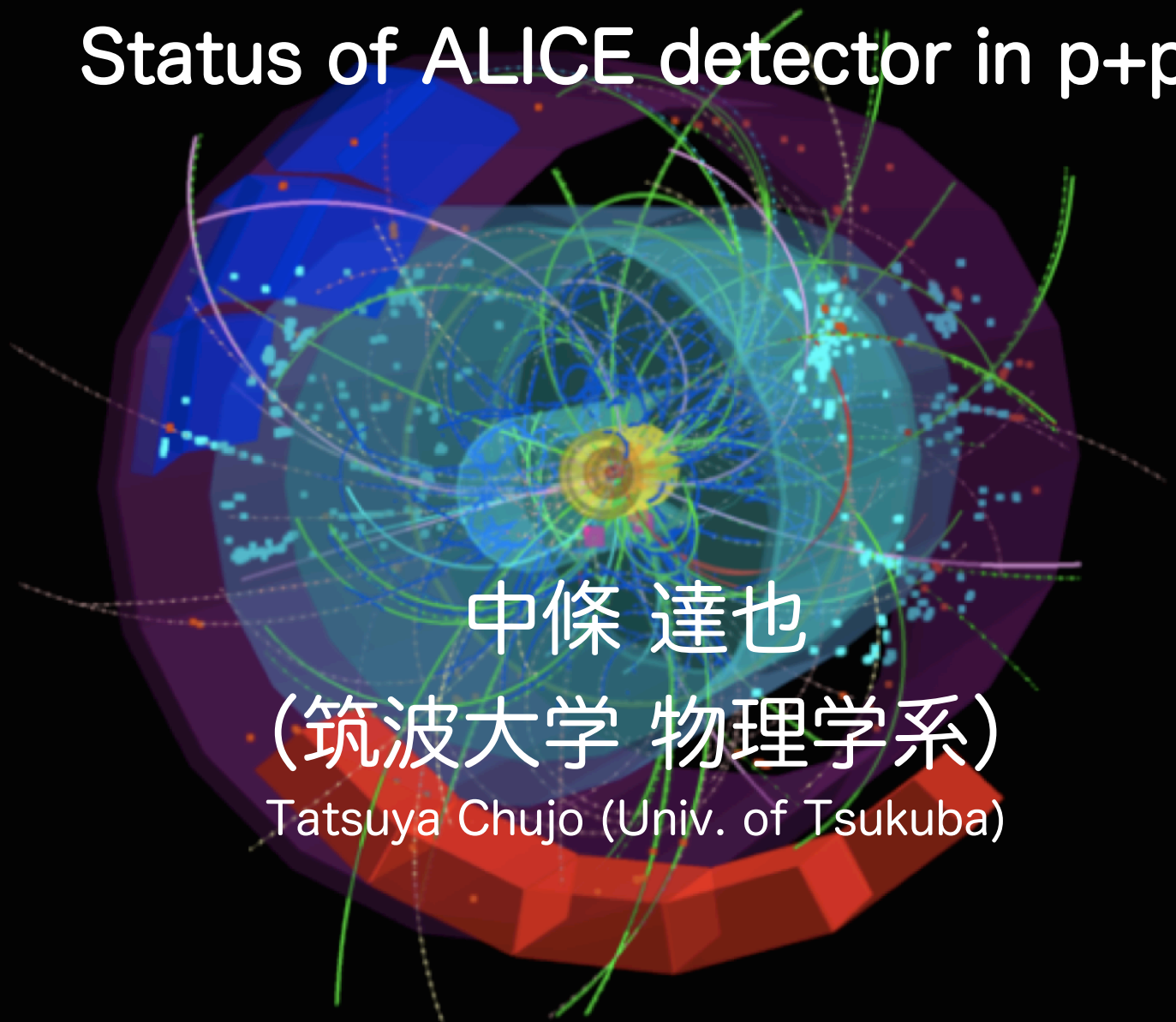
ALICE実験測定器の現状

Status of ALICE detector in p+p



中條 達也

（筑波大学 物理学系）

Tatsuya Chujo (Univ. of Tsukuba)

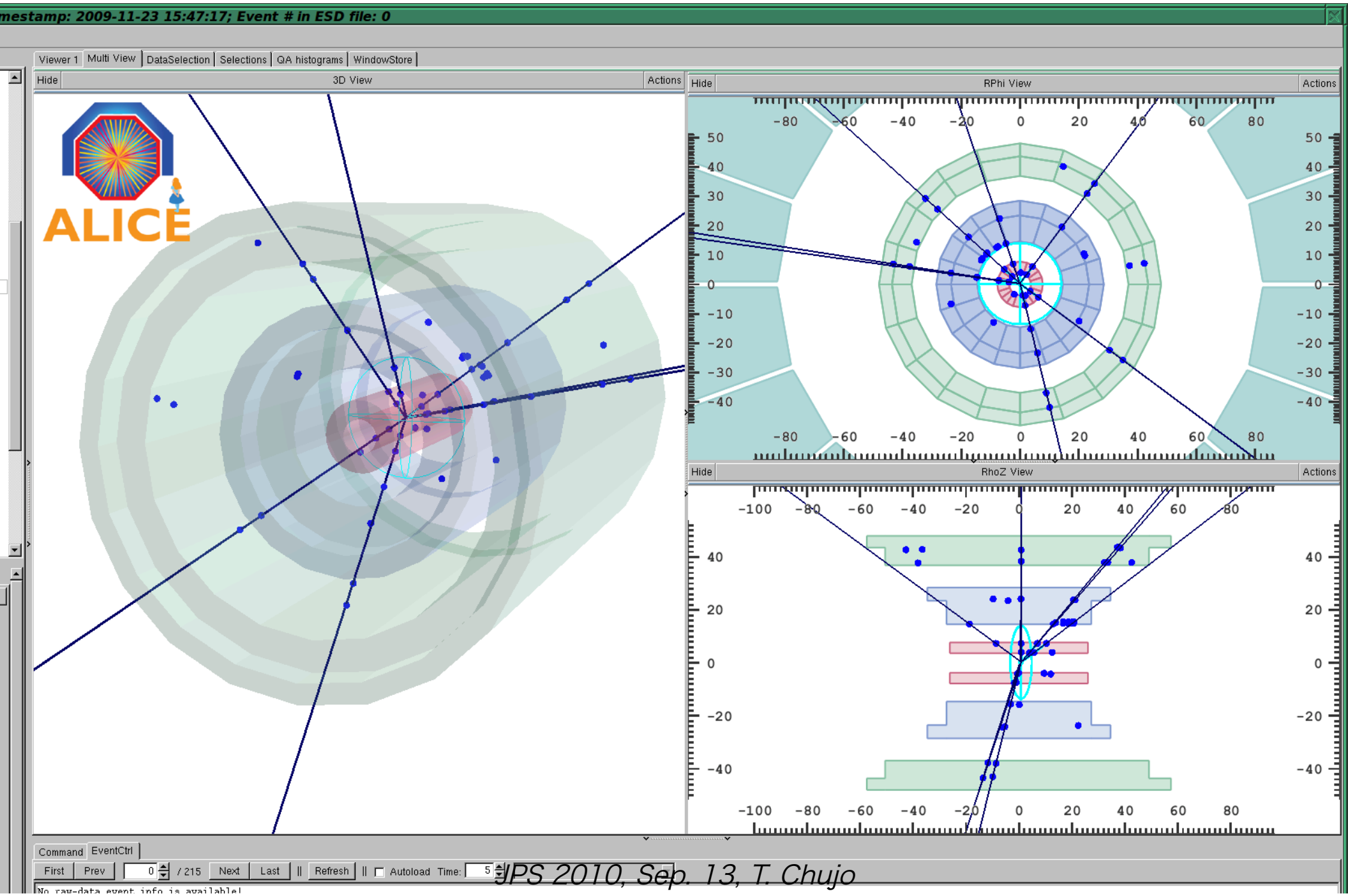
日本物理学会 ２０１０年秋季大会（九州工業大学）　２０１０年９月１３日

Snap shot of ALICE Control Room (2010.08.25)

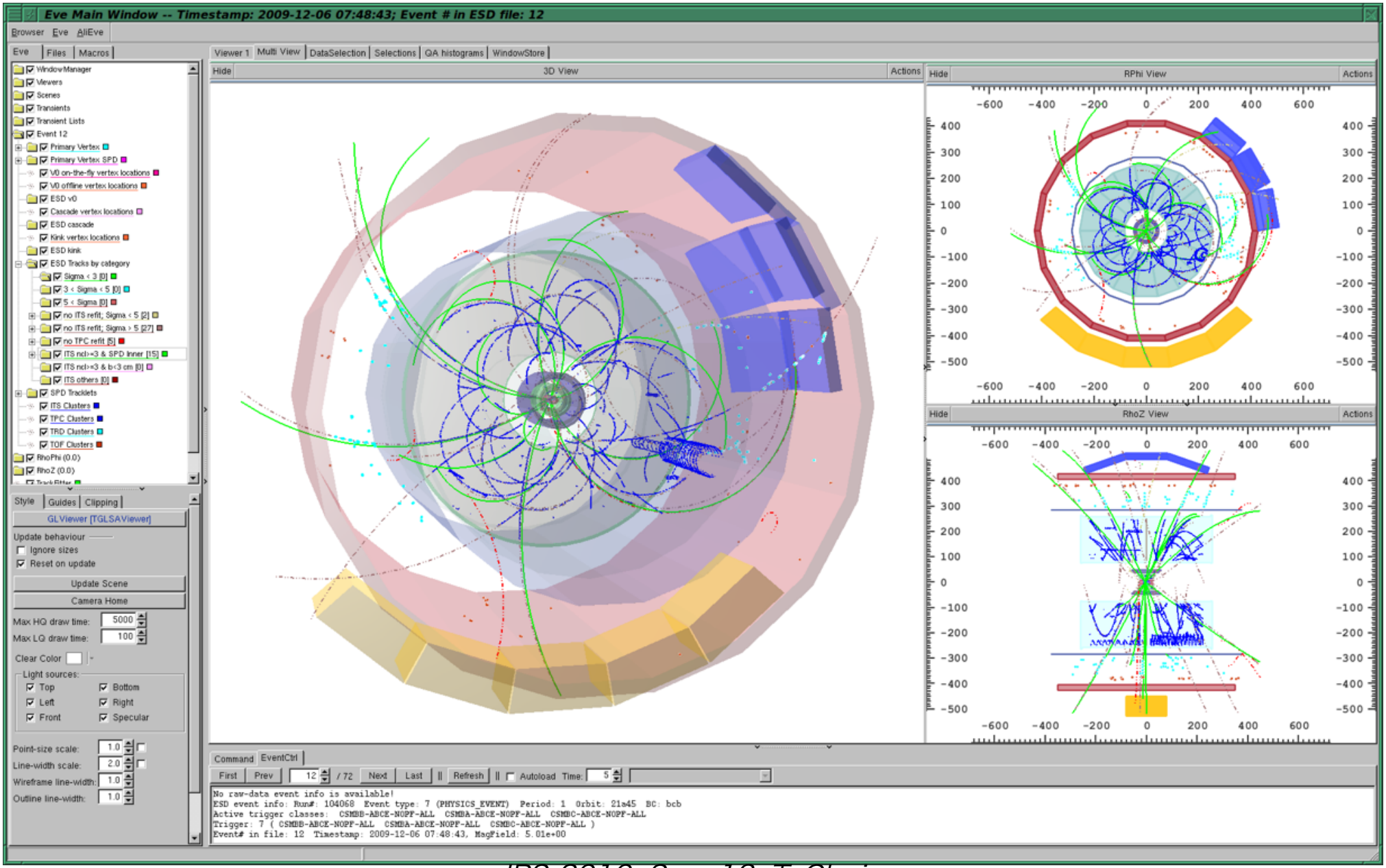
- Data taking period, very quite… -


最初の陽子-陽子衝突を喜ぶ研究者たち
First collision p+p √s= 900 GeV
(2009.11.23, ALICE Control Room)
Same Room

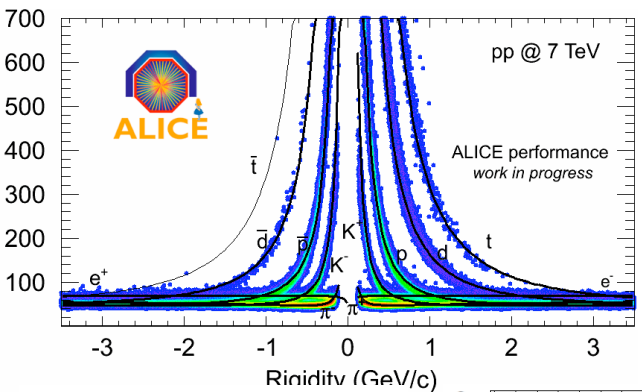
The first “event” in p+p 0.9 TeV

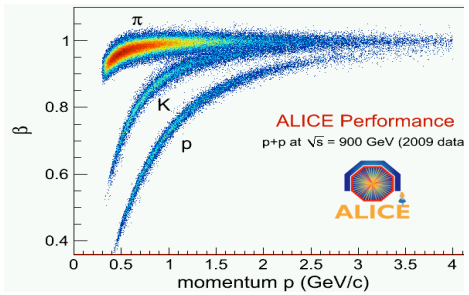


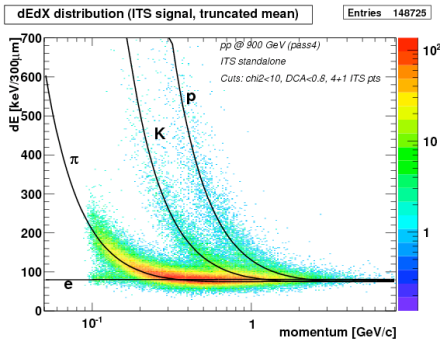
… and 7 TeV p+p

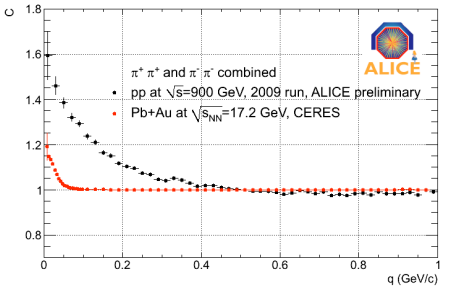

Eve Main Window -- Timestamp: 2009-12-06 07:48:43; Event # in ESD file: 12
Browser Eve AliEve
Eve Files Macros
Viewer 1 Multi View DataSelection Selections QA histograms WindowStore
Hide 3D View Actions
Hide RPhi View Actions
Hide RhoZ View Actions
Style Guides Clipping
GLViewer [TGLSAViewer]
Update behaviour
Ignore sizes
Reset on update
Update Scene
Camera Home
Max HQ draw time: 5000
Max LQ draw time: 100
Clear Color
Light sources:
Top Bottom
Left Right
Front Specular
Point-size scale: 1.0
Line-width scale: 2.0
Wireframe line-width: 1.0
Outline line-width: 1.0
Command EventCtrl
First Prev 12 / 72 Next Last Refresh Autoload Time: 5
No raw-data event info is available!
ESD event info: Run#: 104068 Event type: 7 (PHYSICS_EVENT) Period: 1 Orbit: 21a45 BC: bcb
Active trigger classes: CSMBB-ABCE-NOPF-ALL CSMBA-ABCE-NOPF-ALL CSMBC-ABCE-NOPF-ALL
Trigger: 7 (CSMBB-ABCE-NOPF-ALL CSMBA-ABCE-NOPF-ALL CSMBC-ABCE-NOPF-ALL)
Event# in file: 12 Timestamp: 2009-12-06 07:48:43, MagField: 5.01e+00

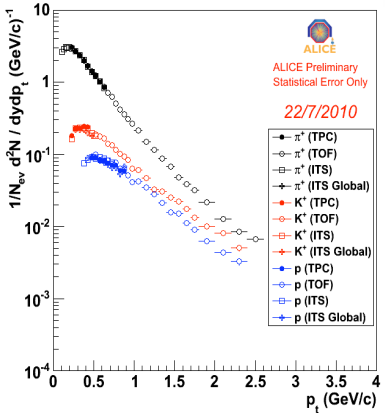
After ~9 months later…
Already lots of first results from ALICE !

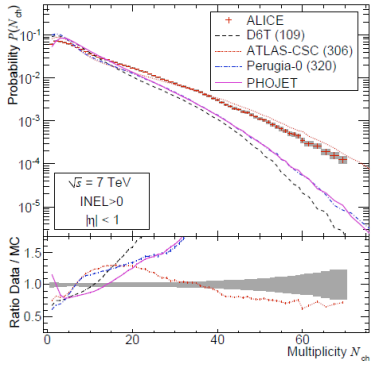


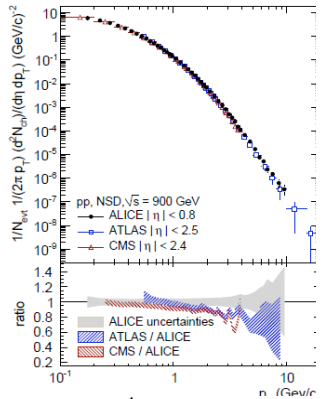


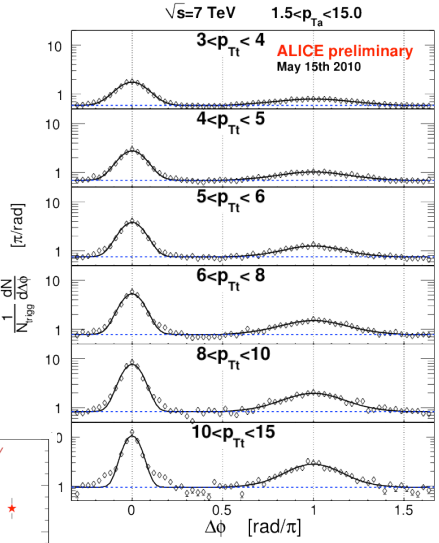


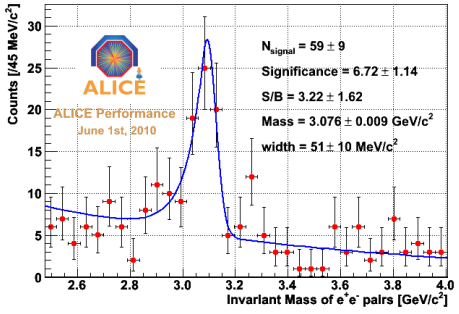


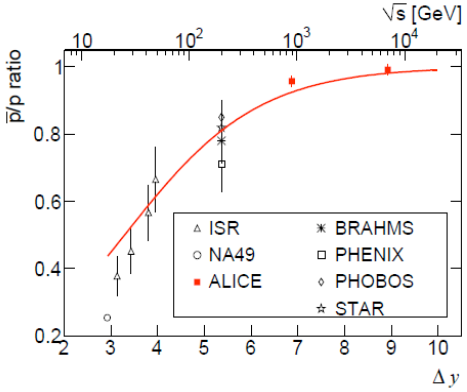


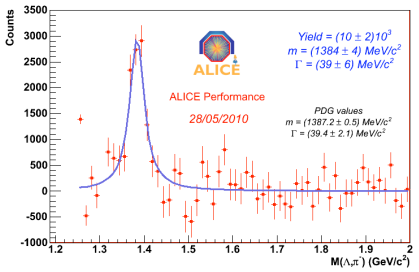


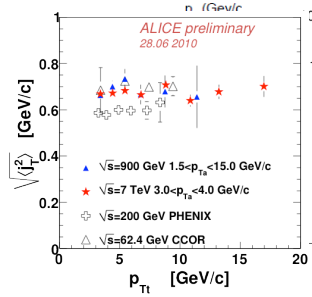


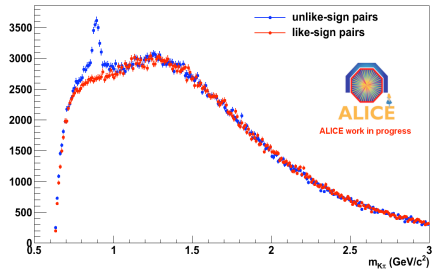


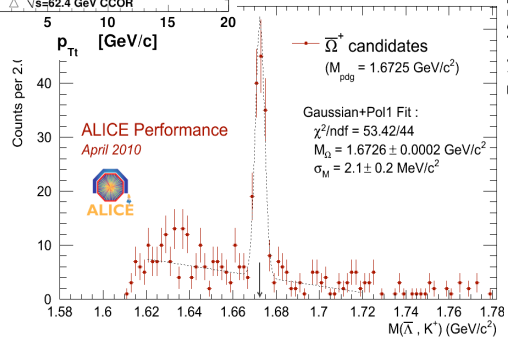


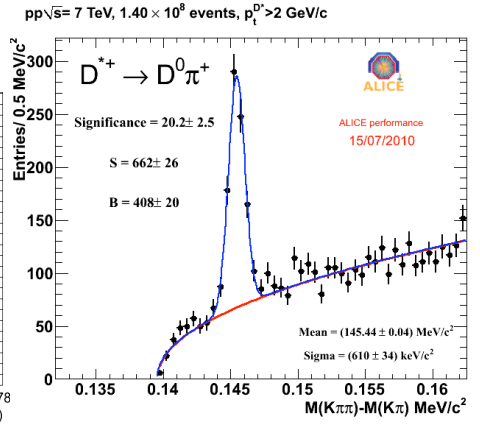






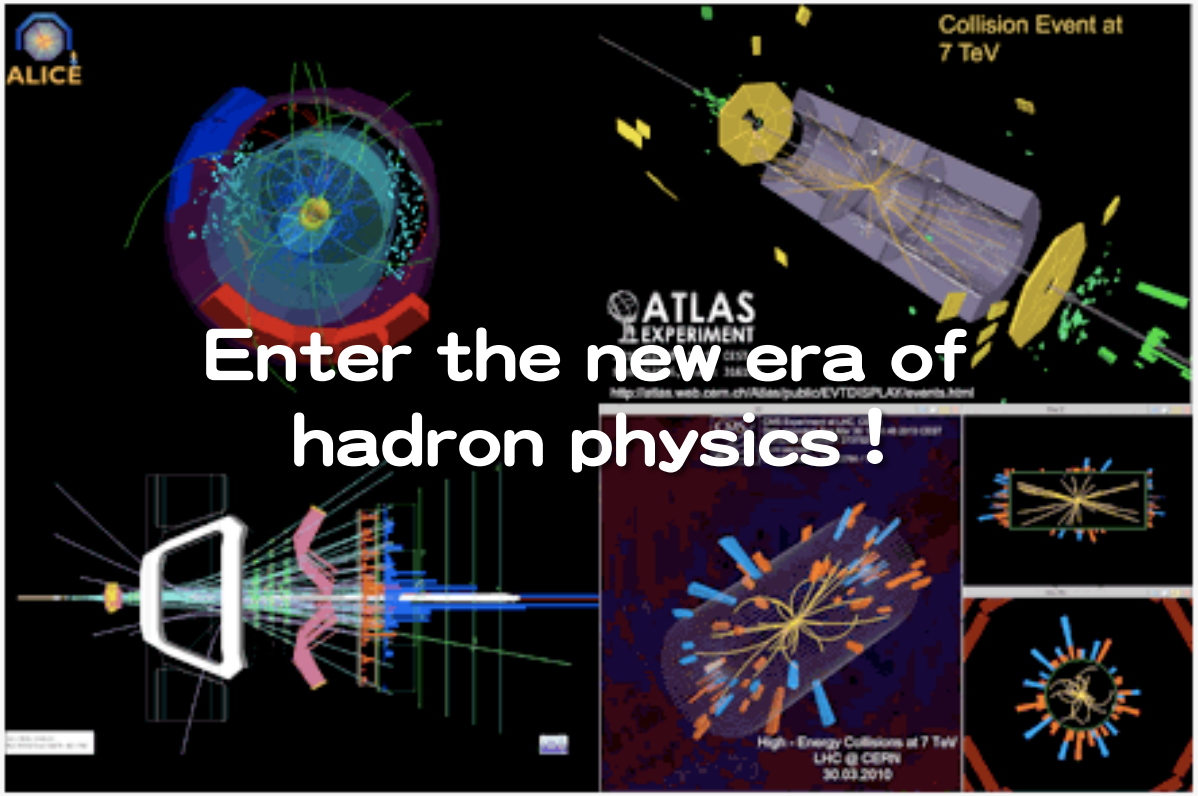






30 March 2010

LHC First Physics



Enter the new era of hadron physics !

