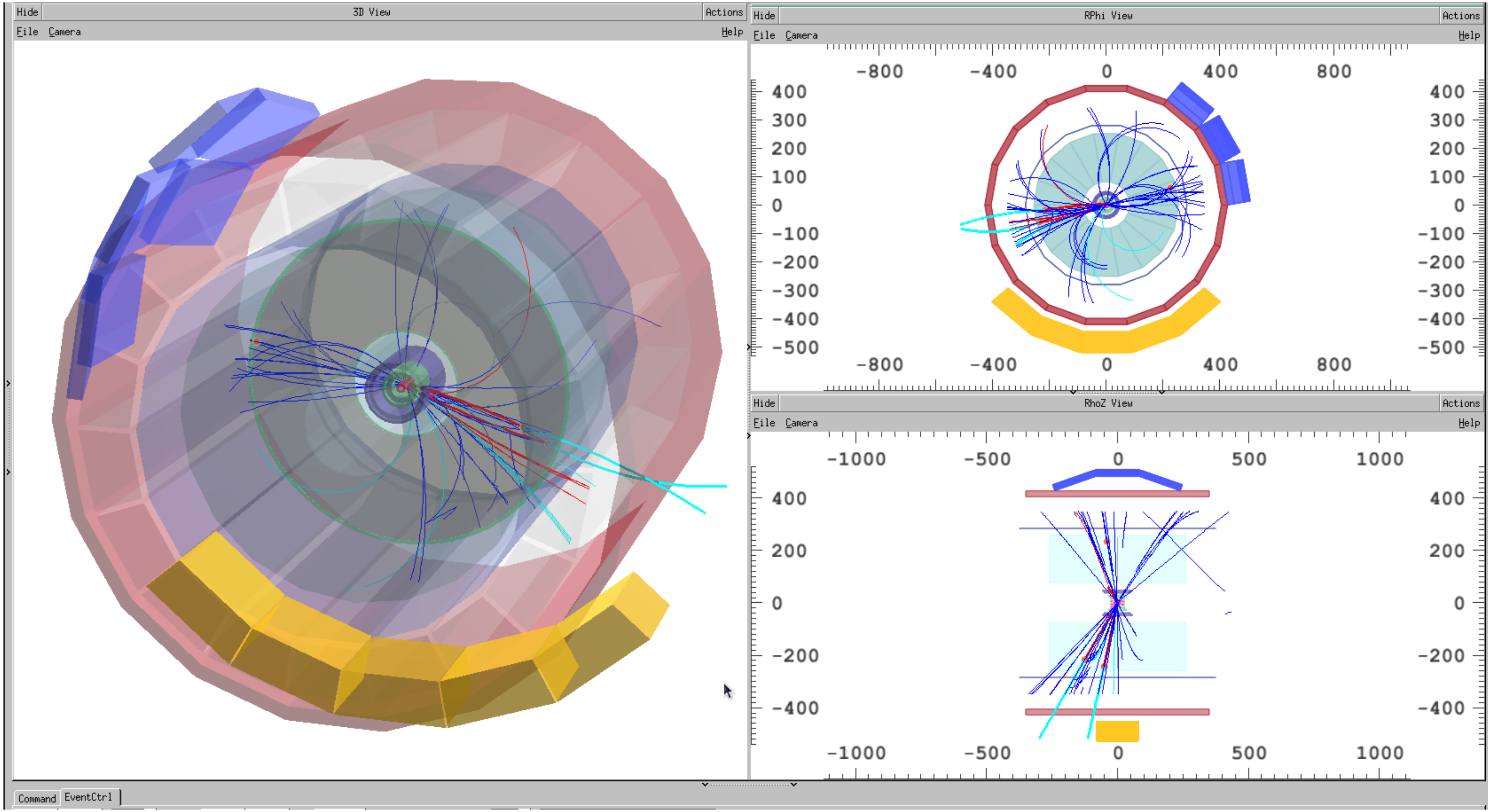
- mean p_t in $0.3<p_t<4$ GeV/c and $|\eta|<0.8$
- TPC multiplicity scale not corrected yet for efficiency
- large sensitivity to QCD phenomenology