7 TeV collision events seen today by the LHC's four major experiments (clockwise from top-left: ALICE, ATLAS, CMS, LHCb). More LHC First Physics images »

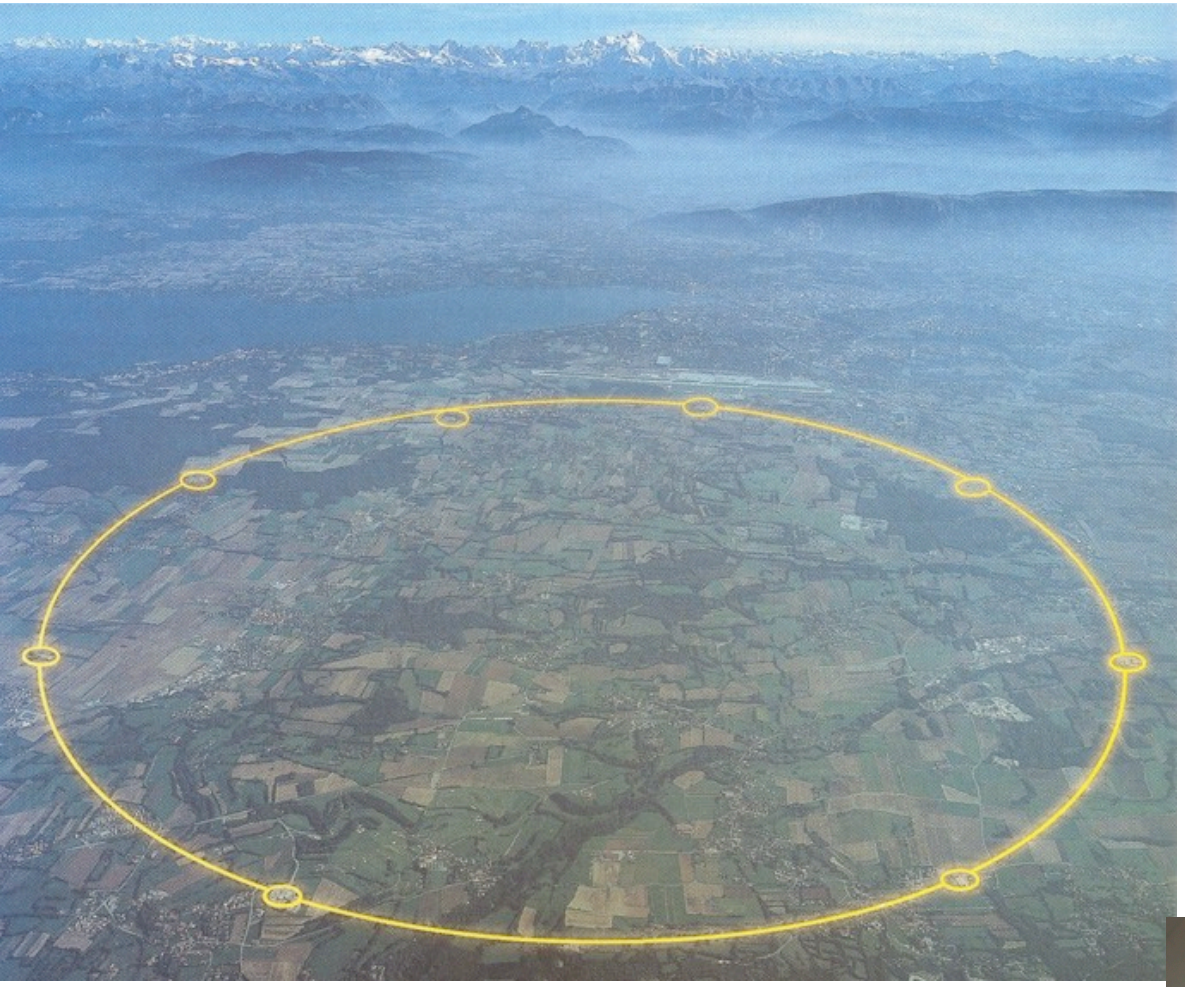
LHC research programme gets underway

Geneva, 30 March 2010. Beams collided at 7 TeV in the LHC at 13:06 CEST, marking the start of the LHC research programme. Particle physicists around the world are looking forward to a potentially rich harvest of new physics as the LHC begins its first long run at an energy three and a half times higher than previously achieved at a particle accelerator. Read more...

JPS 2010, Sep. 13, T. Chujo

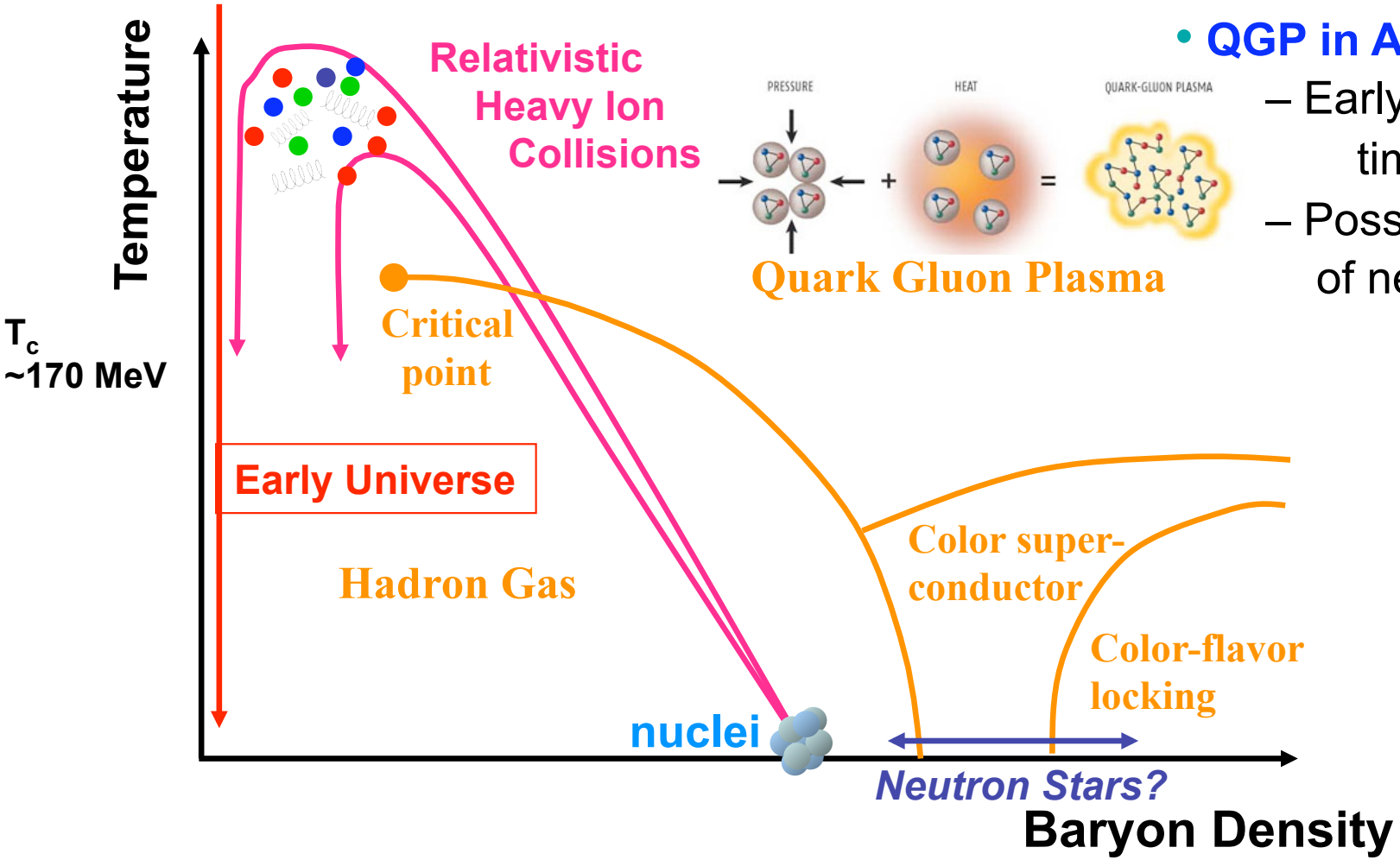
Outline

1. Quark Gluon Plasma (QGP) at LHC
2. LHC & ALICE
3. ALICE & QGP
   - Parton energy loss
   - Collectivity
   - Temperature
4. Summary



1. QUARK GLUON PLASMA & LHC

QCD phase diagram and QGP



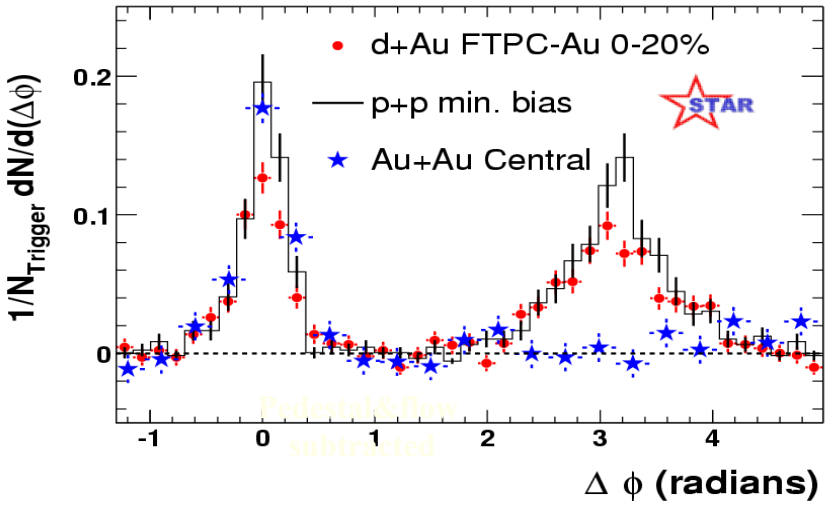
- **QGP in Astrophysics**
  - Early universe:
    time $< 10^{-6}$ seconds
  - Possibly in the interior
    of neutron stars

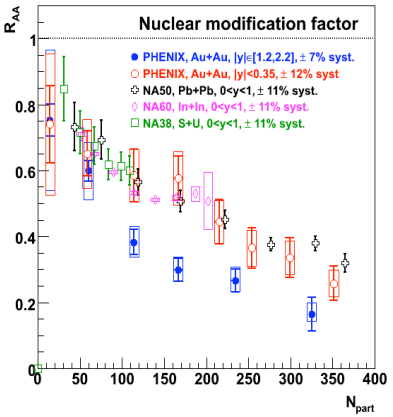
- **QGP in Nuclear Physics**
  - Create at the lab. by heavy ion collisions
  - Study the nature of QCD matter
    at the extreme temperature and energy density

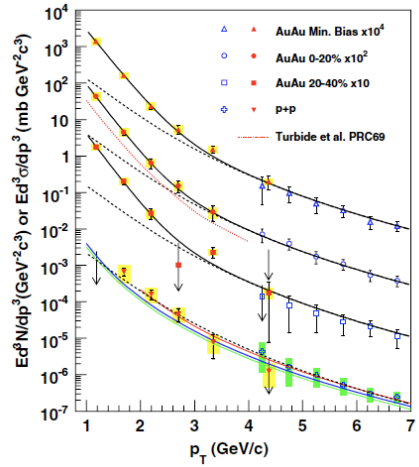
Highlights at RHIC

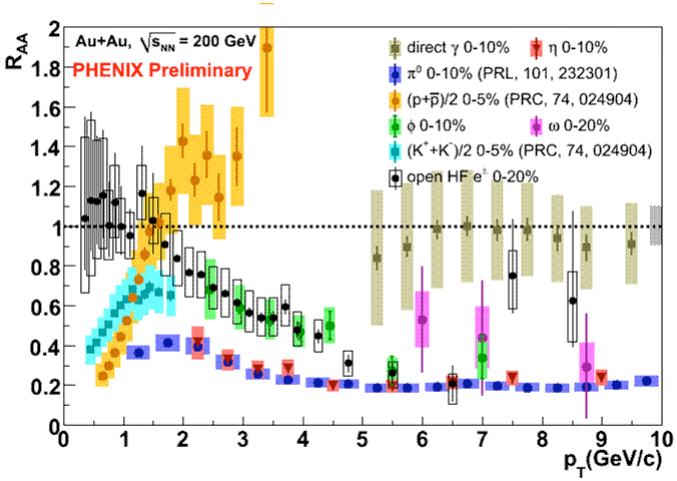
- Jet quenching, indicating $dN_g/dy \sim 1100$, $\varepsilon > 100\ \varepsilon_0$.
- Jet-medium interaction: shock wave (hit to c_s)?
- Collective flow, suggesting quark recombination.
- Heavy quark suppression and flow.
- Thermal photon emission
  - $T > 300$ MeV $> T_c$.

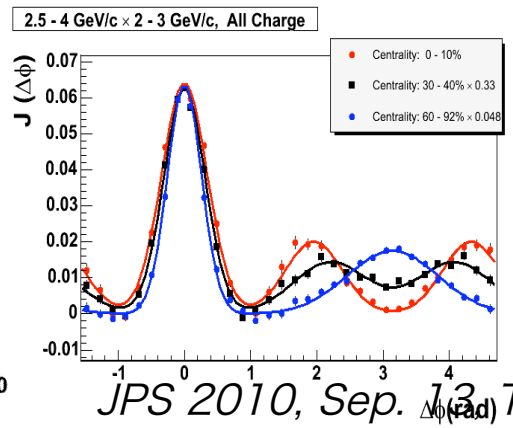
Phys. Rev. Lett. 91, 072304

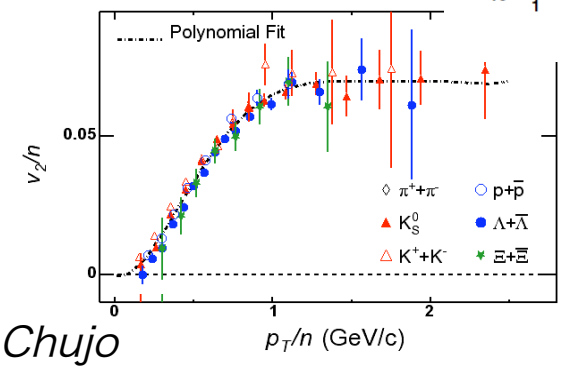


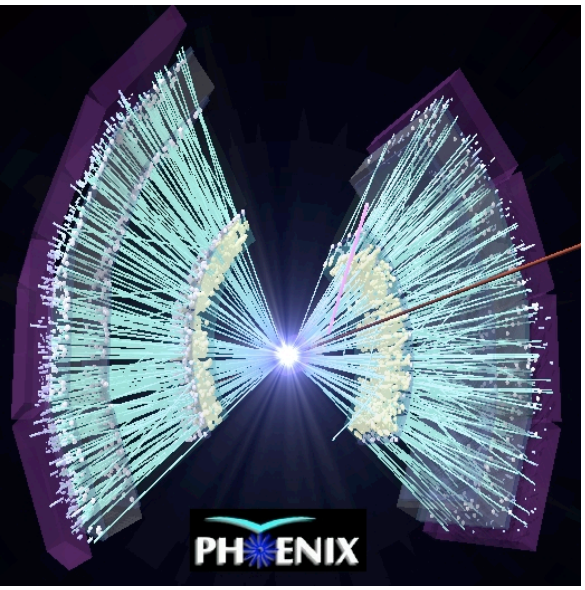






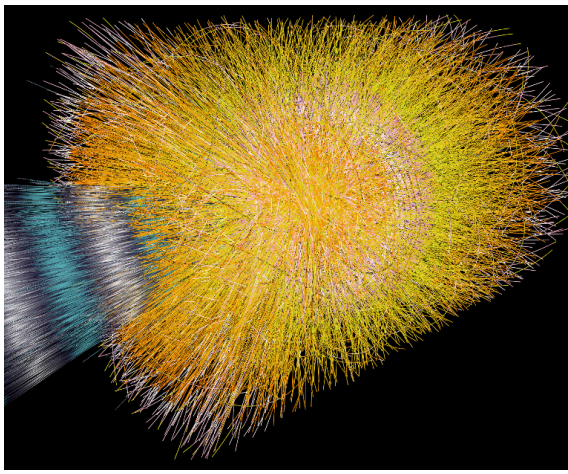




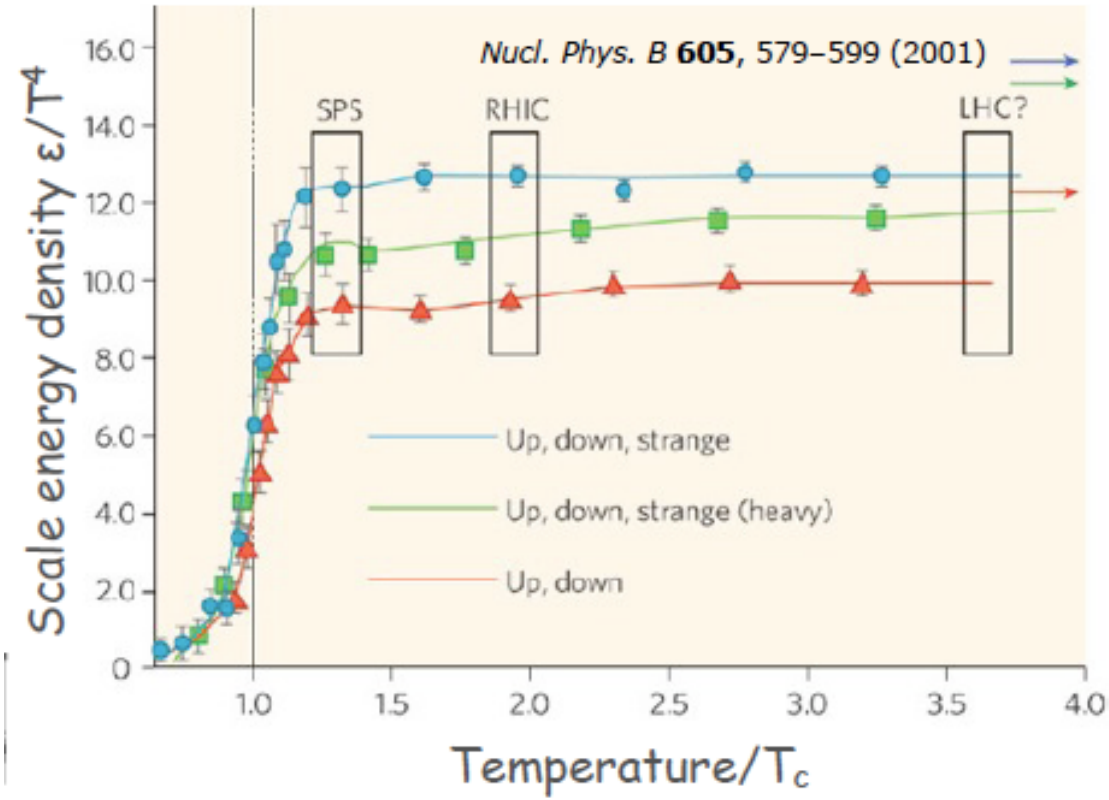


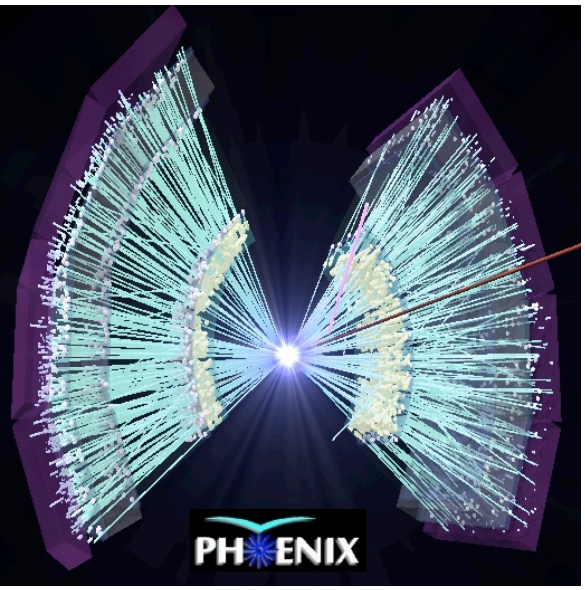
RHIC vs. LHC

	RHIC	LHC
$\sqrt{s_{NN}}$ (GeV)	200	5500
T/T_c	1.9	3.5-4.0
ε (GeV/fm^3)	5	15-60
τ_{QGP} (fm/c)	2-4	> 10



- **High temperature QGP ($2 \times T_{RHIC}$).**





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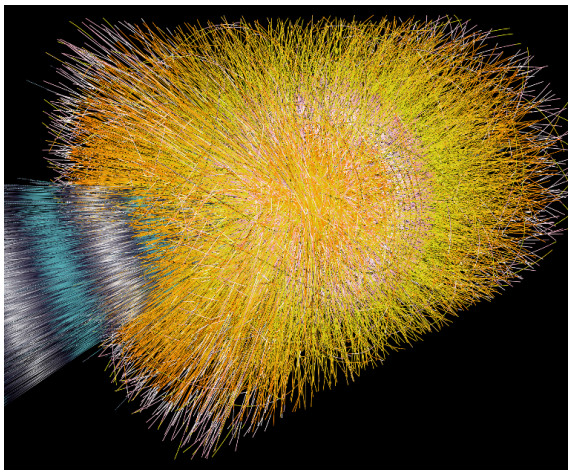
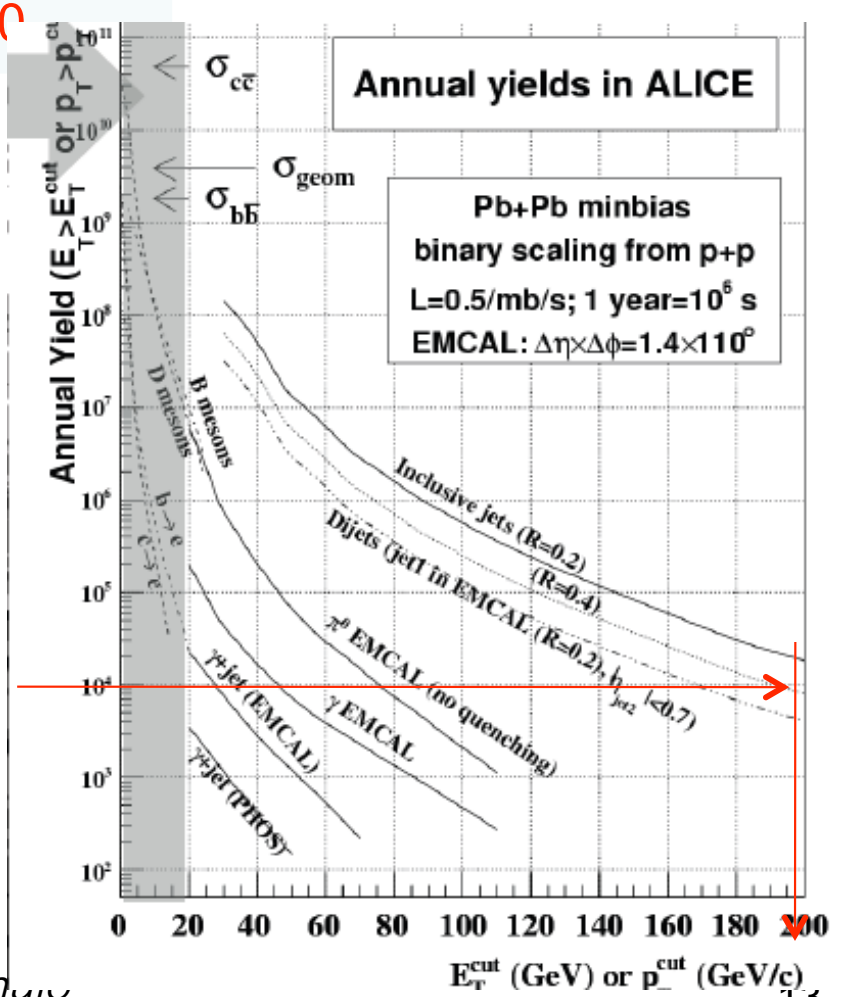
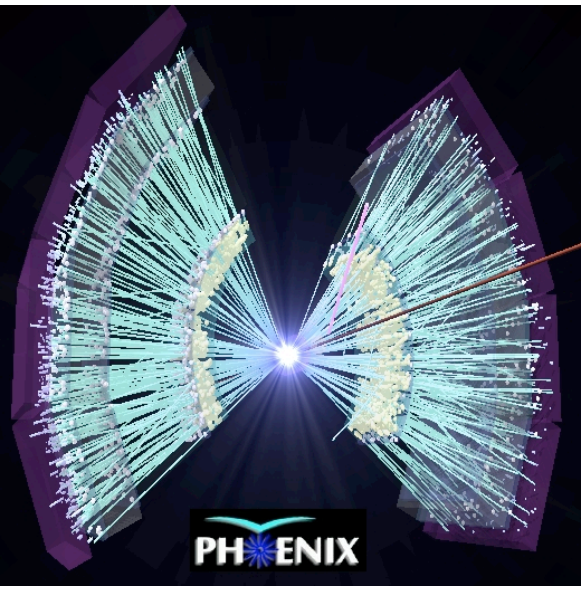


- **High temperature QGP ($2 \times T_{RHIC}$).**
- **Jet production dominant.**

LHC:
Inclusive jets,
annual yield; 10^4 @
p_T = 200 GeV/c
(5.5 TeV, Year-1)





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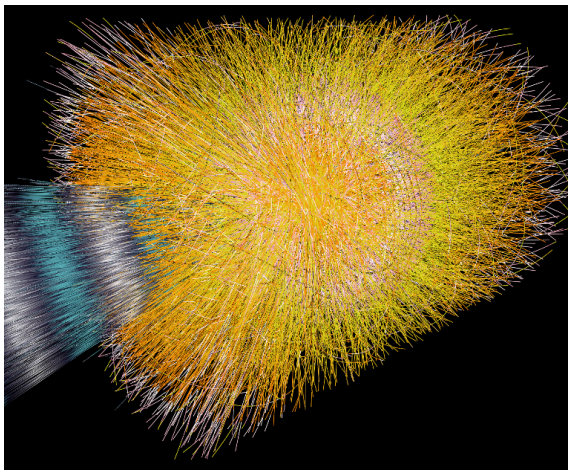
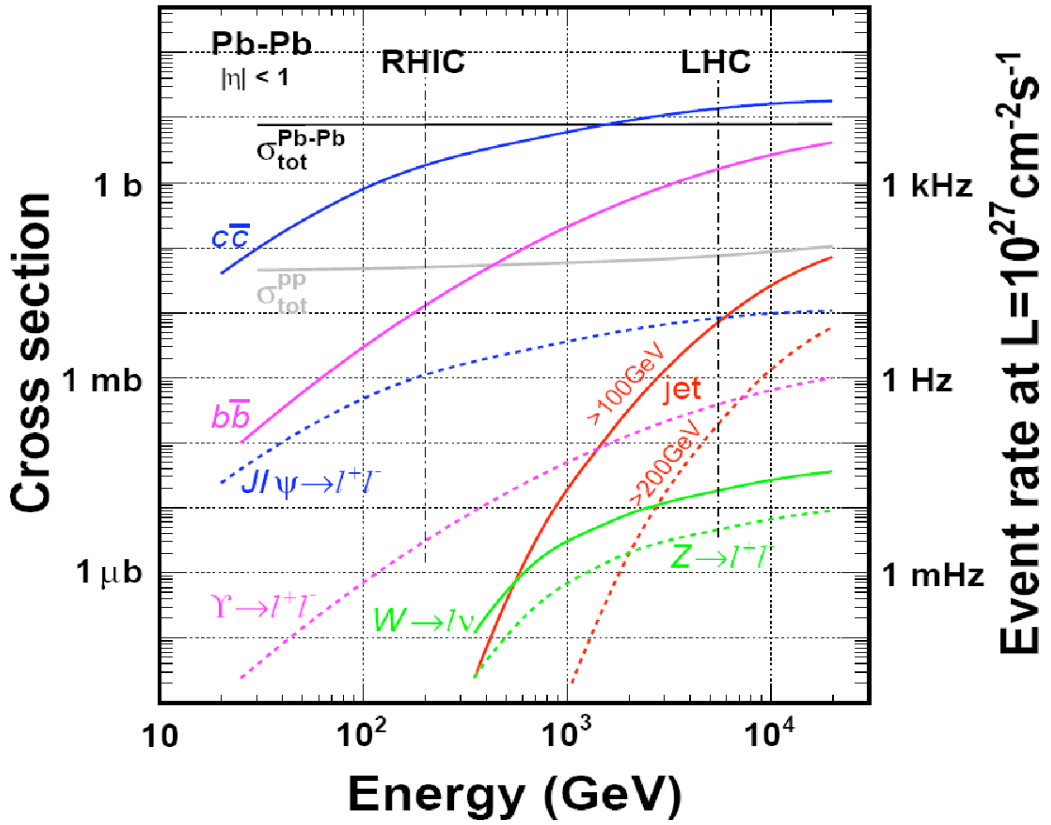
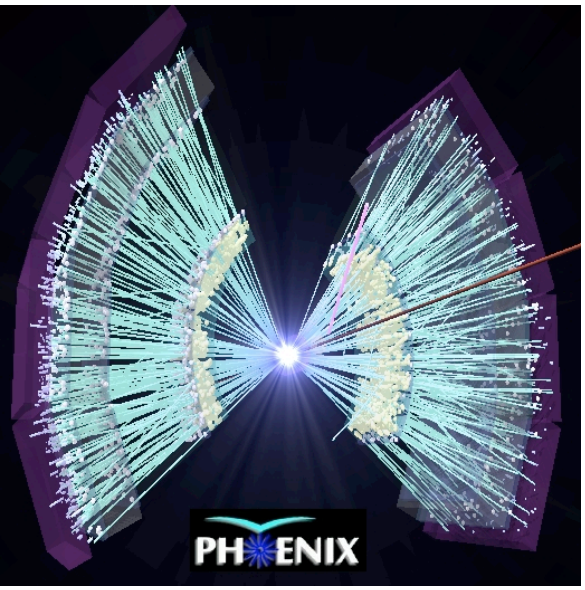


[JW Harris, Winter WS on Nucl. Dynamics (2008)]

- **High temperature QGP (2 x T_{RHIC}).**
- **Jet production dominant.**
- **Copious heavy quark production (10x $\sigma_{c\text{-}cbar}$).**





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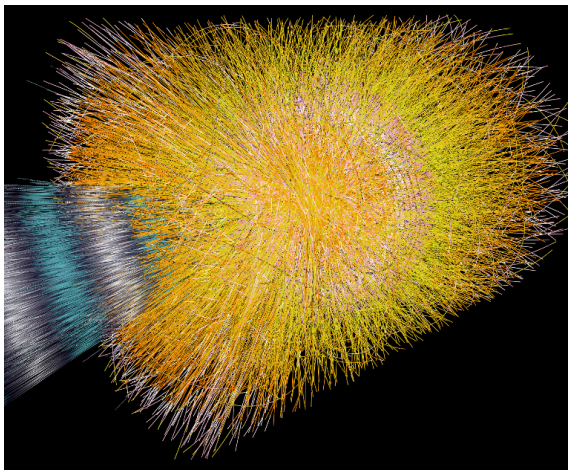
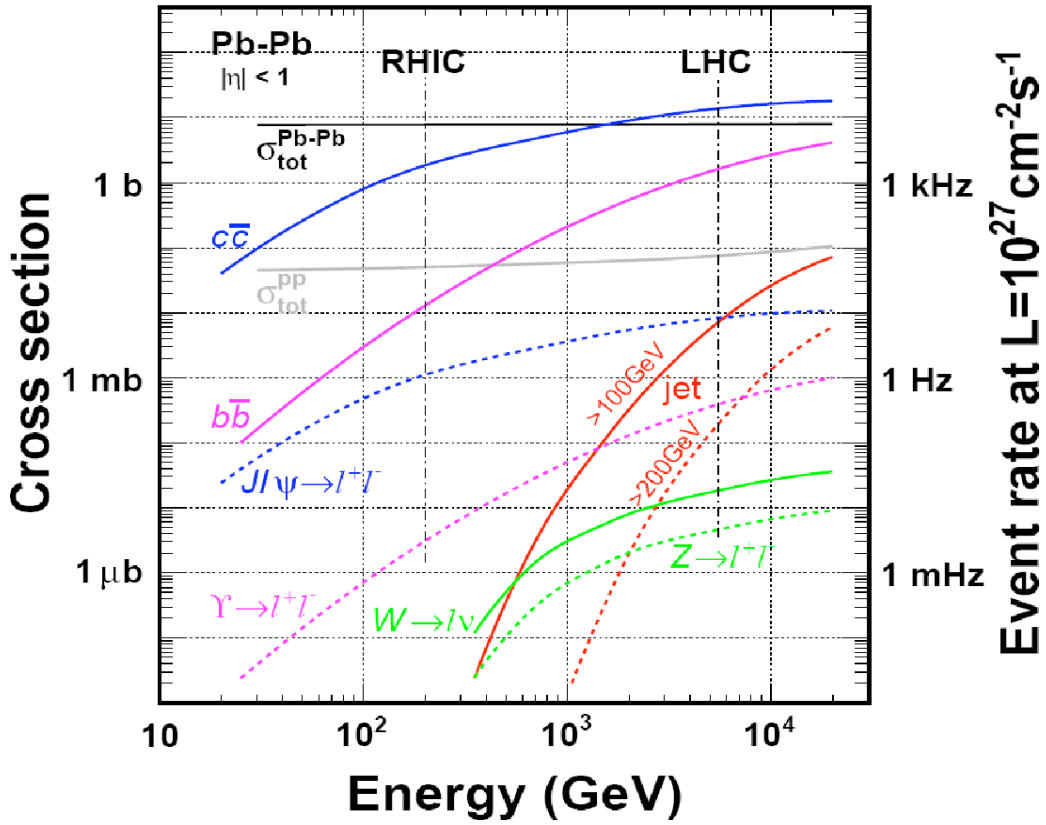
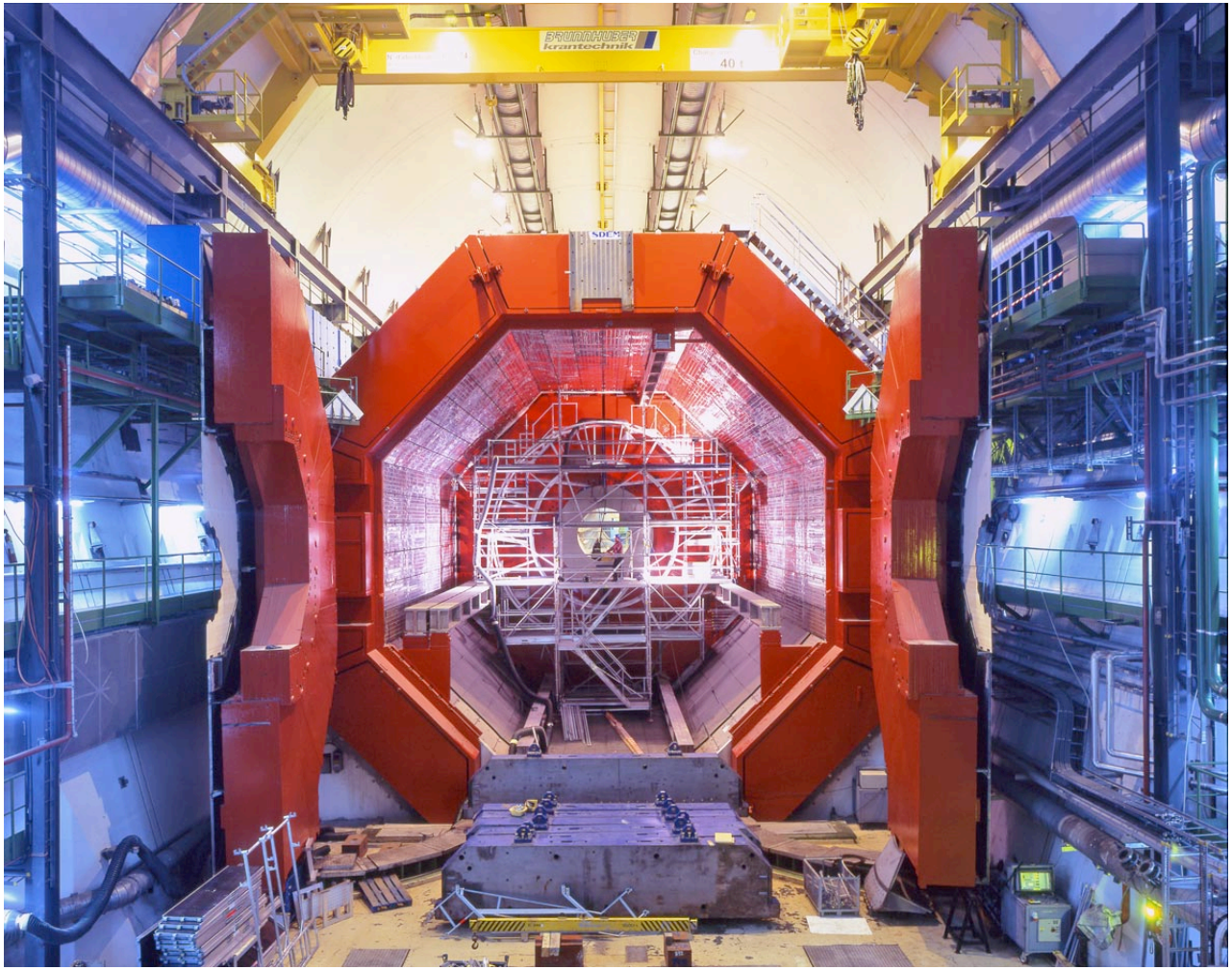


- **High temperature QGP (2 x T_{RHIC}).**
- **Jet production dominant.**
- **Copious heavy quark production (10x $\sigma_{c\text{-}cbar}$).**
- **LHC:**
  - **Study the matter by clean probes, and response of bulk matter in HI collisions.**





2. LHC & ALICE EXPERIMENT

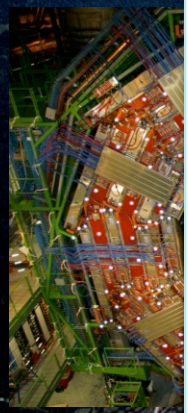
Large Hadron Collider (LHC)

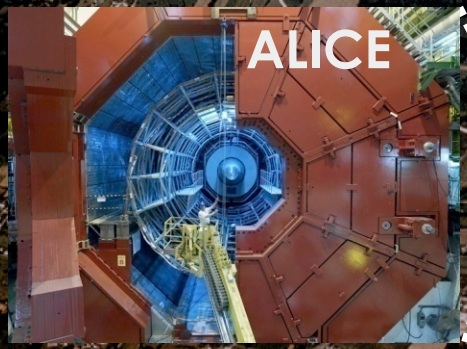
LHC Basics :

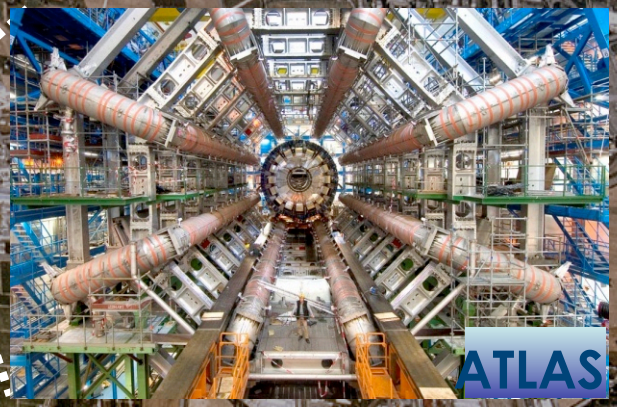
Magnets: 1232, 15 m long, 9 T, superconducting dipoles
Circumference: 27 km

$p+p\ \sqrt{s} = 14\ TeV,\ L = 10^{34}\ cm^{-2}s^{-1}$

$Pb+Pb\ \sqrt{s_{NN}} = 5.5\ TeV,\ L = 10^{27}\ cm^{-2}s^{-1}$







ALICE experiment

ALICE = *A Large Ion Collider Experiment*

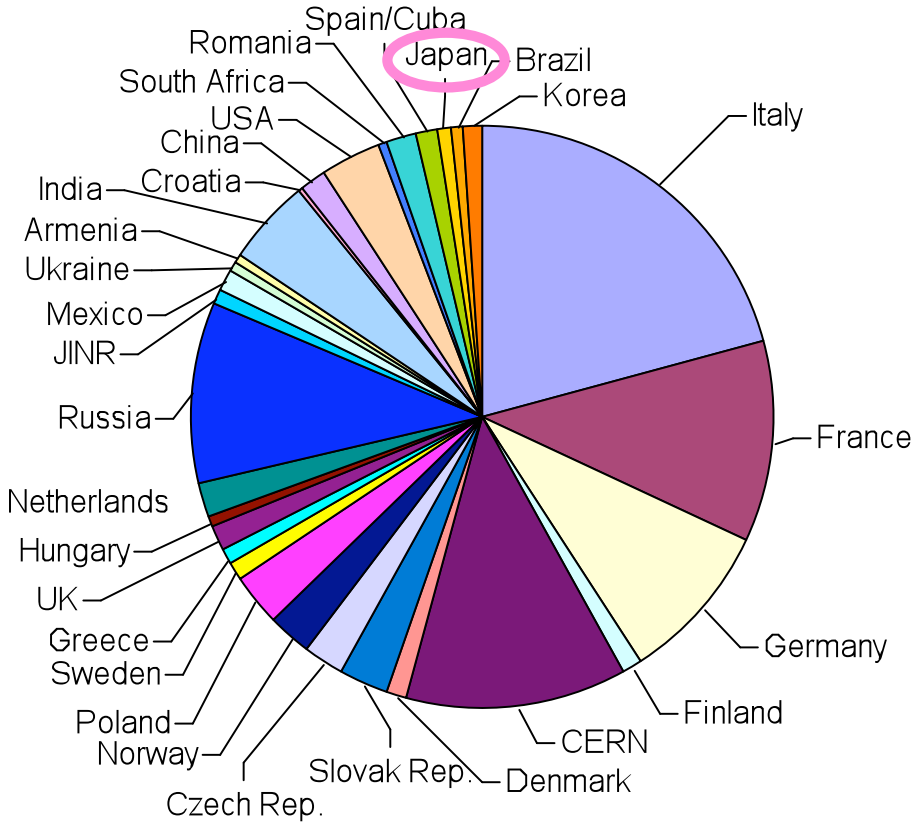
- Dedicated heavy ion experiment at LHC:
  - Study 'state of matter' at high temperature & energy density; QGP.
  - LHC: **30 x energy** of RHIC
    - Expect very different type of 'QGP'
    - 'hard signals' to probe QGP (jets, γ, c and b quark)
    - First Pb+Pb (2.76 TeV) collisions Nov. 2010

- ALICE Institutes from Japan(ese).
  - Hiroshima Univ.: PHOS
  - Tokyo Univ. (CNS): TRD, FoCAL upgrade
  - Univ. of Tsukuba: EMCal, DCal

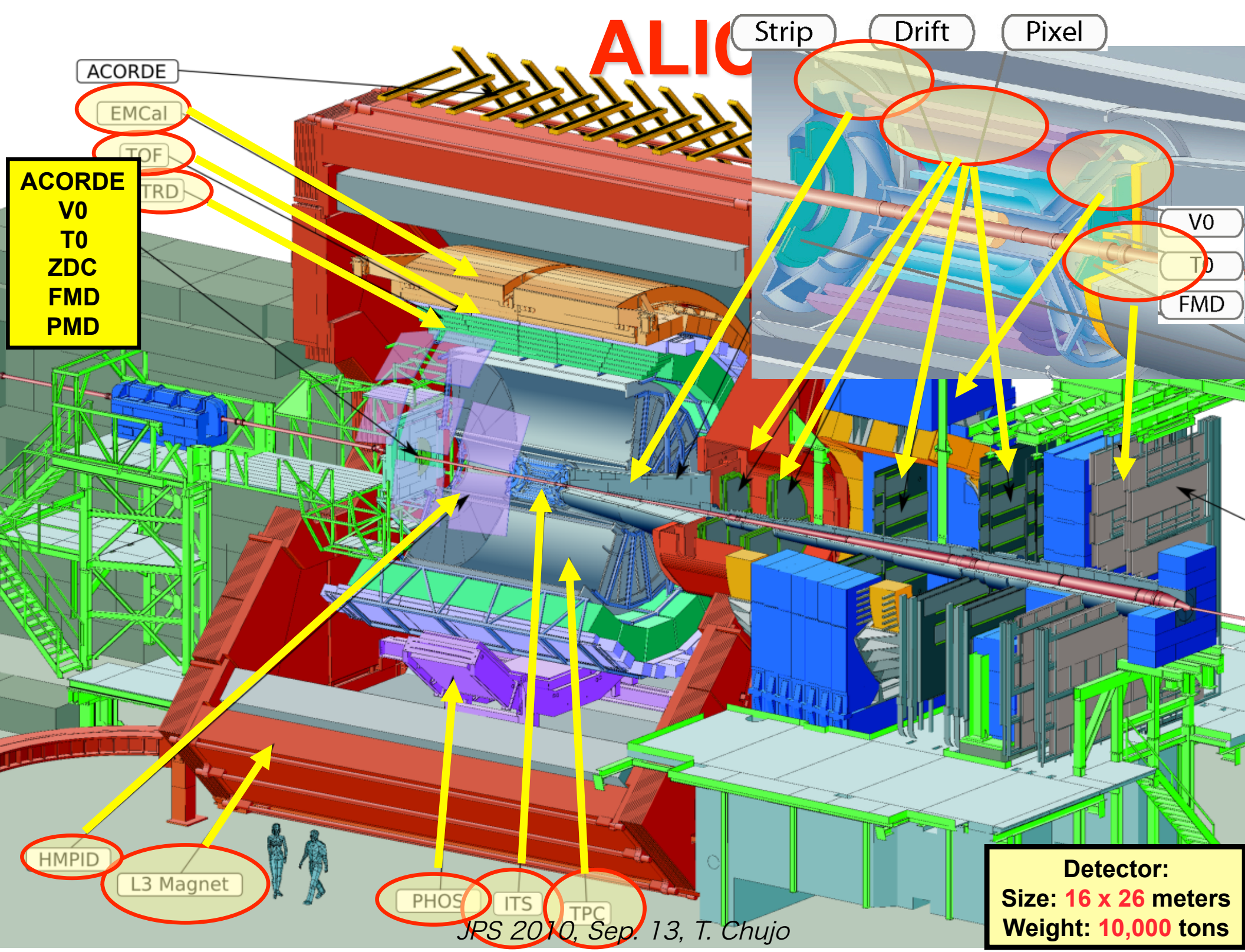
  + Heidelberg Univ. (K. Oyama): TRD, Trigger