particle correlations



- Space-time evolution
- Important reference to Pb-Pb

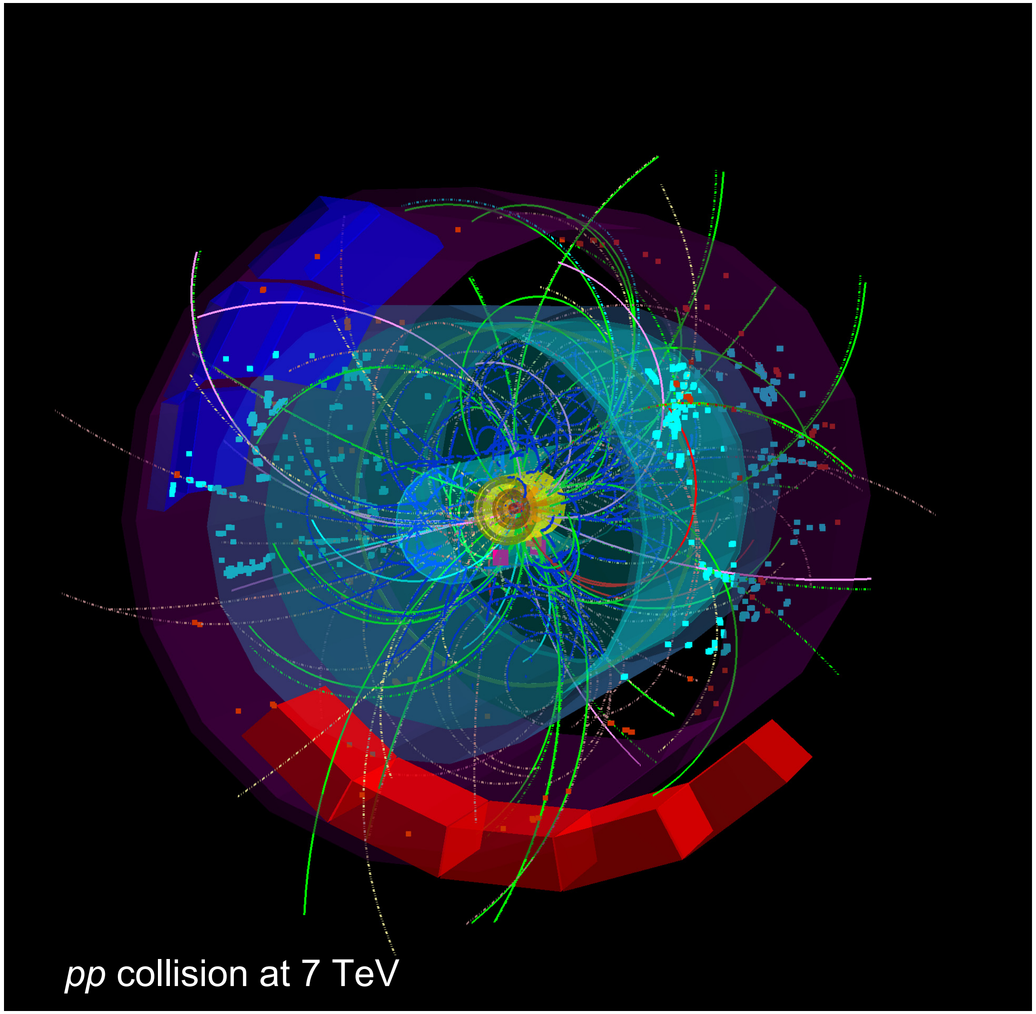
jets



Hide
3D View
Actions
File Camera
Help
Hide
RPhi View
Actions
File Camera
Help
-800 -400 0 400 800
400 300 200 100 0 -100 -200 -300 -400 -500
Hide
RhoZ View
Actions
File Camera
Help
-1000 -500 0 500 1000
400 200 0 -200 -400
Command EventCtrl