広島大学 東京大学 THE UNIVERSITY OF TOKYO CNS 筑波大学 University of Tsukuba

ALICE Collaboration



Collaboration:
> 1000 Members
> 100 Institutes
> 30 countries

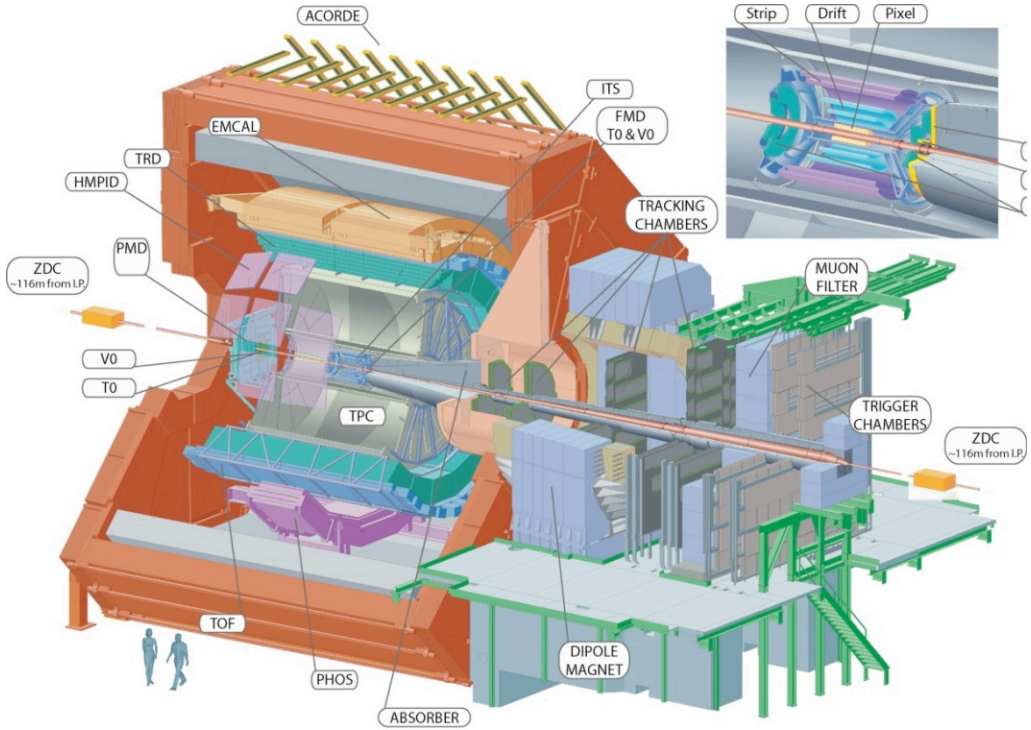

ALIC
Strip
Drift
Pixel
ACORDE
EMCal
TOF
TRD
ACORDE
V0
T0
ZDC
FMD
PMD
V0
T0
FMD
HMPID
L3 Magnet
PHOS
ITS
TPC
Detector:
Size: 16 x 26 meters
Weight: 10,000 tons

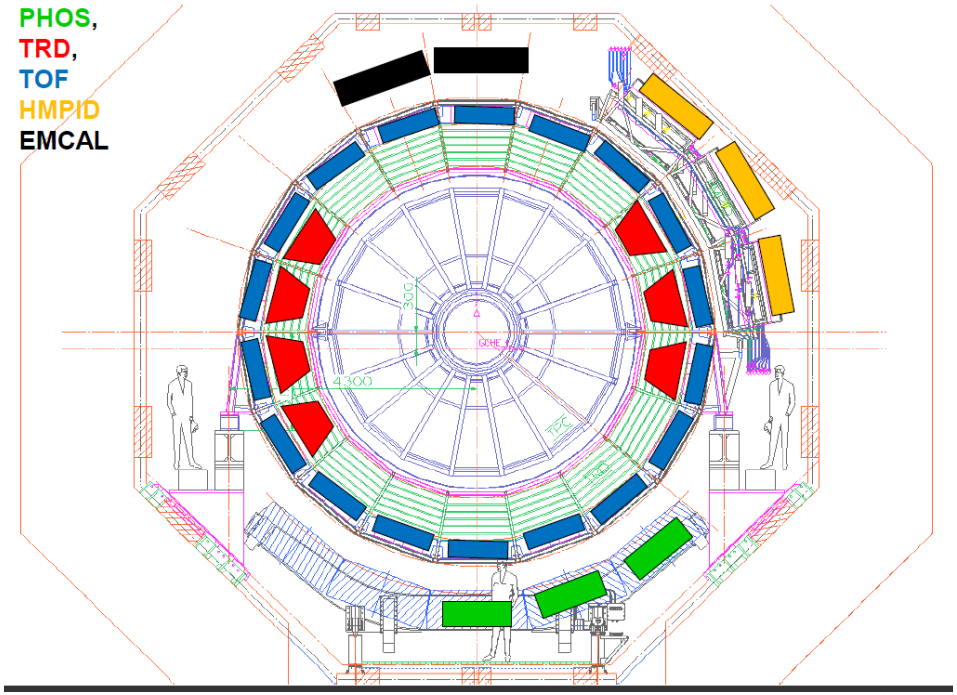
Detector configuration 2010

- ITS, TPC, TOF, HMPID, MUON, V0, T0, FMD, PMD, ZDC (100%)
- TRD (7/18)
- EMCAL (4/12)
- PHOS (3/5)
- HLT (60%)

◆ **Full hadron and muon capabilities**

◆ **Partial electron and photon**

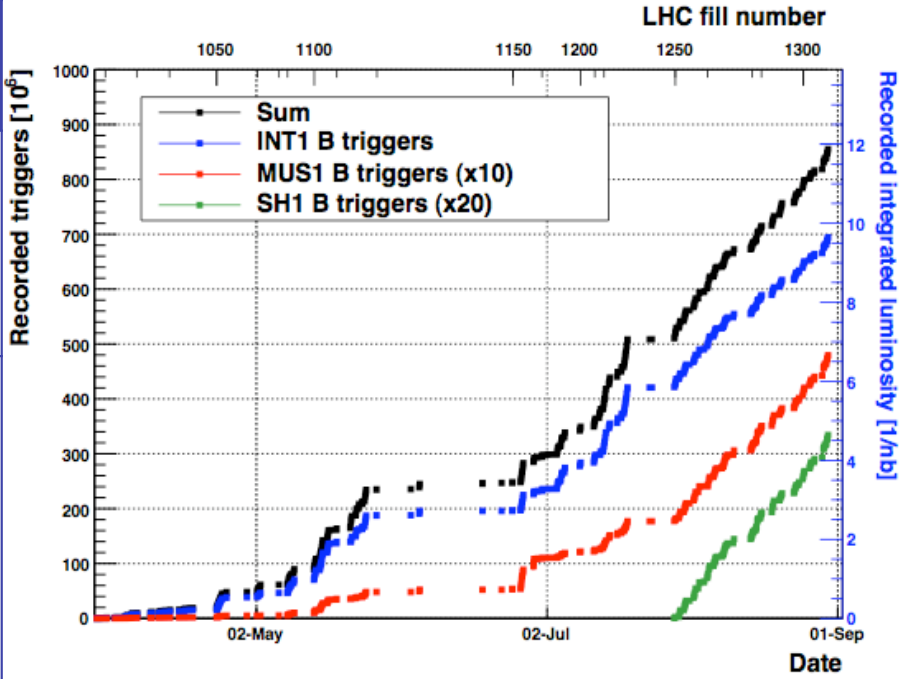




ALICE detector is fully operational !

Data taking / Trigger (2009-2010)

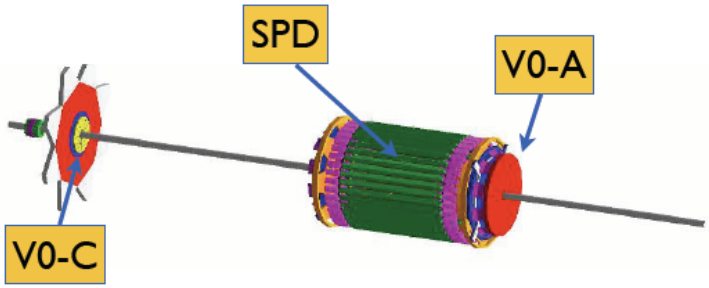
Run	Period	System	√s (TeV)	# of events
Run 1	Nov. – Dec. 2009	p+p	0.9	500 k (MB)
Run 2	Mar. 30 – Oct. 2010	p+p	7.0	**700 M (MB)** 500 M (single muon) 300 M (high multi.)
		p+p	0.9	2 M (MB)



Recorded trigger vs. Date

Trigger:

- Minimum bias (MB_{or}): SPD ***or*** V0-A ***or*** V0-C (96% eff. for INEL).
  - → at least one charged particle in 8 pseudorapidity units
- $V0_{AND}$: Hit on both side of V0. (93% eff. for NSD).

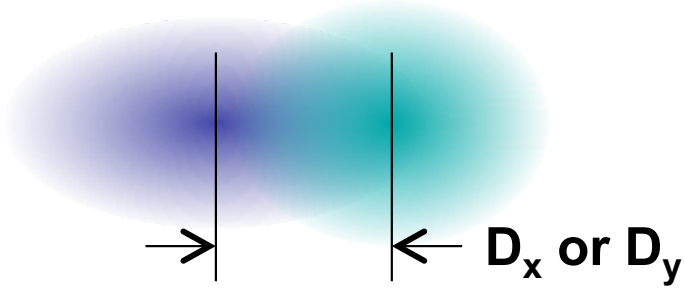


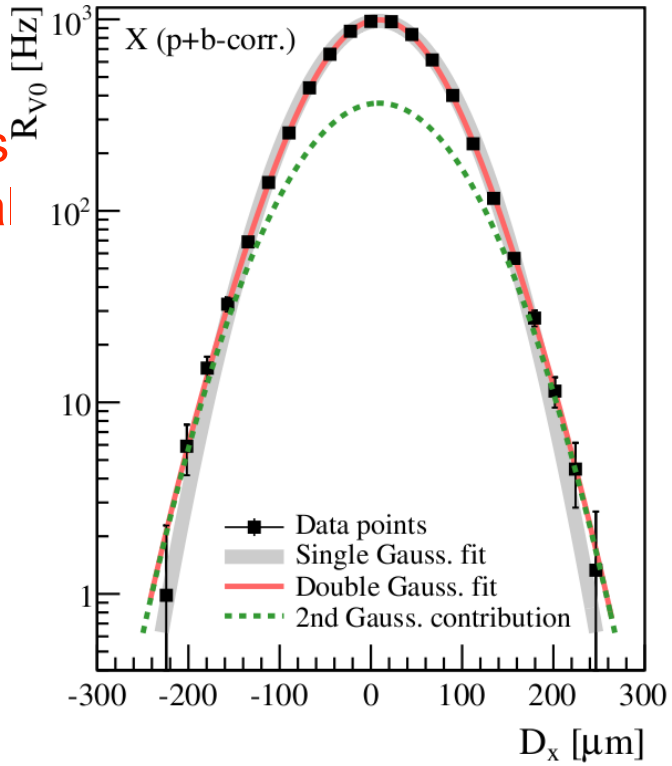
Absolute normalization

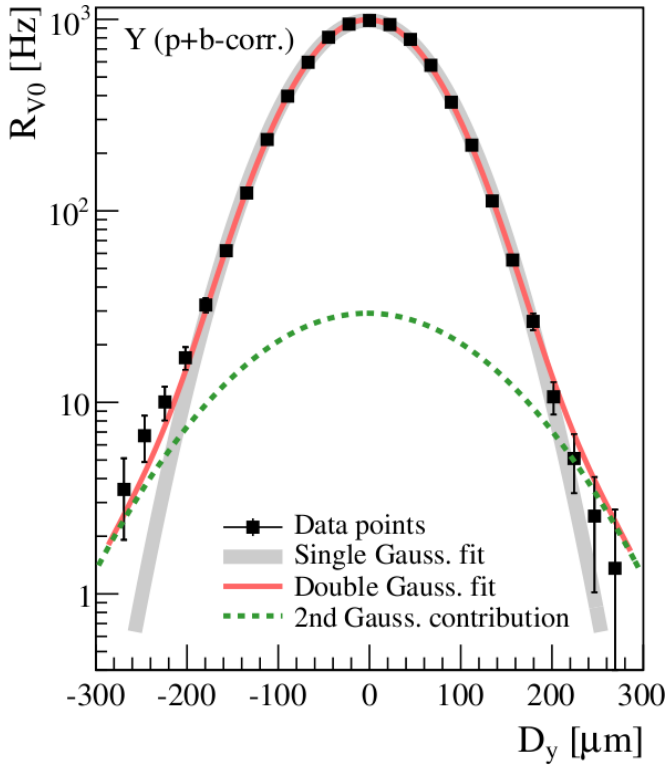
- Vernier (van der Meer) scan tells trigger cross section
- Performed in Apr. for p+p at 7 TeV
- V0-AND trigger cross section (~62 mb) measured with 8 % of syst. uncertainty

$$R_{\mathrm{V0}}(D_x, D_y) = \underbrace{R_{\mathrm{V0}}(0,0)}_{\text{top rate}} \cdot \exp\left(-\frac{D_x^2}{2\sigma_{scan-x}^2}\right) \exp\left(-\frac{D_y^2}{2\sigma_{scan-y}^2}\right)$$

  - beam size @ β^*=2 m
    - **X: 44 μm**
    - **Y: 47 μm**
- Using this result, the cross section normalization for al measurements (J/ψ, charm) are on going



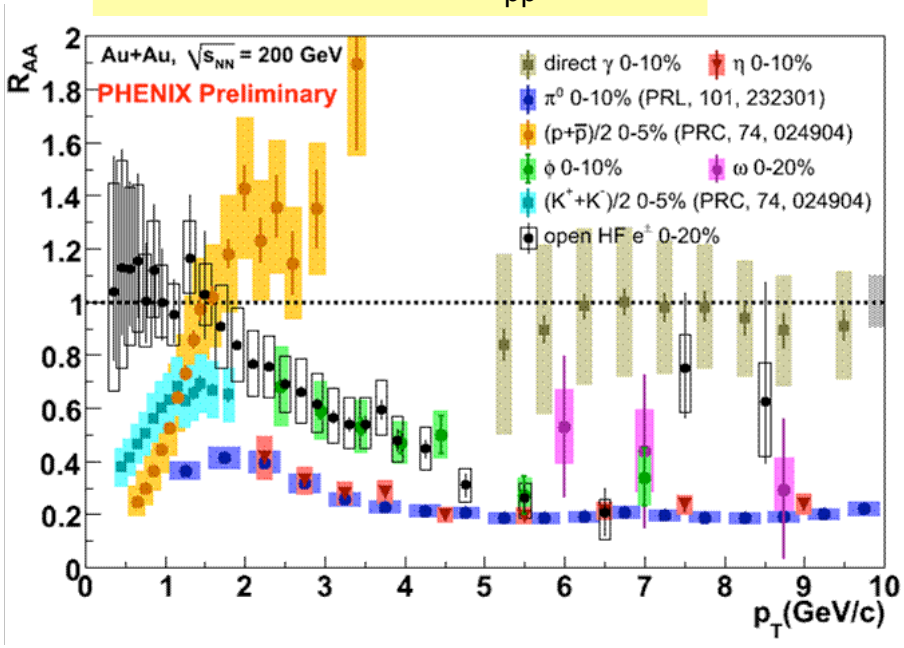




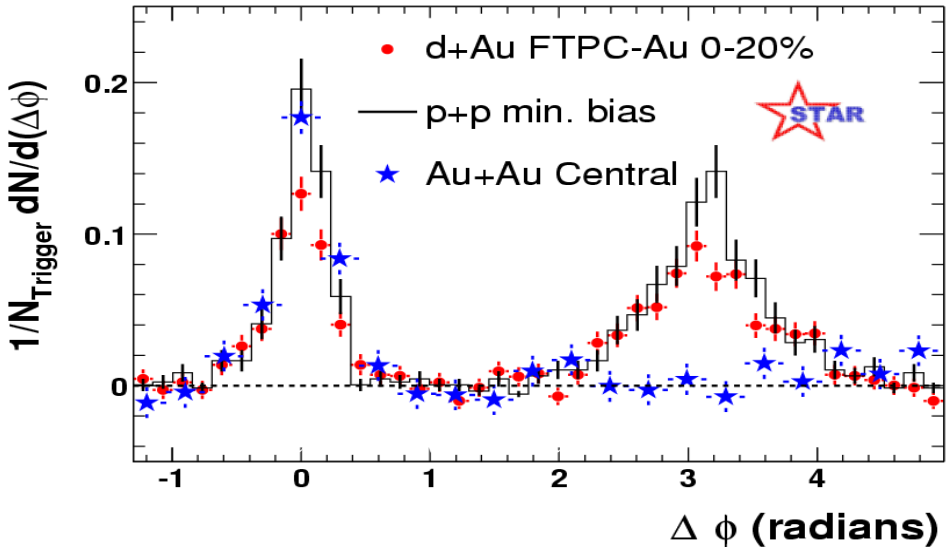
3. ALICE EXPERIMENT AND QGP PHYSICS

(1)Energy loss of parton

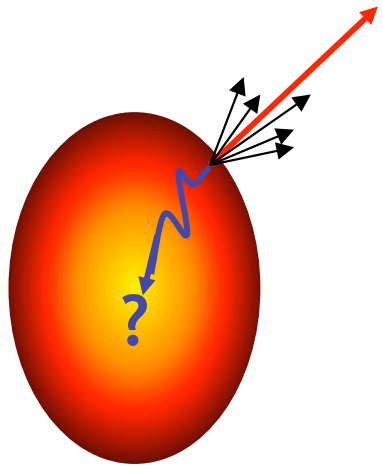
$$R_{AA} = \frac{Yield_{AuAu} / \langle N_{binary} \rangle_{AuAu}}{Yield_{pp}}$$



Phys. Rev. Lett. 91, 072304 (2003).

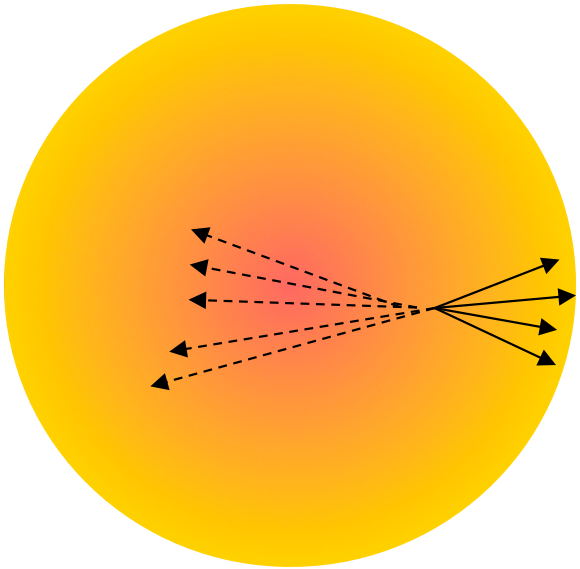


- At RHIC energy:
  - High p_T yield suppression.
    - Gluon density: $dN_g/dy \sim 1100$
    - Energy density: **$\varepsilon > 100\ \varepsilon_0$ (!)**
      - $= \varepsilon > 15$ GeV / fm^3
  - Disappearance of away side jet.

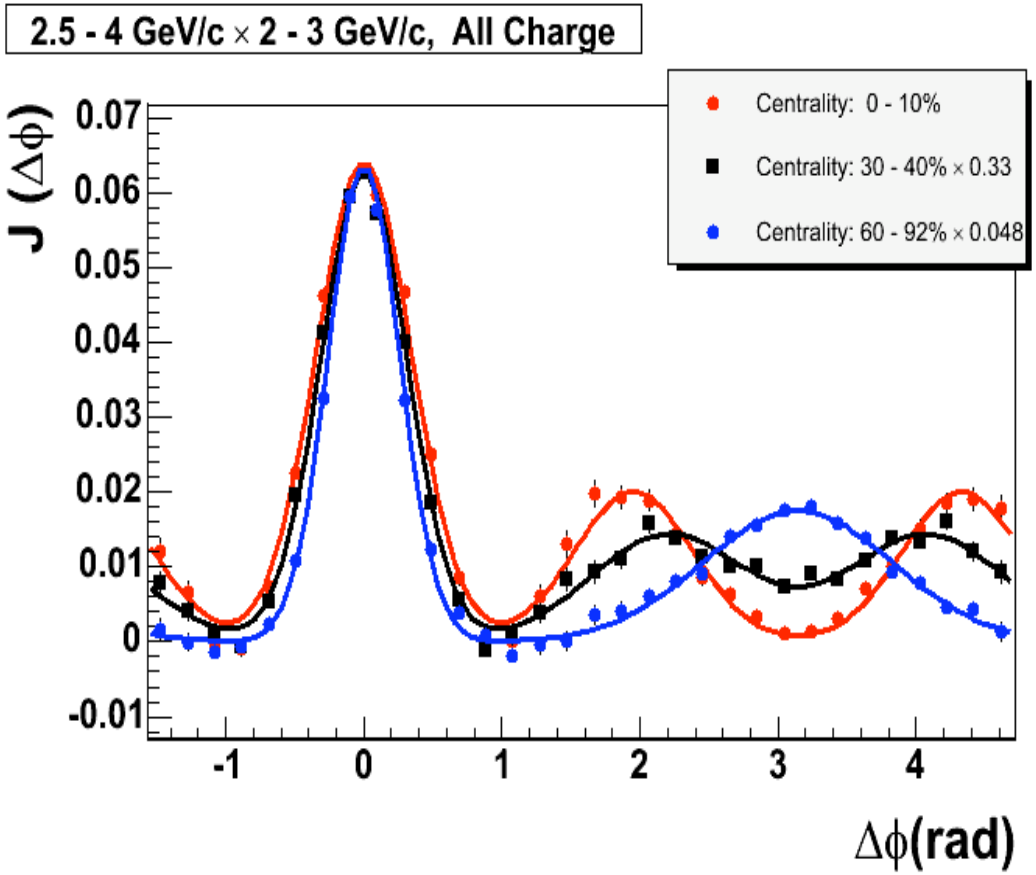


Where is the lost energy?

How parton propagates in dense matter ?



PHENIX (PRL 97, 052301, 2006)

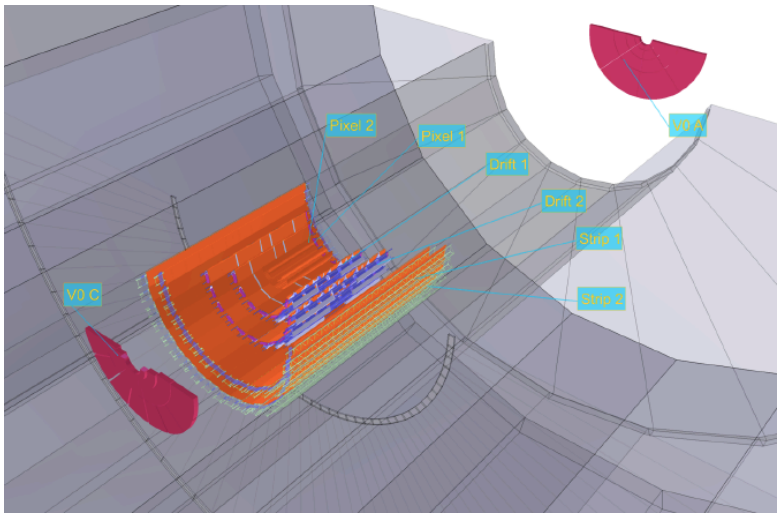


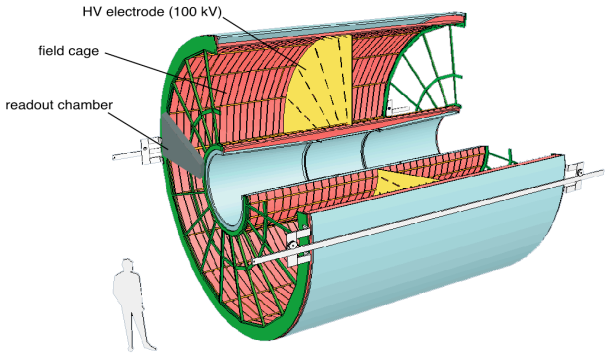
Two peaks in Away side.

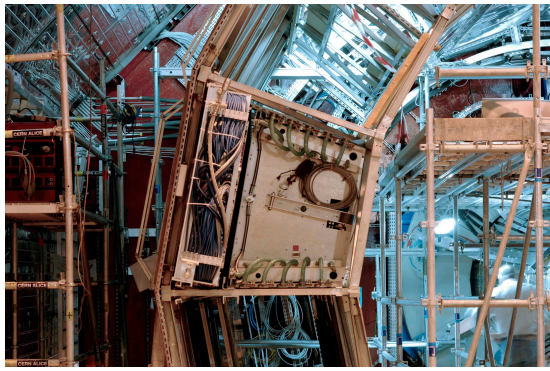
Shock wave?

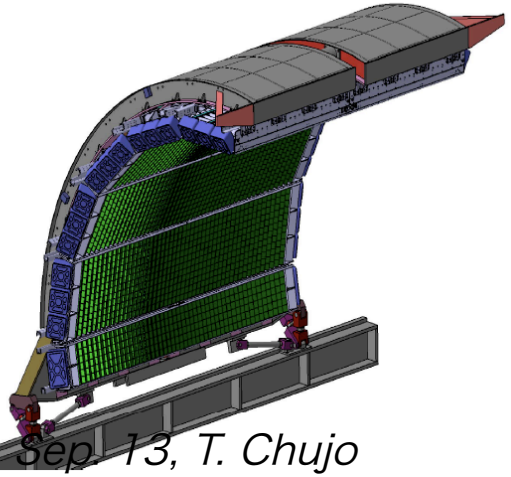
Key detectors for hard probes in ALICE

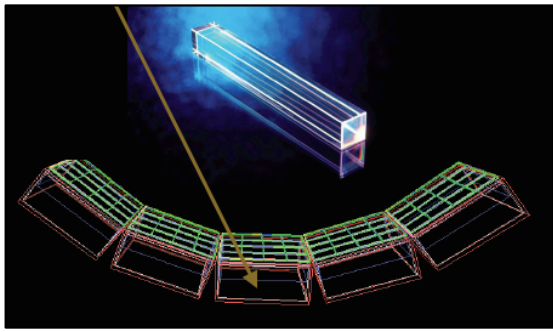
- **ITS, TPC, TRD (40%), TOF, HMPID**
  - Charged particles $\Delta\eta$ = 1.8.
  - Excellent momentum resolution.
  - **Excellent PID** and heavy flavor tagging.
  - TRD: high p_T and electron trigger.
- **EMCal (40%)**
  - Pb-Scint.
  - Energy of neutral particles
  - $\Delta\phi$ = 107°, $\Delta\eta$ = 1.4
  - **Energy resolution ~10%/$\sqrt{E_\gamma}$**
  - Jet and γ trigger
- **PHOS (60%)**
  - PWO
  - 220° < ϕ < 320°, $\Delta\eta$ = 0.24
  - **Energy resolution ~3%//$\sqrt{E\gamma}$**
  - γ trigger.



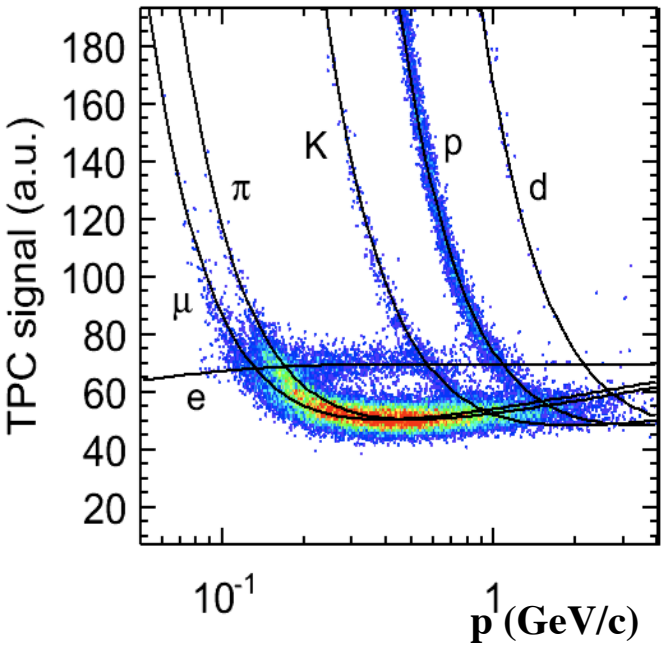




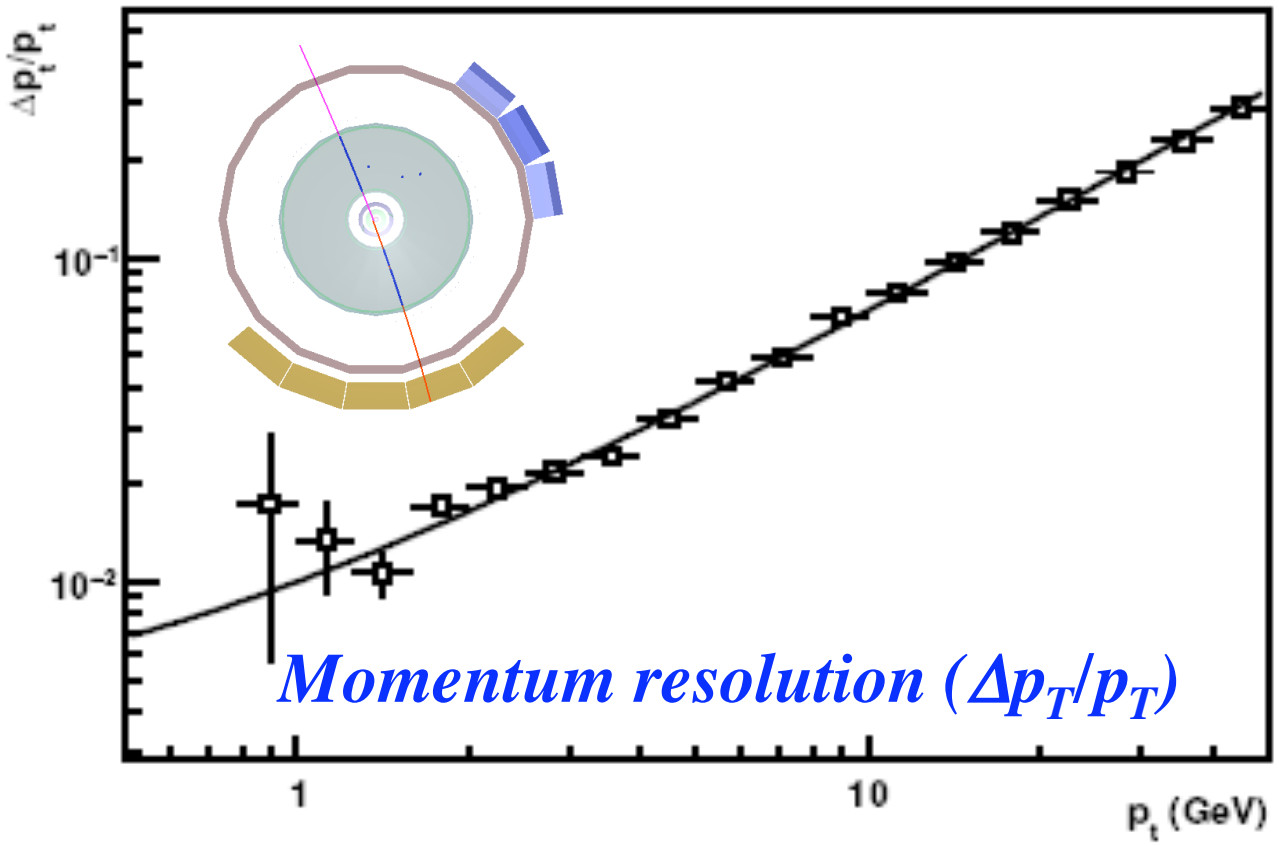




Time-Projection Chamber (TPC)



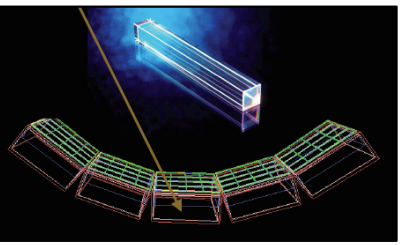
TPC dE/dx vs. p

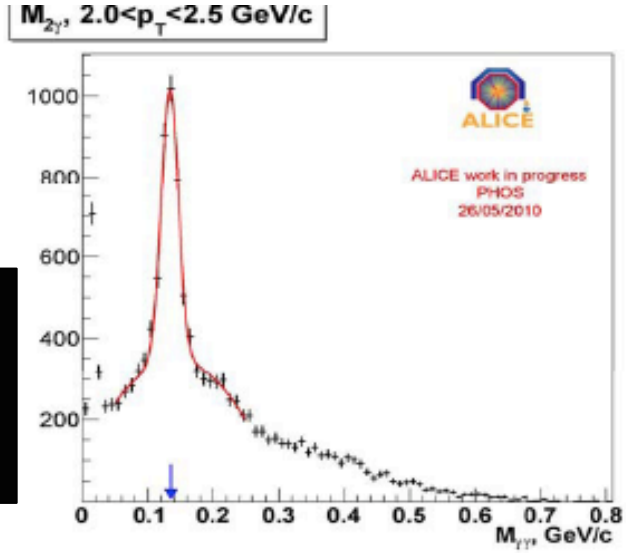


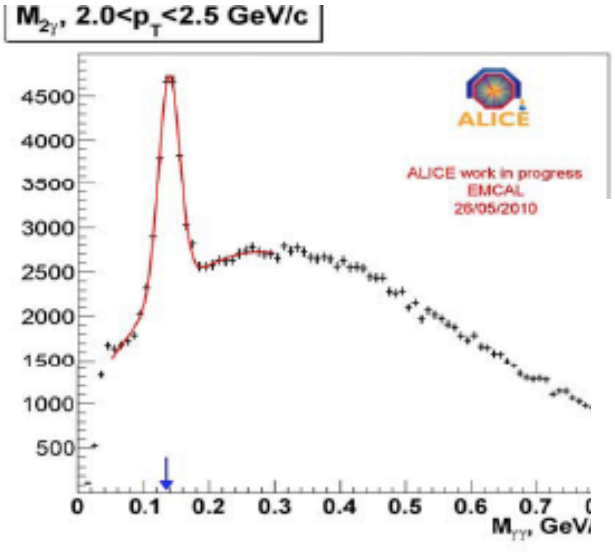
Momentum resolution ($\Delta p_T/p_T$)

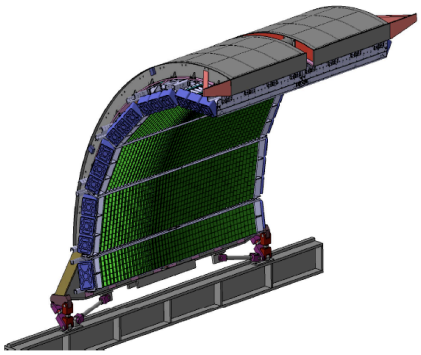
- Detector fully operational: 99.9% of all channels
- dE/dx resolution: < 5%
- Momentum resolution: < 7% at 10 GeV
- Working on distortion map: $\Delta p/p$ < 5% at 10 GeV
- Read-out rate up to 1kHz

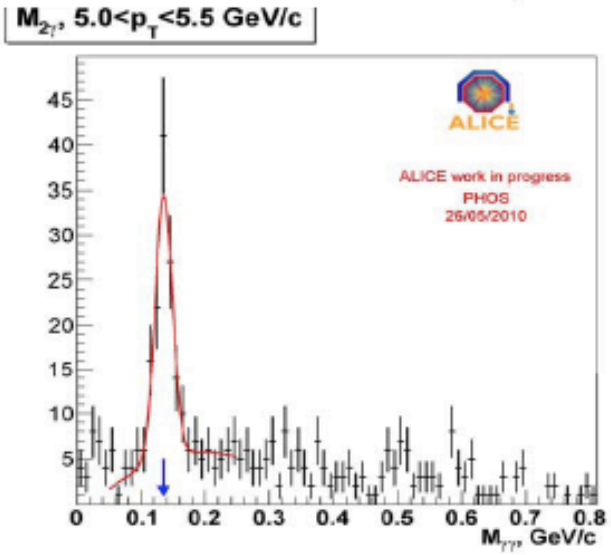
Calorimeters: PHOS, EMCAL

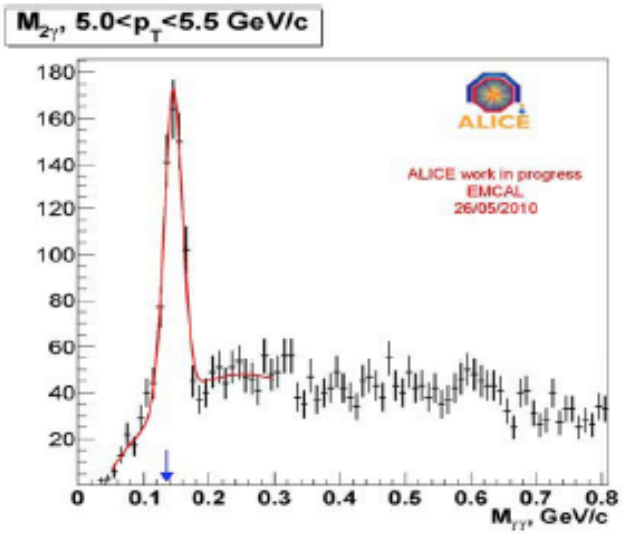






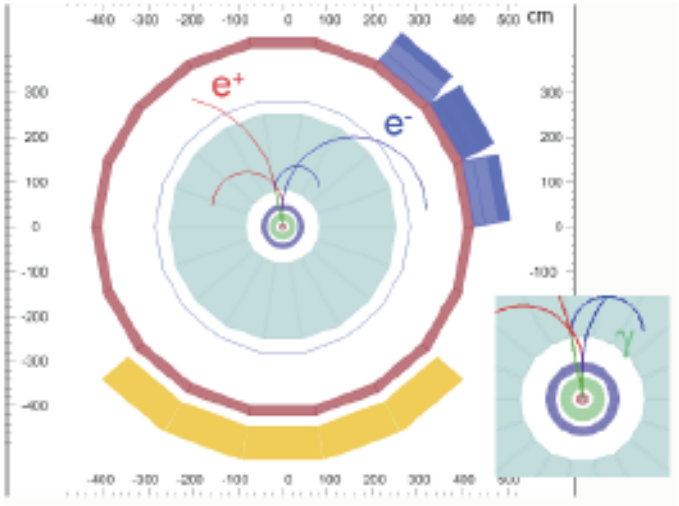




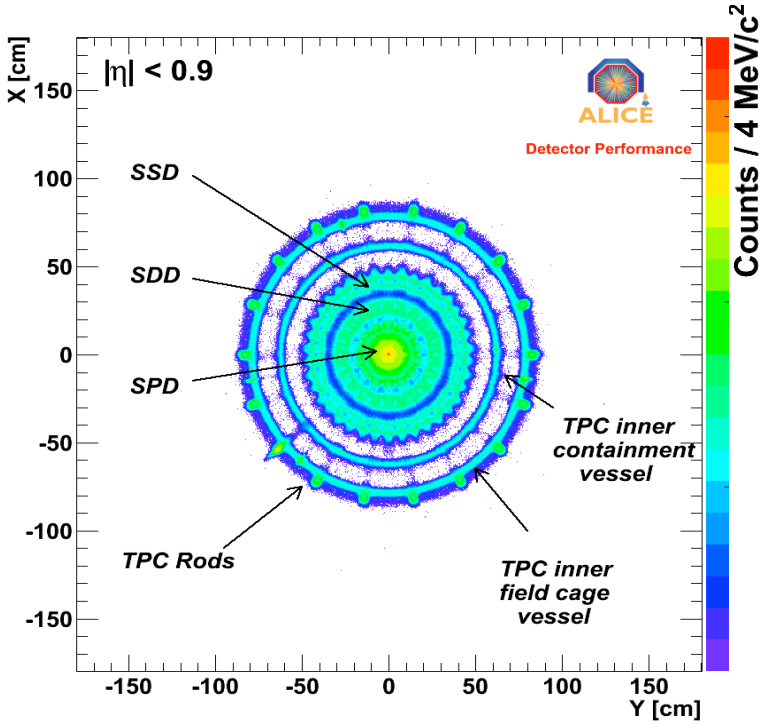


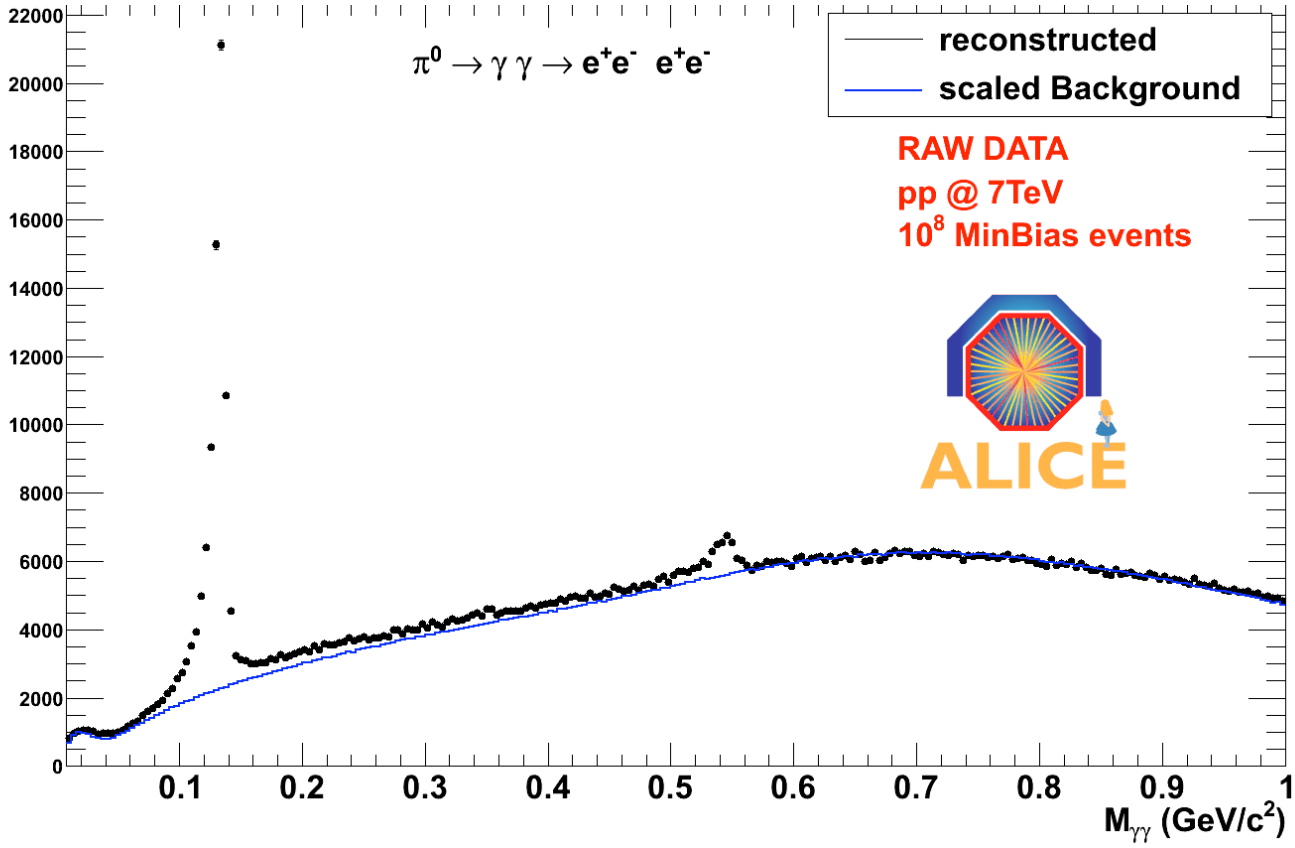
- Invariant mass of π^0 at 7 TeV p+p data.

π^0 and η from γ conversion

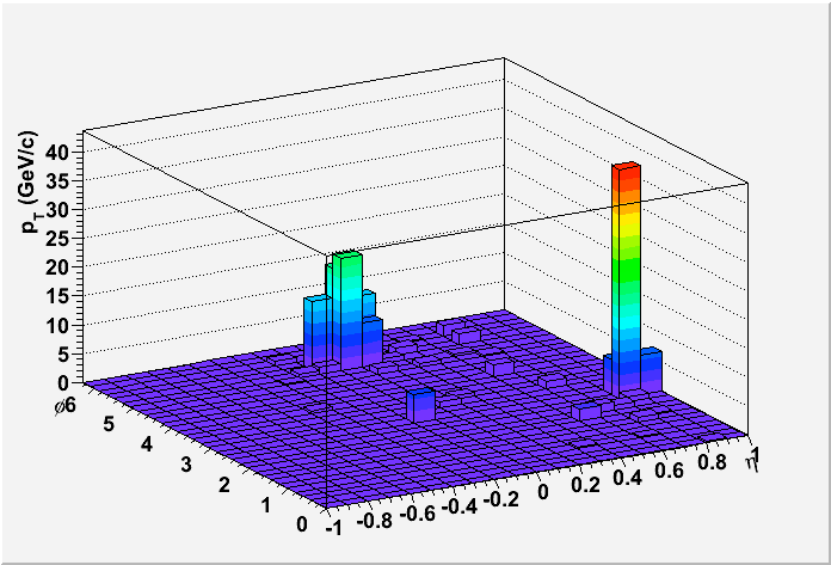


- $e^{\pm}$ identification in TPC
- Study of γ conversion points/material budget

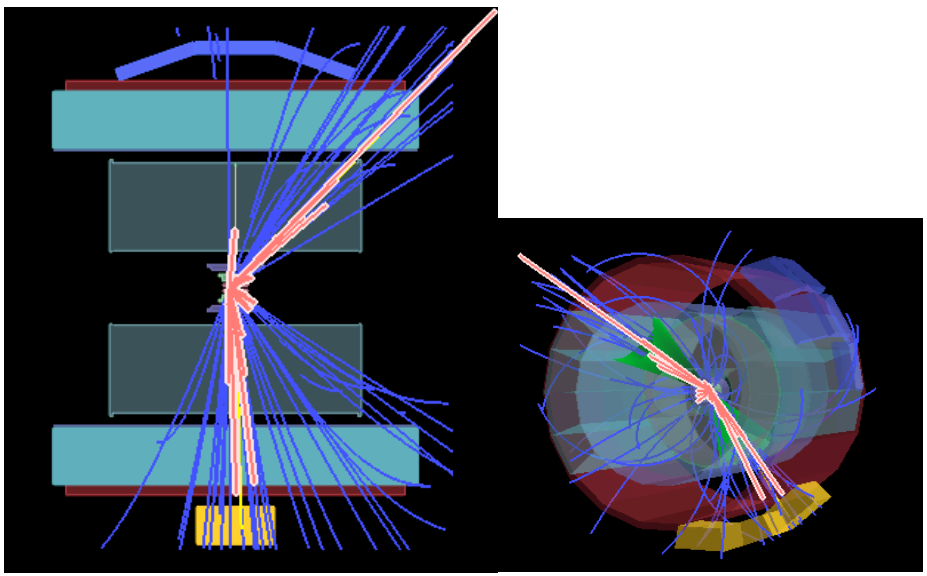


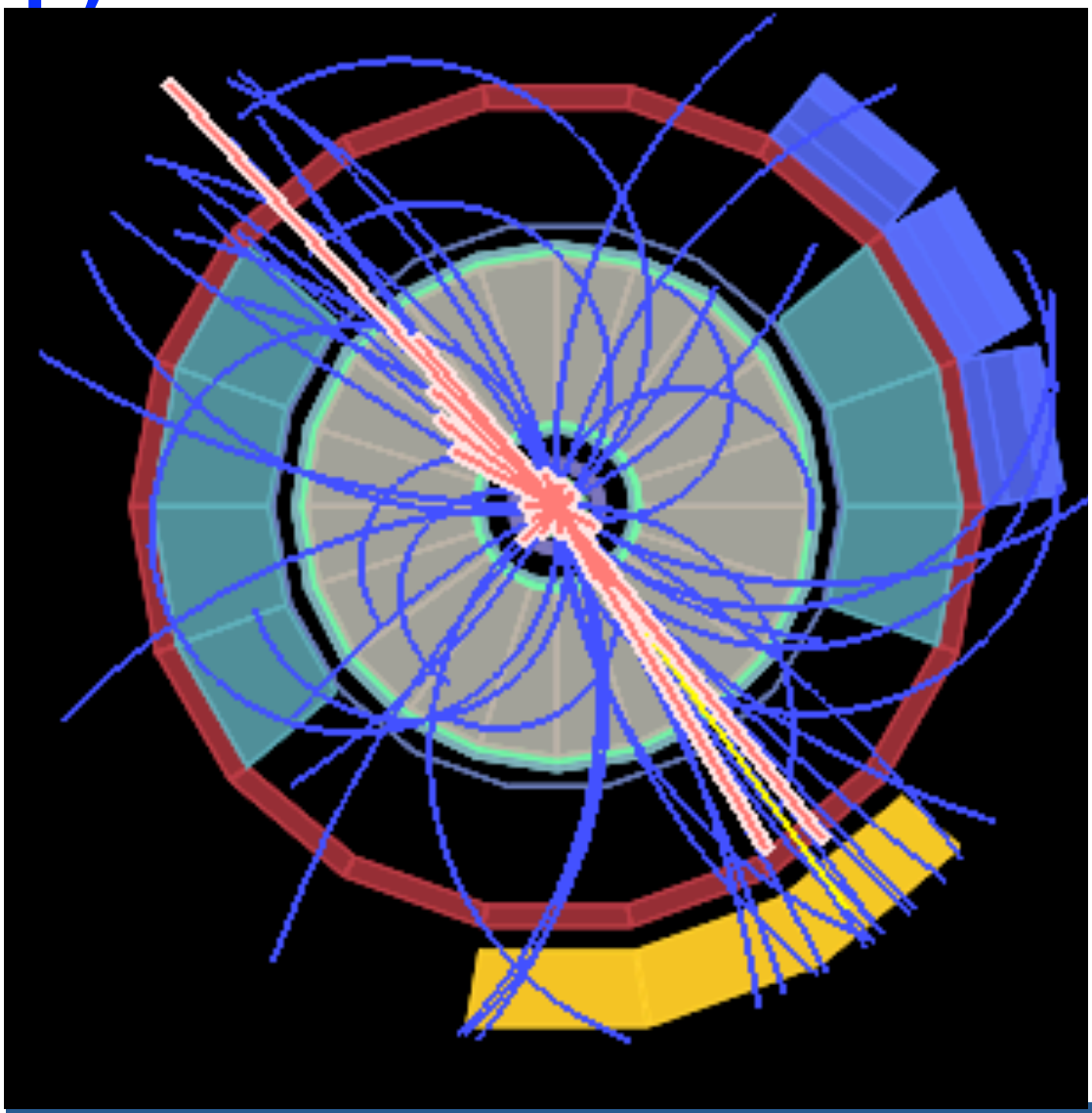


Di-Jet event (7 TeV p+p)