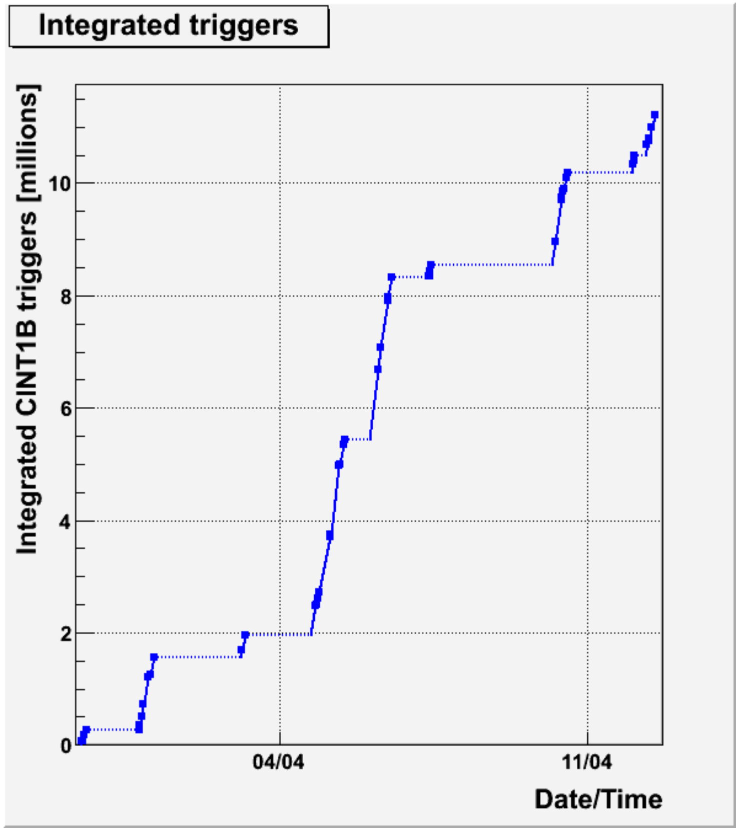
first collisions at 7 TeV

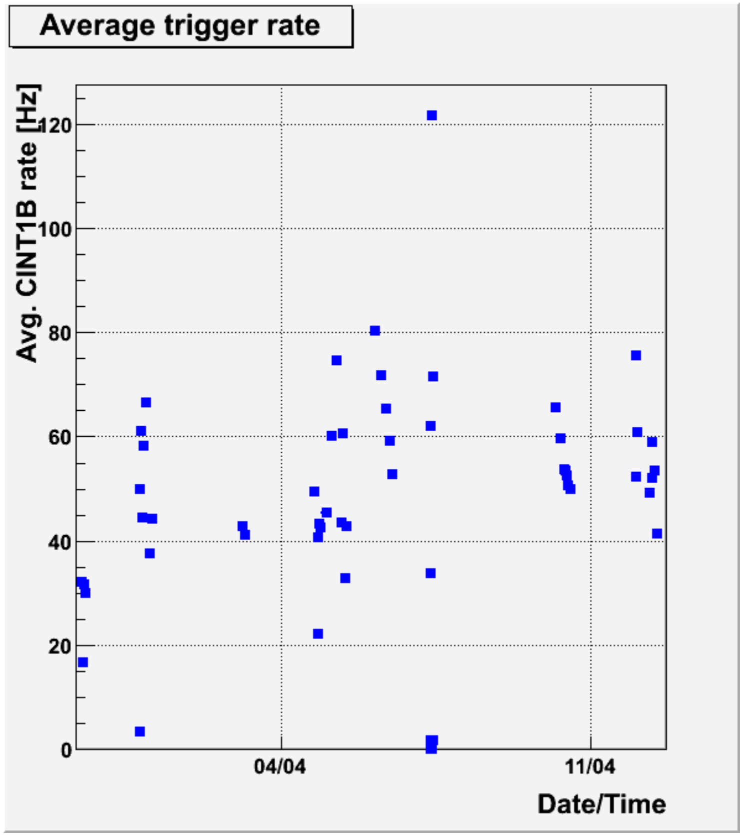
first collisions at 7 TeV



- 30.3.2010, 13:01: first pp collisions at $\sqrt{s}$ = 7 TeV

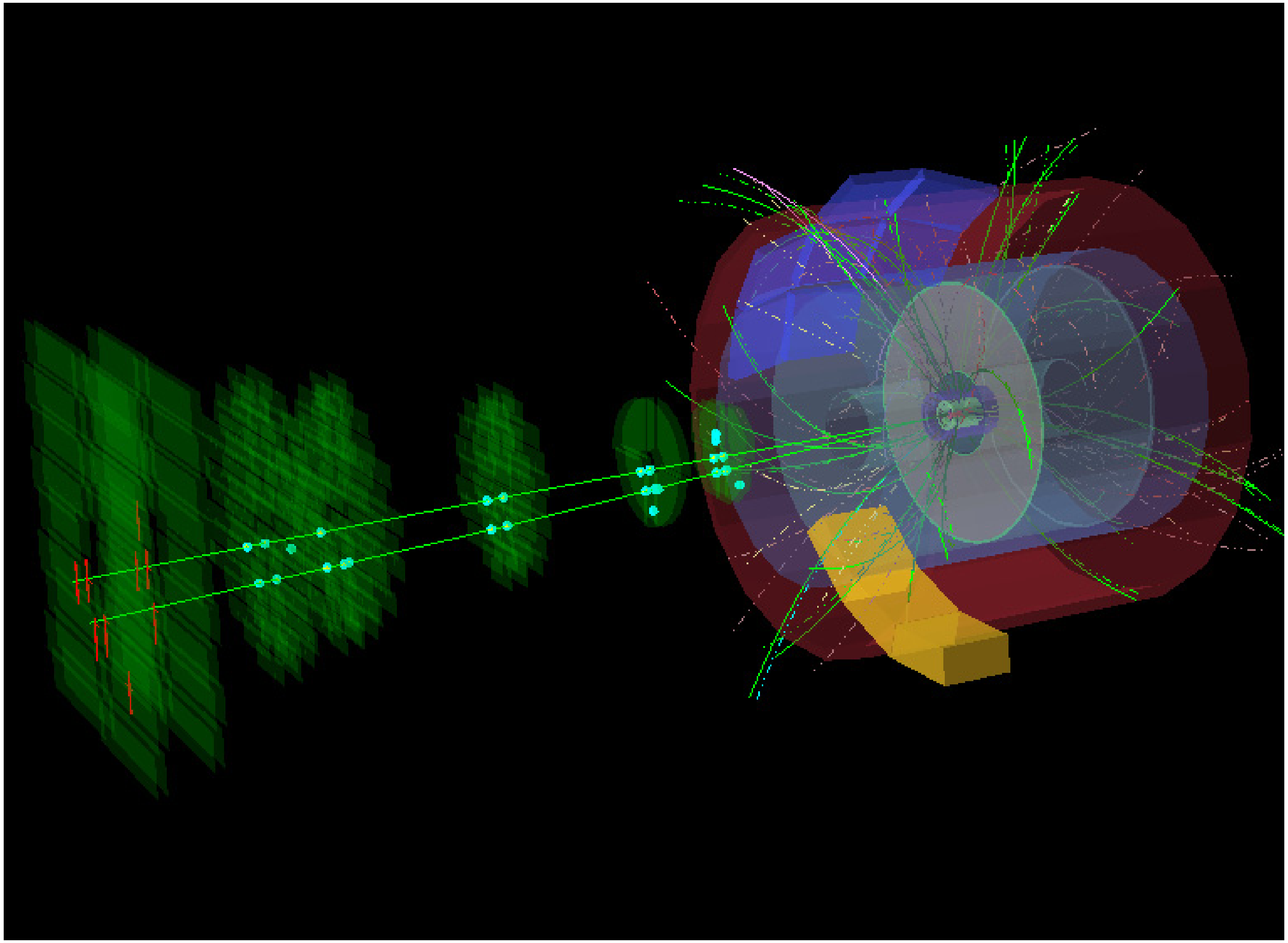
first collisions at 7 TeV





14.4.2010: ~13 million pp events recorded

first collisions at 7 TeV