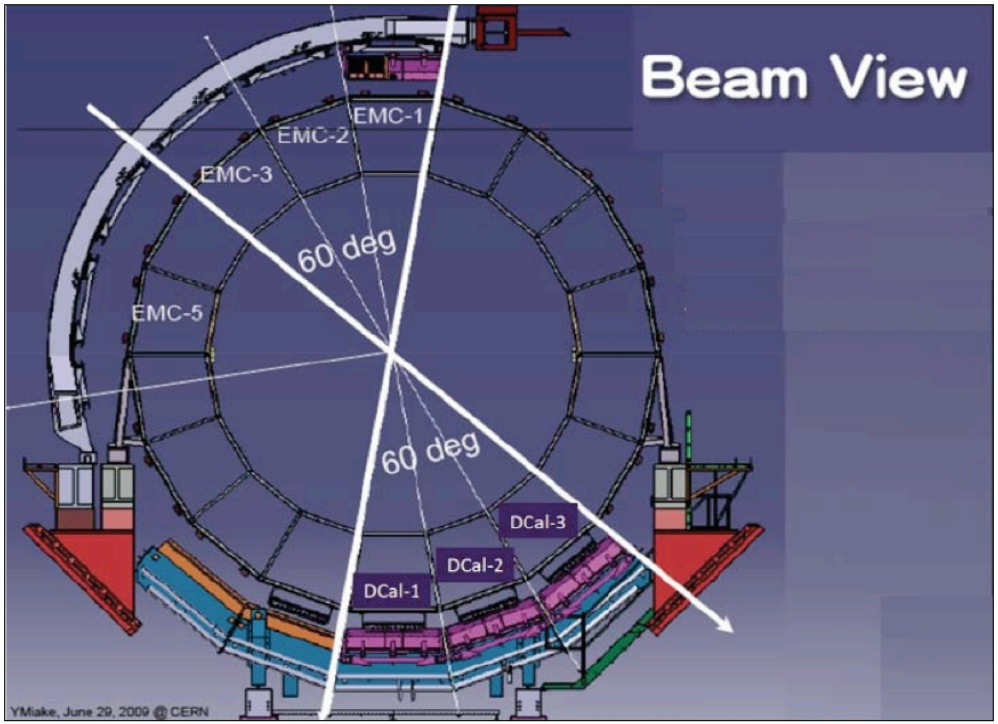
η-ϕ grid





Reconstructed Jets UA1 Cone R = 0.4:
Jet 1: η = 0.02, ϕ = 306°, p_T = 71 GeV, Tracks 15
Jet 2: η = 0.84, ϕ = 132, p_T = 47 GeV, Tracks 9
Δϕ = 174°
Total Tracks 108

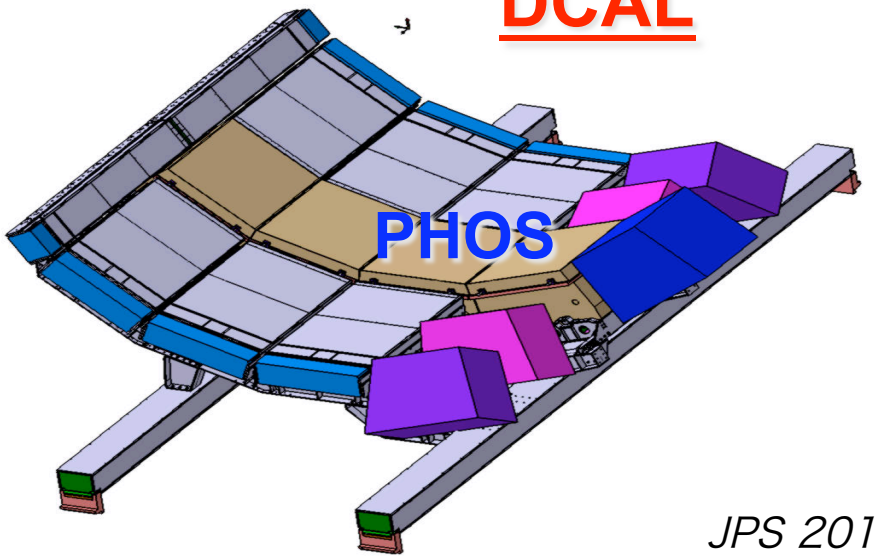
DCAL (Dijet Calorimeter)

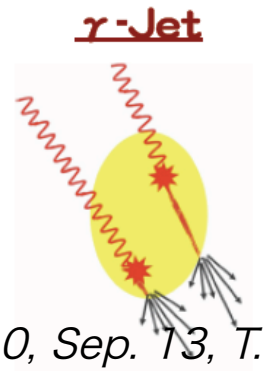


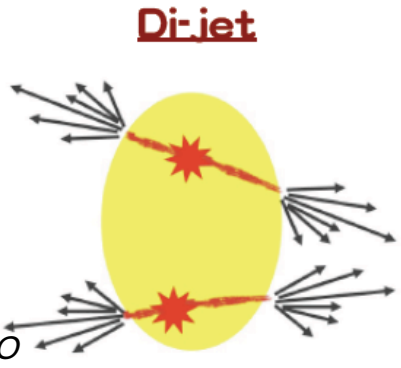
A 60% expansion of EMCal arranged to permit back-to-back hadron-jet, jet-jet and gamma-jet measurements.

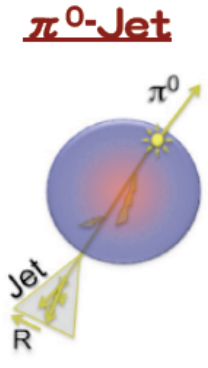
Goal: QGP tomography via detailed «jet quenching» studies: PbPb/pp jet x-section ratios, fragmentation functions, …

(➔ T. Gunji's Talk)

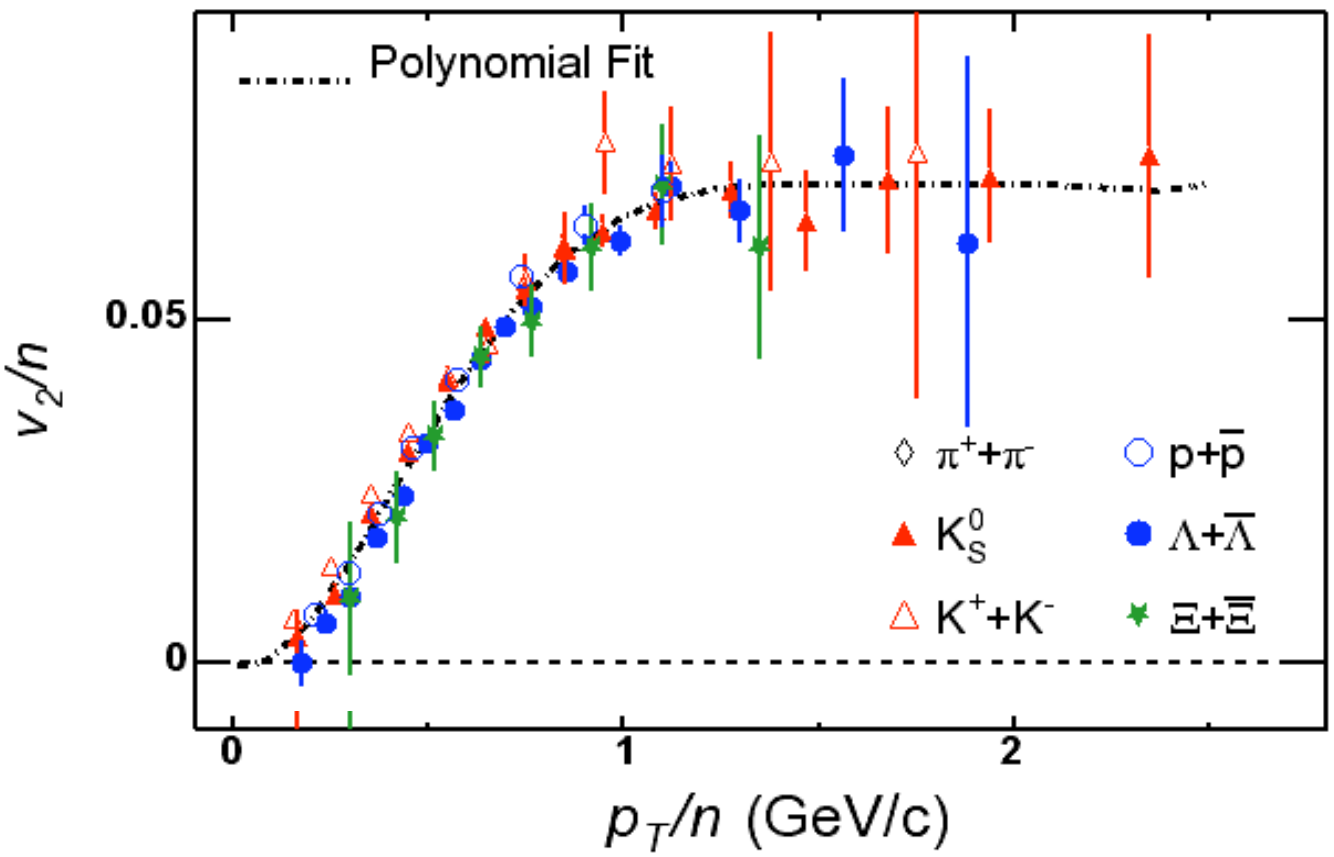


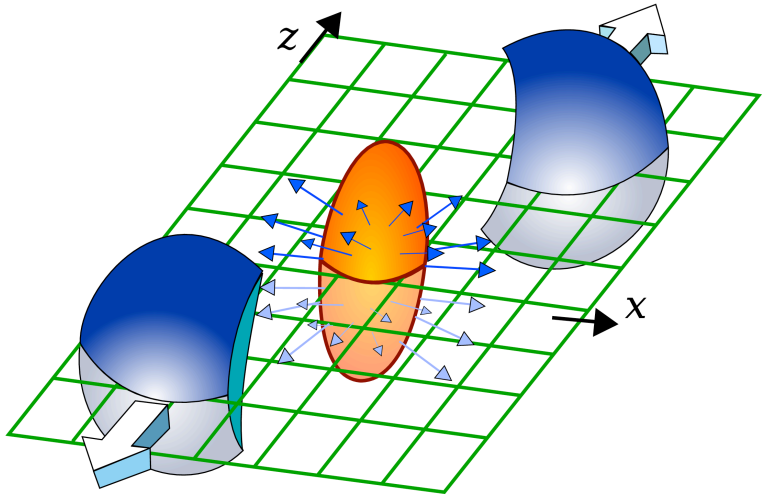


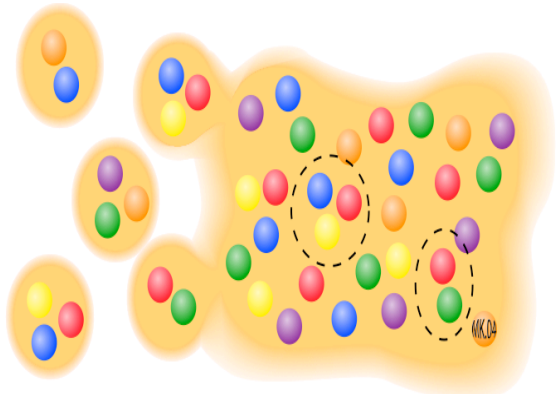




(2) Collectivity

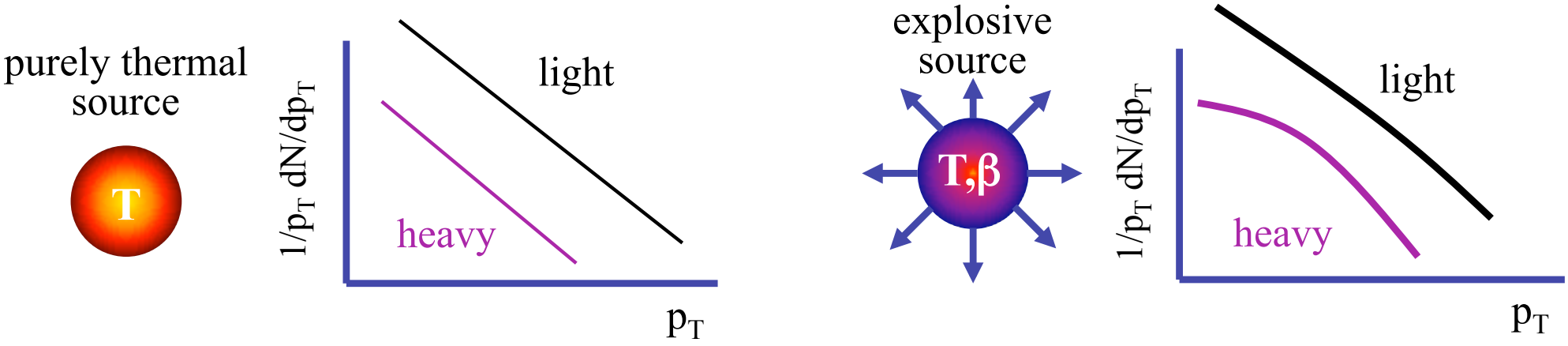


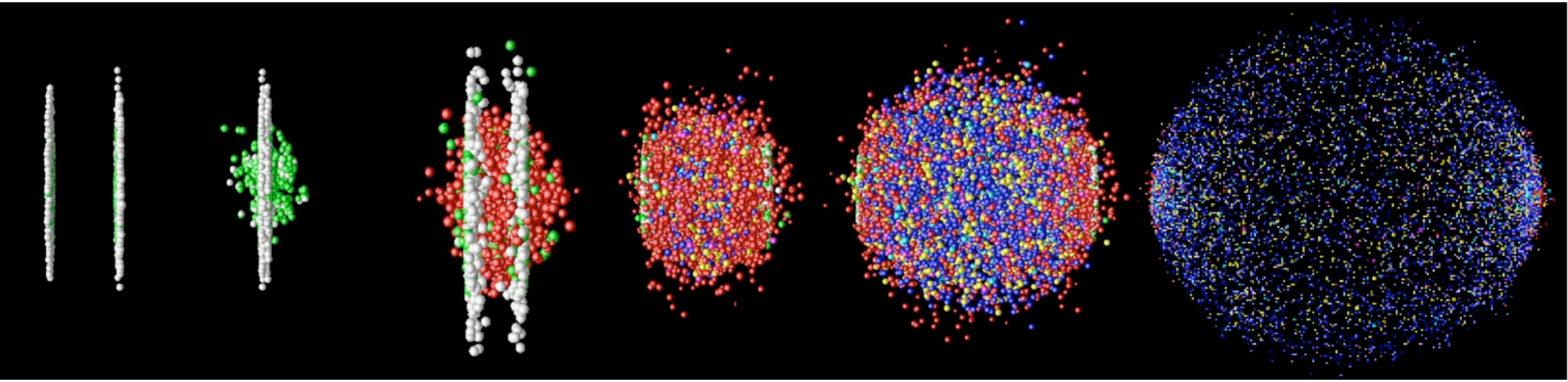




- At RHIC energy:
- Quark number scaling of v_2 works.
- Indication of quark level collective motion at RHIC.
- What happens at LHC?

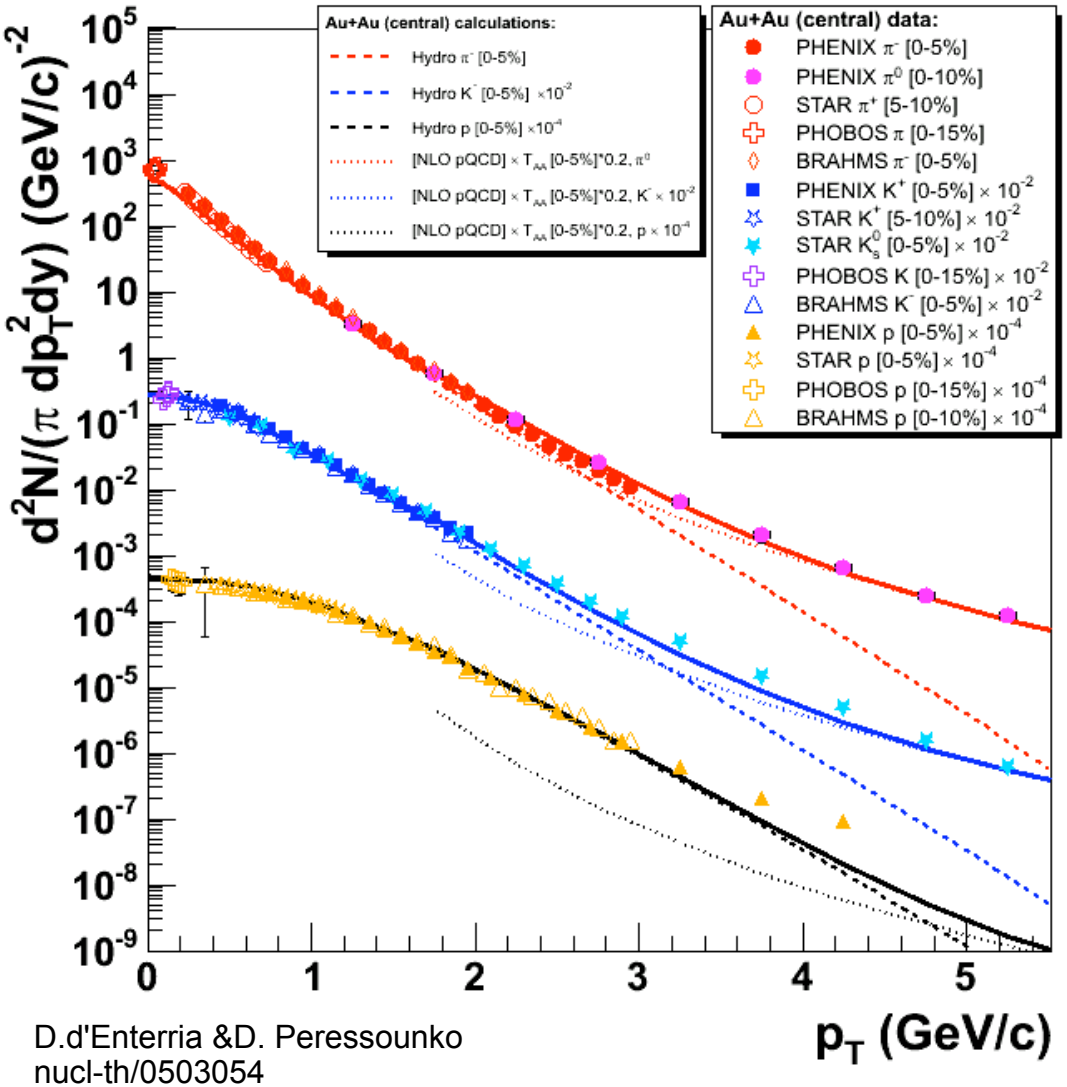
Radial flow


purely thermal source
T
1/p_T dN/dp_T
light
heavy
p_T
explosive source
T,β
1/p_T dN/dp_T
light
heavy
p_T

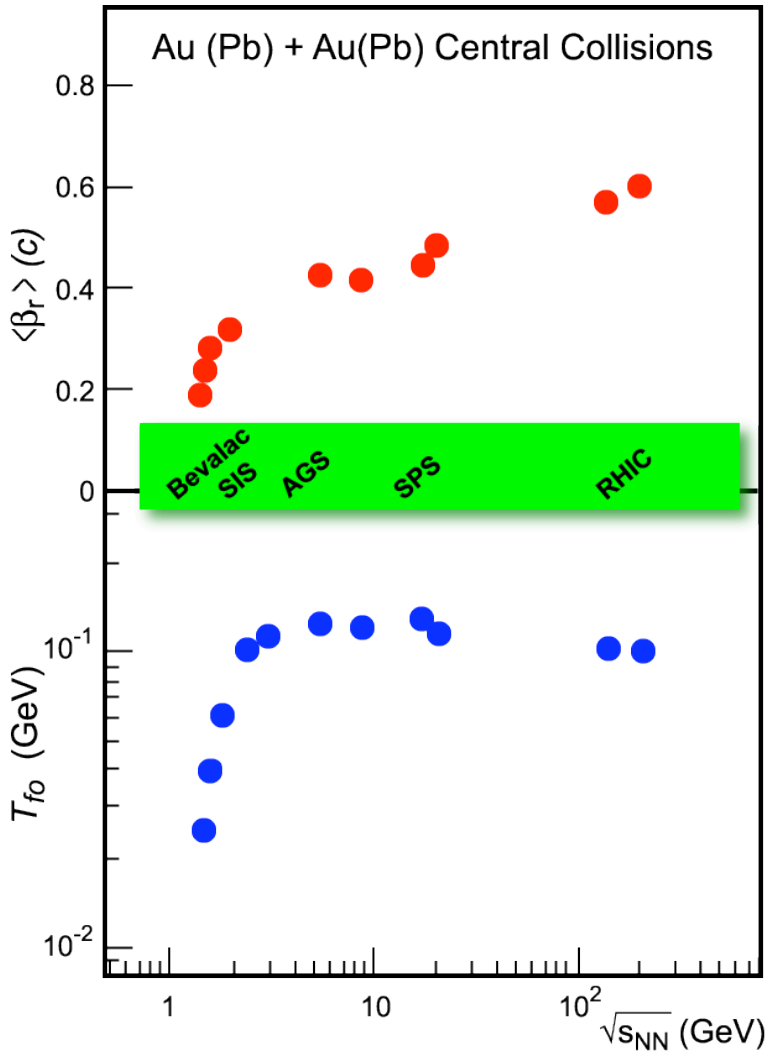


Radial flow at RHIC

Au+Au 200 GeV central (b < 2.6 fm)