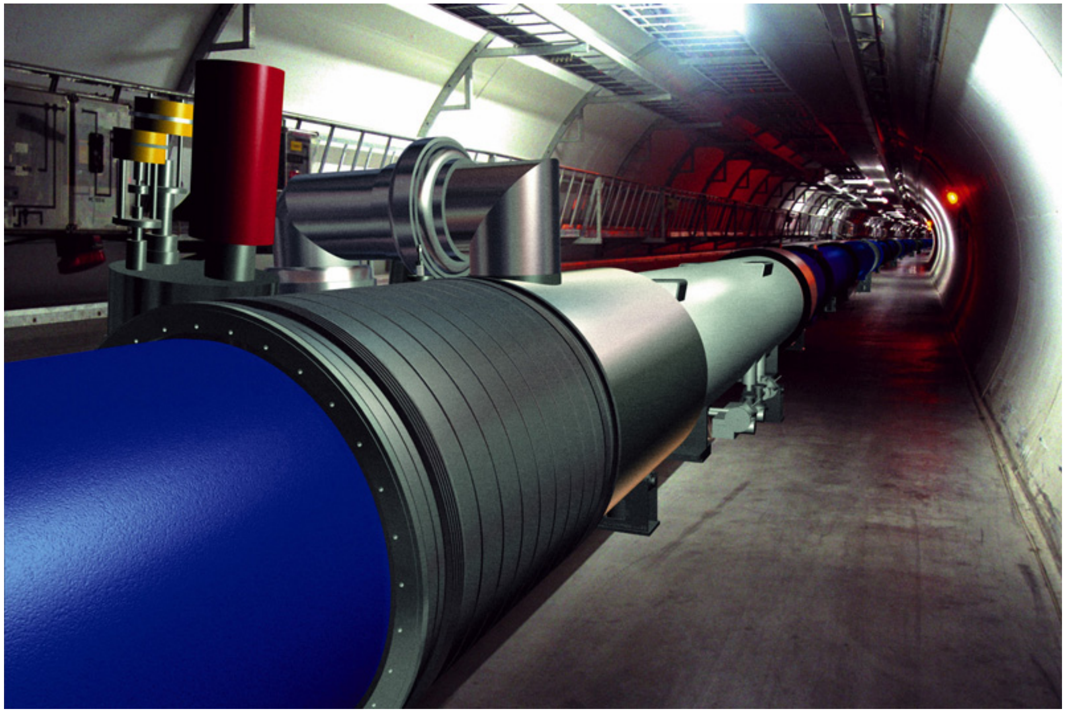
- one (out of 12) J/ψ candidates in the muon arm

summary

- upon arrival of first collisions, ALICE was ready for first physics
- first analyses of global observables in pp presented by ALICE
- impressive agreement between first physics results of the LHC experiments
- data taking of pp at 7 TeV started successfully, PbPb collisions at $\sqrt{s_{NN}}$= 2.76 TeV expected in the fall

backup

CERN Large Hadron Collider



1232 dipoles:

- 15 m each
- ~ 1 MCHF each
- 8.3 T field (~11850 A)
- superconducting, operated at 1.9 K

p – design luminosity: 10^{34} cm^{-2}s^{-1}

2808 bunches with 10^{11} protons each → I = 0.5 A

E_{tot} = 3 x 10^{14} x 7 TeV ~= 300 MJ → 60 ton truck moving with 200 mph!