D.d'Enterria &D. Peressounko
nucl-th/0503054



- **Large radial flow observed at RHIC.**
- **Charged particle identification is key to understand matter properties.**

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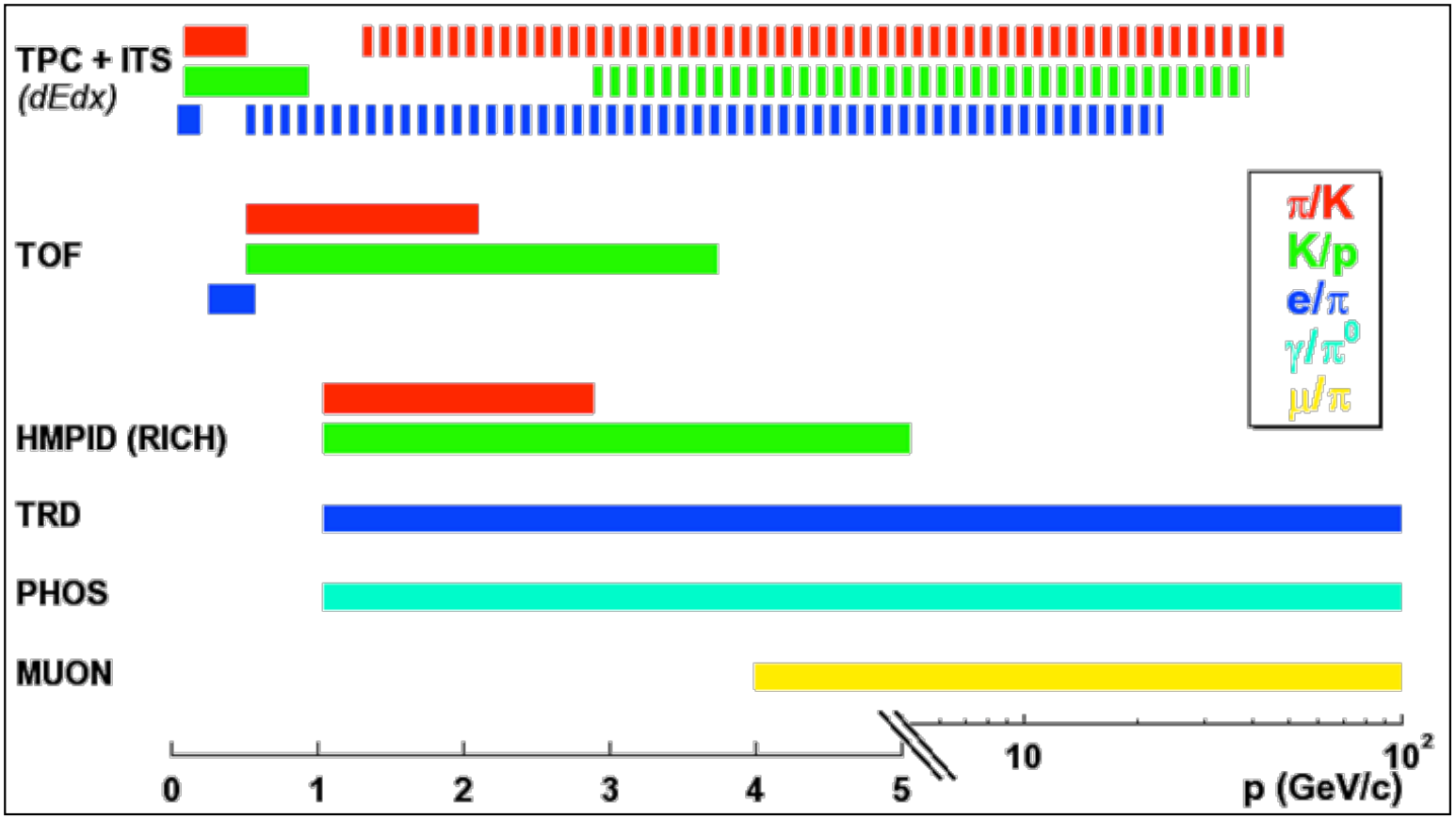
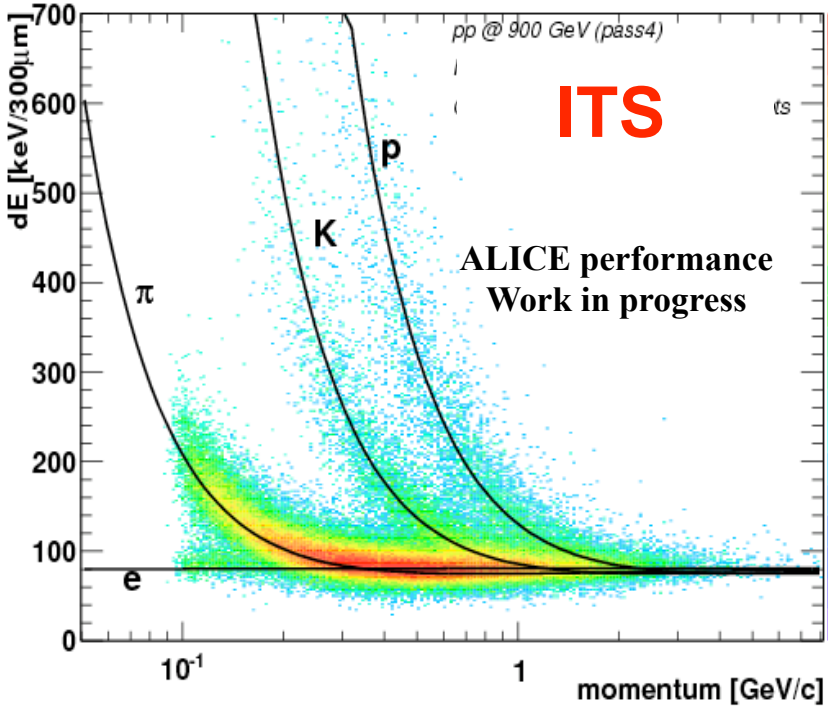
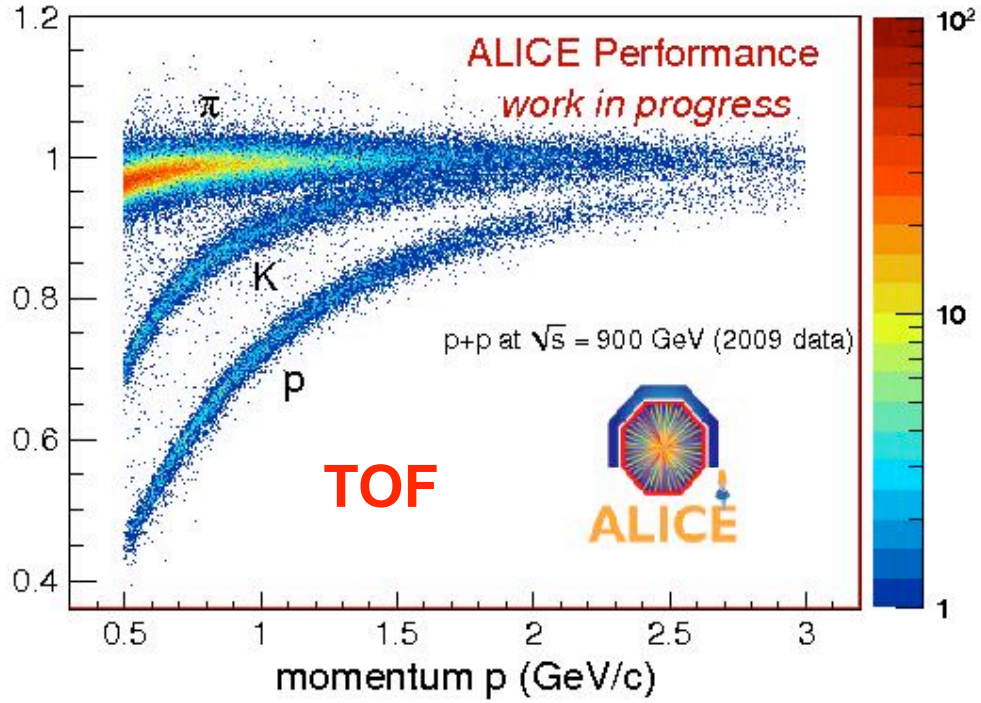
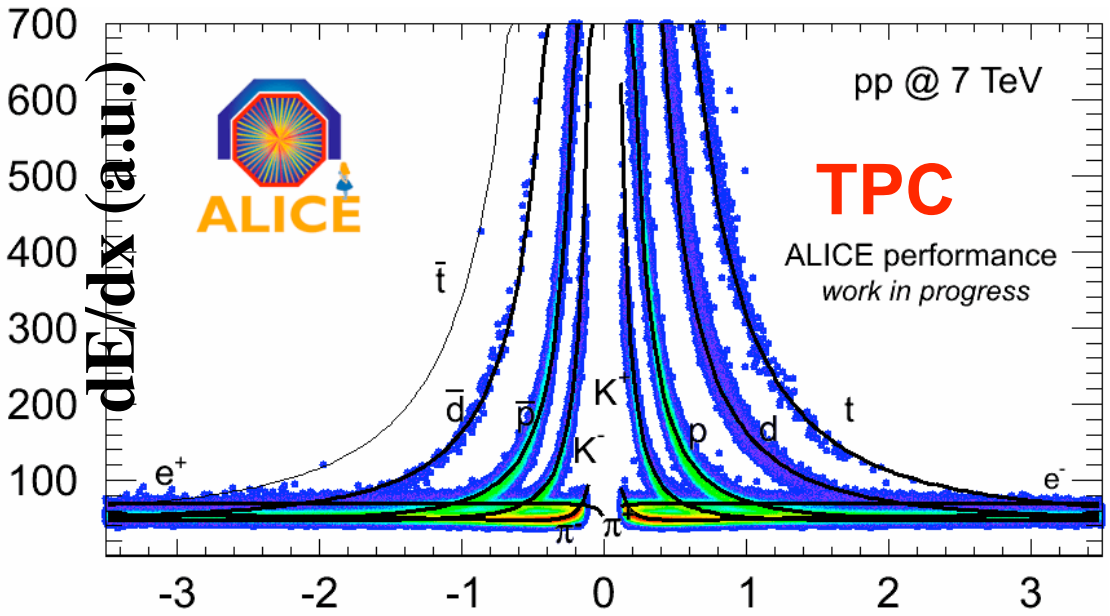
ALICE PID Capability



ALICE PID performance (1)







- PID using ITS, TOF, TPC
- TPC dE/dx:
  - separates p/ K up to 1.1 GeV
- TOF:
  - separates K/ π up to ~ 1.5 GeV

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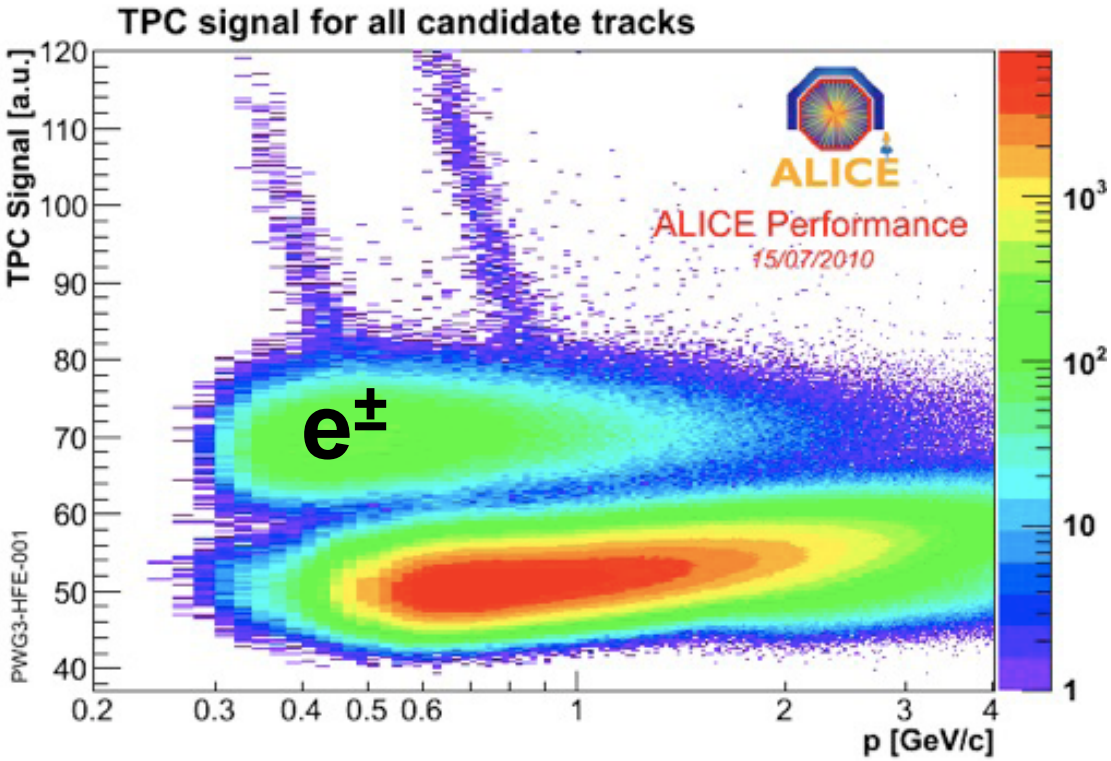
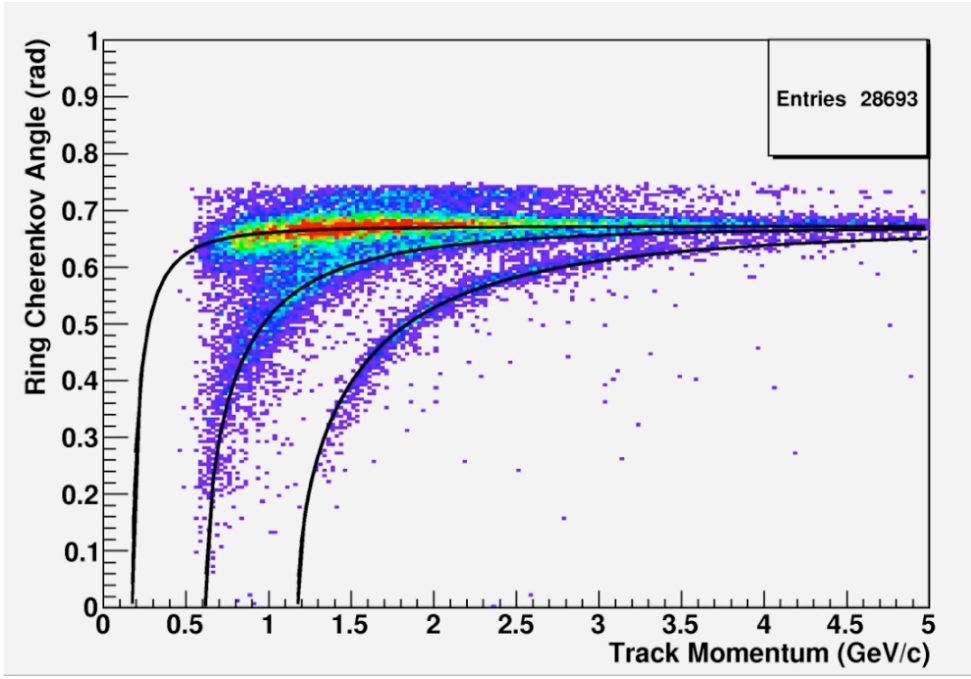
ALICE PID performance (2)

TPC

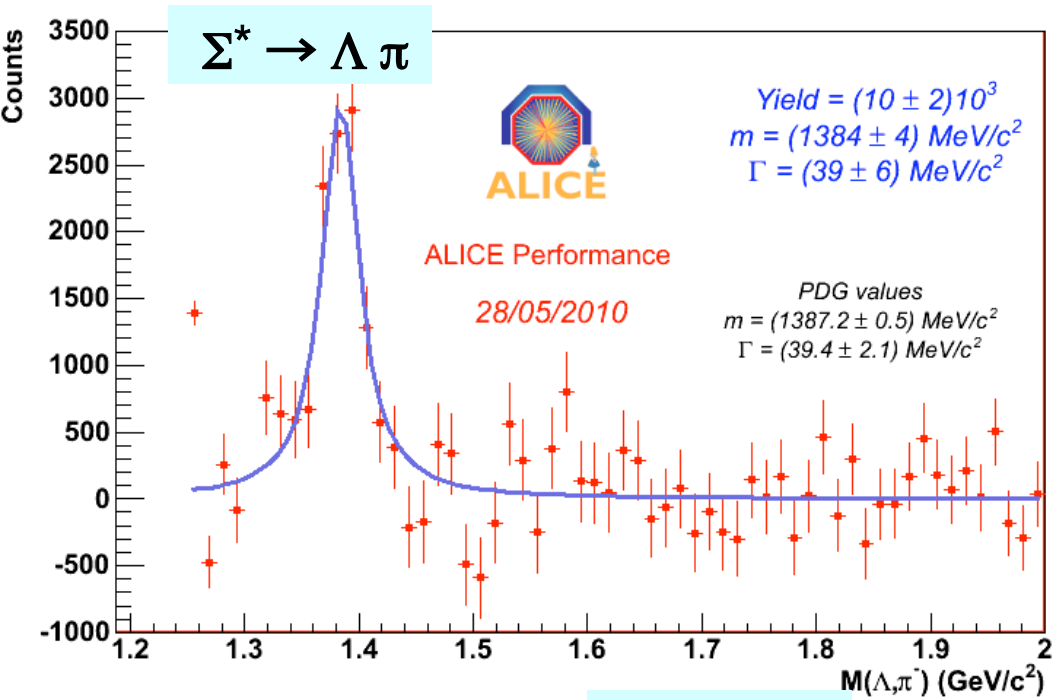


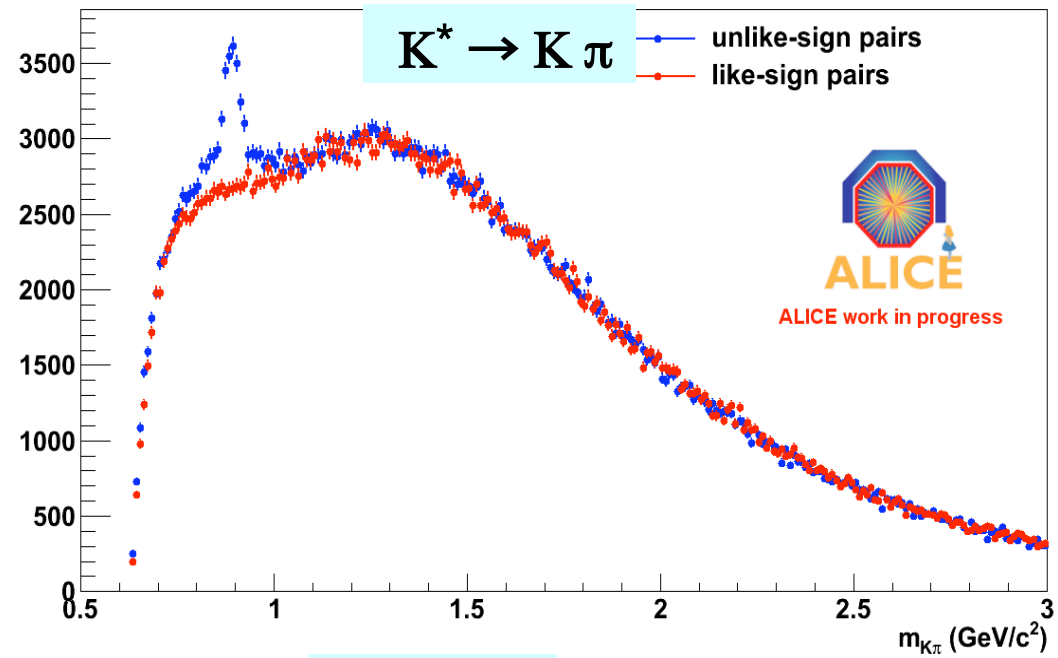
HMPID

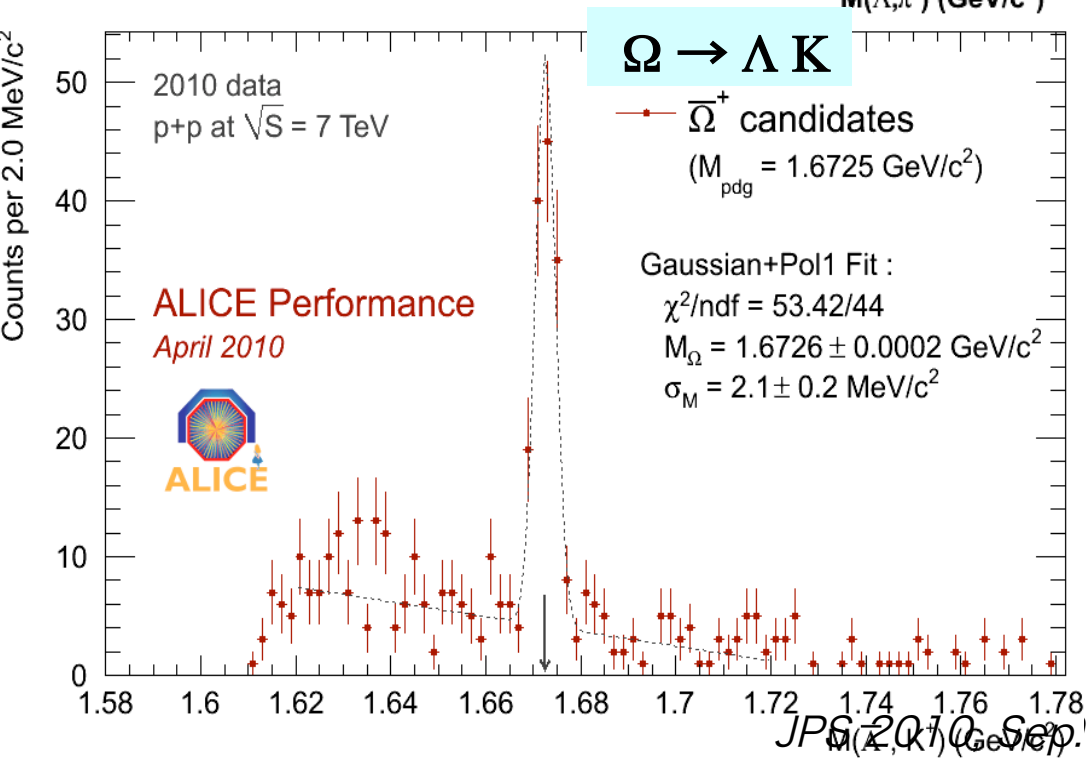
(Cherenkov ring angle vs. momentum)

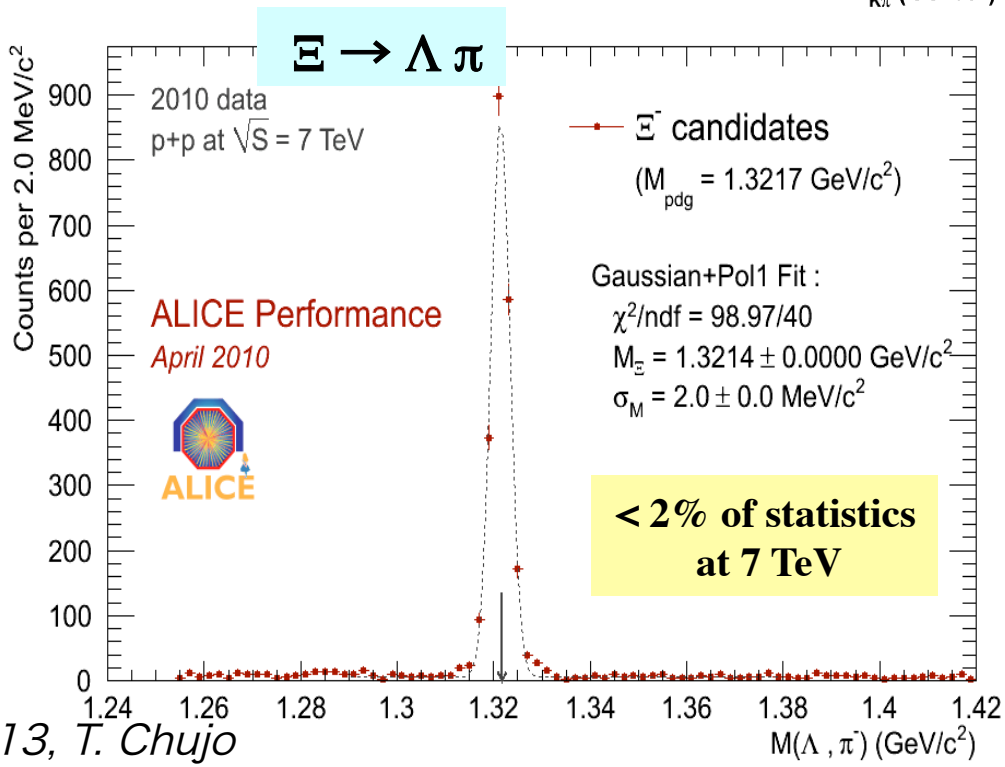


Strangeness productions (p+p 7 TeV)



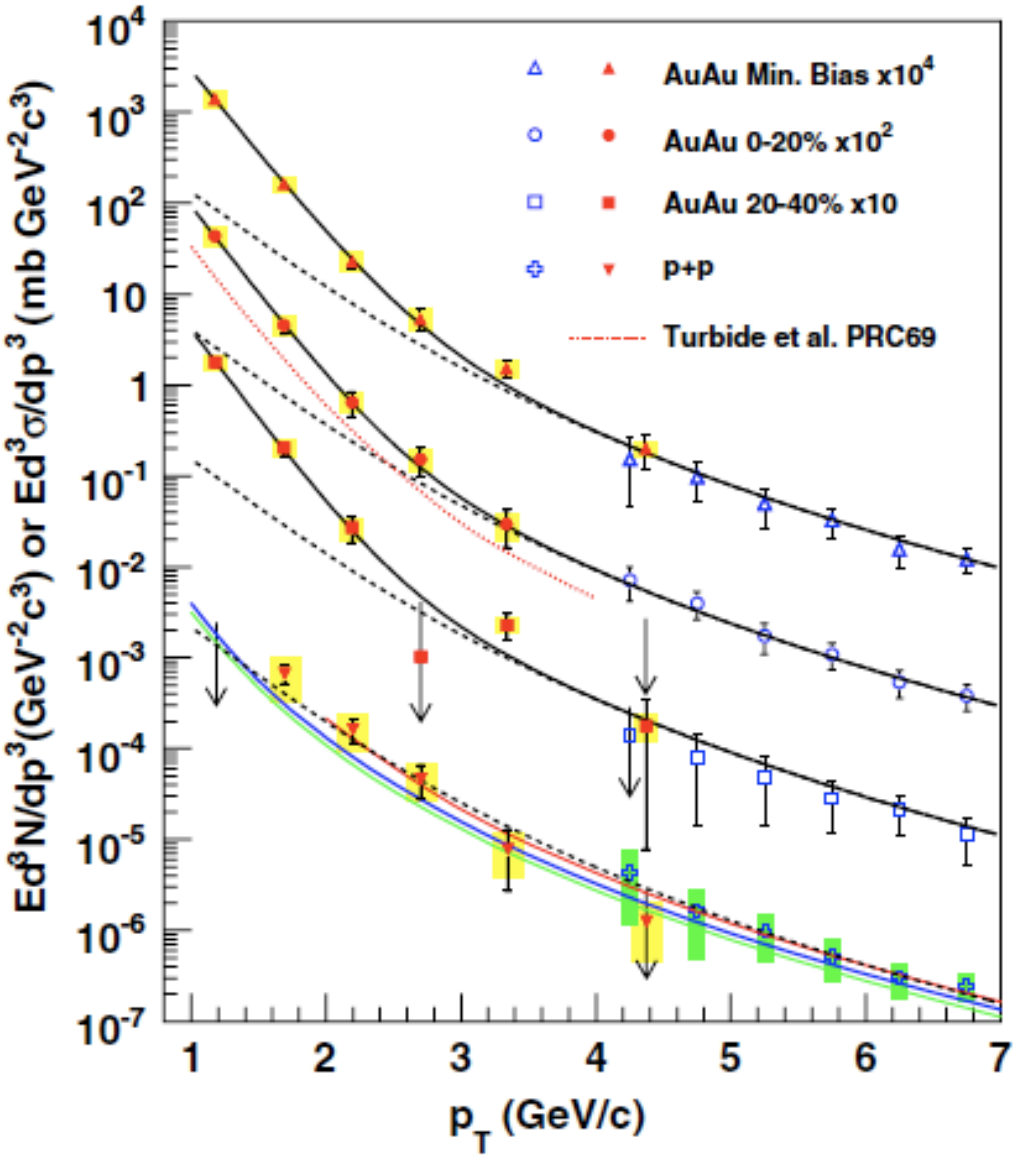


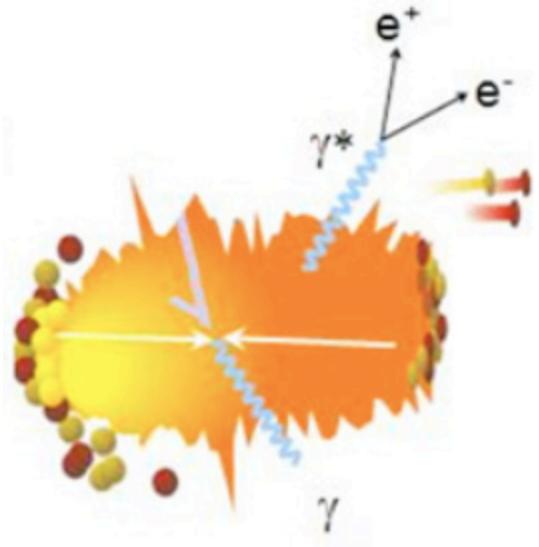




JPS 2010, Sep. 13, T. Chujo

(3) Temperature





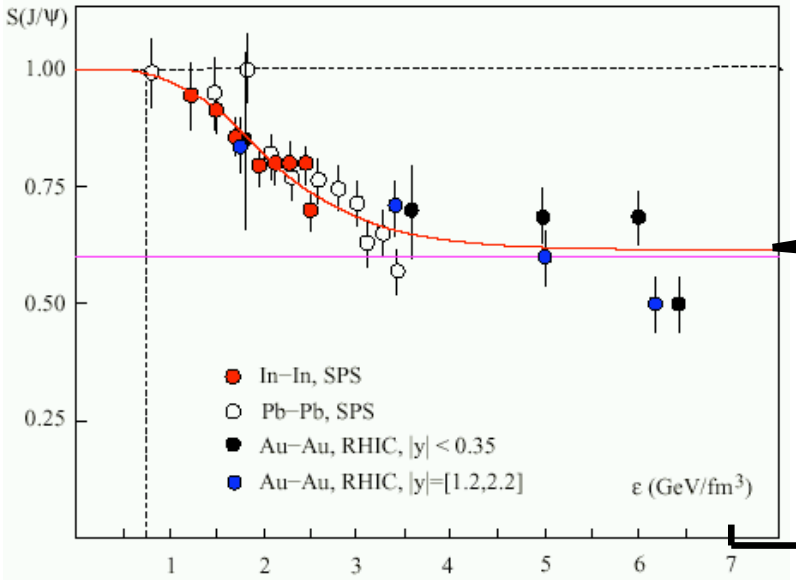
DATA: $T_{ini} > T_{AuAu} \sim 220$ MeV
MODELS: $T_{ini} = 300$ to 600 MeV
Lattice QCD prediction: $T_c \sim 170$ MeV

Indicating thermal photon emission at low p_T.

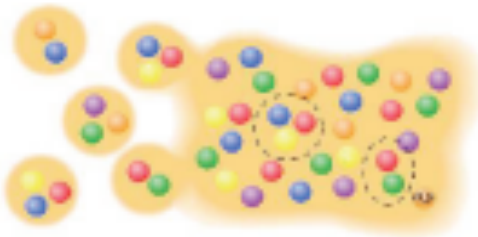
PHENIX (PRL 104, 132301 (2010))

Charmonium: suppression *or* enhancment?

- J/ψ suppression & regeneration at LHC?
- χ_c, ψ' suppression (J/ψ T_D ~ 1.5-2.0 T_c)?



enhanced regeneration

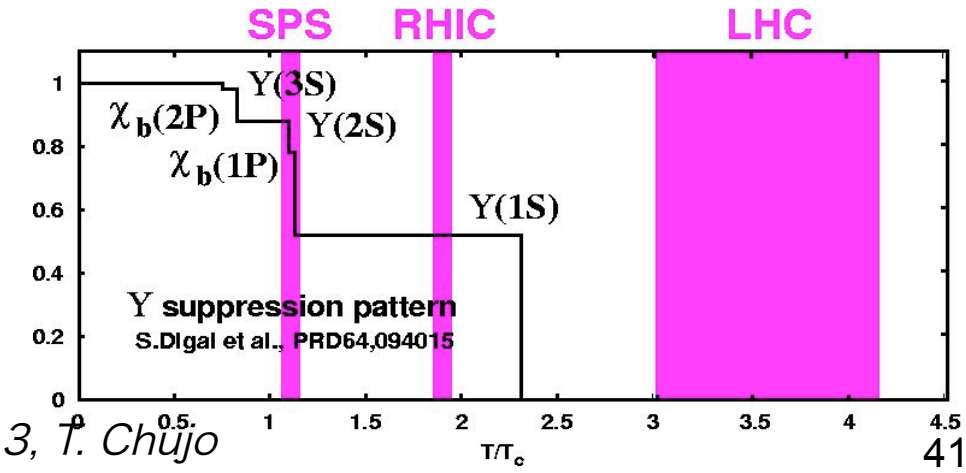


enhanced suppression

T_{LHC} >> J/ψ T_D

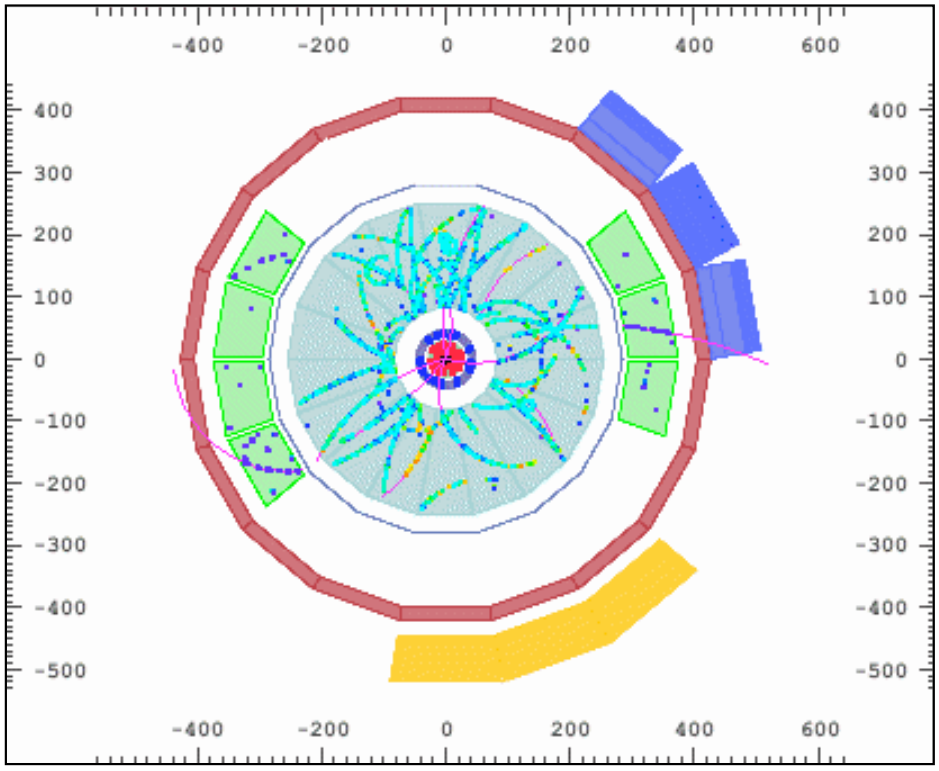
30

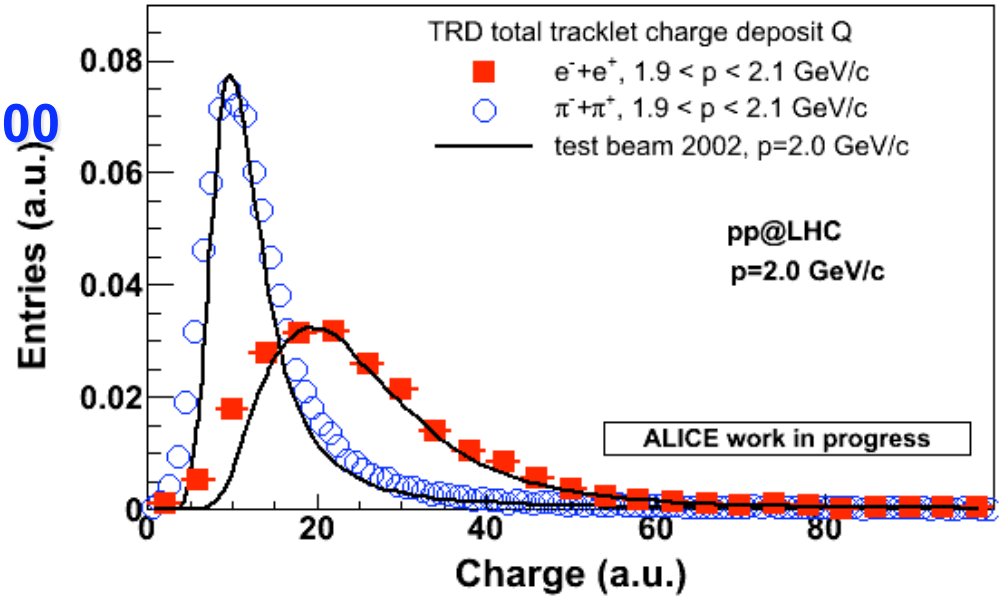
SPS
RHIC
LHC

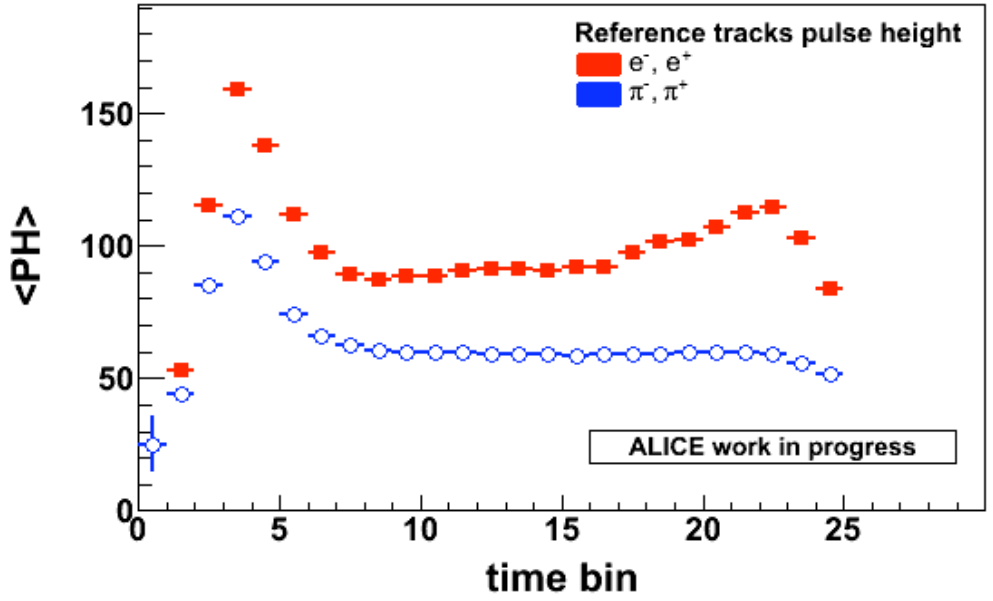


Transition-radiation detector (TRD)

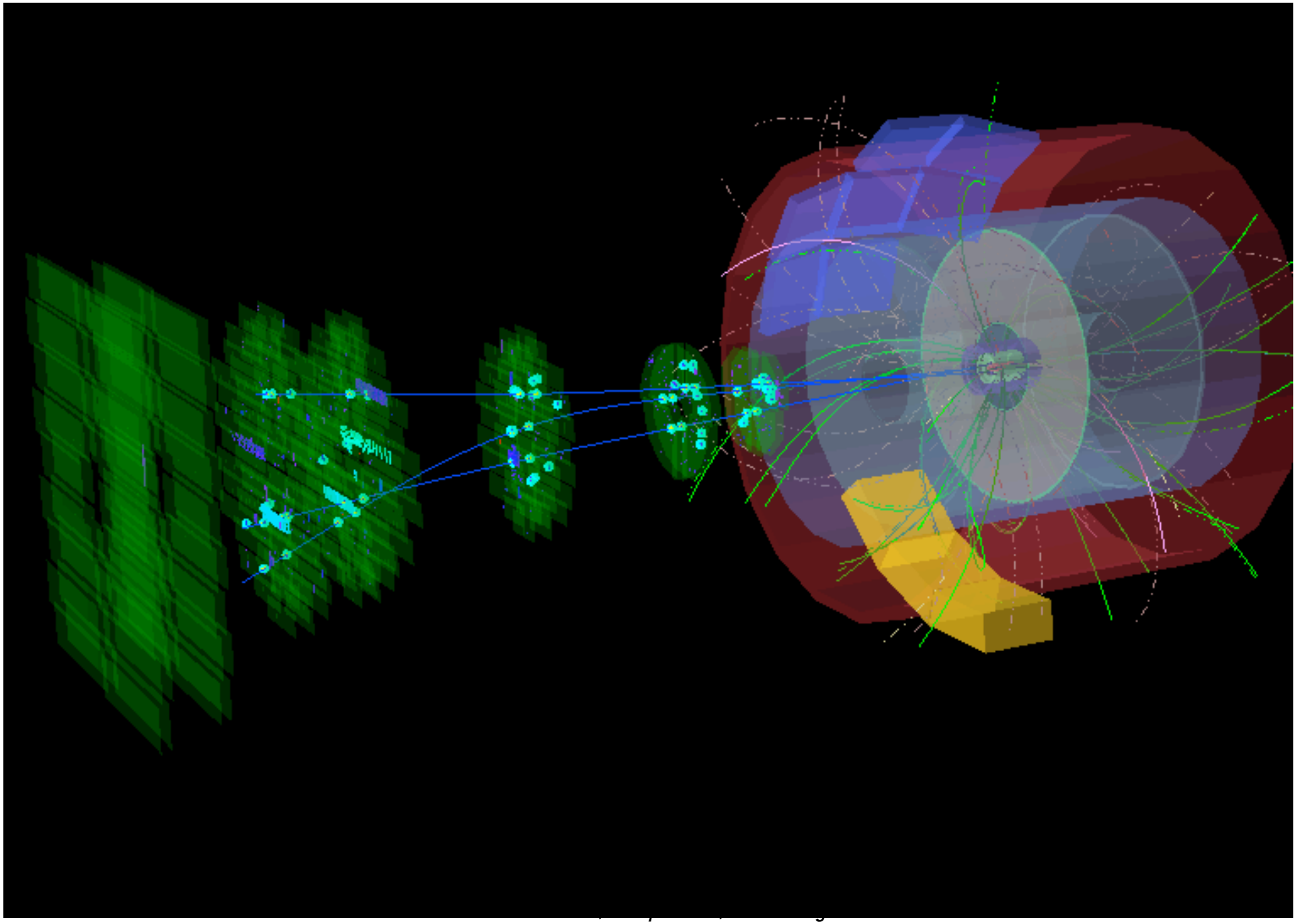
- TRD Dedicated to electron PID.
- Distinguish e from π→ rejection factor 100
- Provide High p_T & Electron trigger





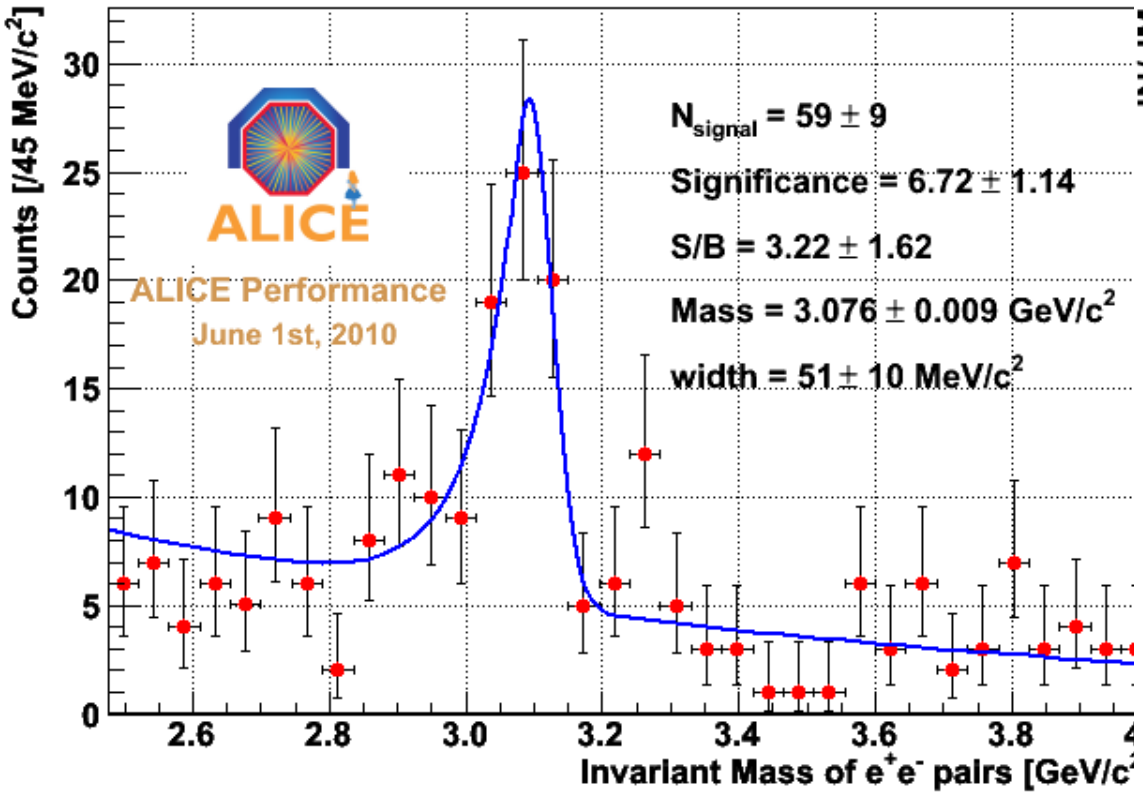


Muon detector (di-muon event display)

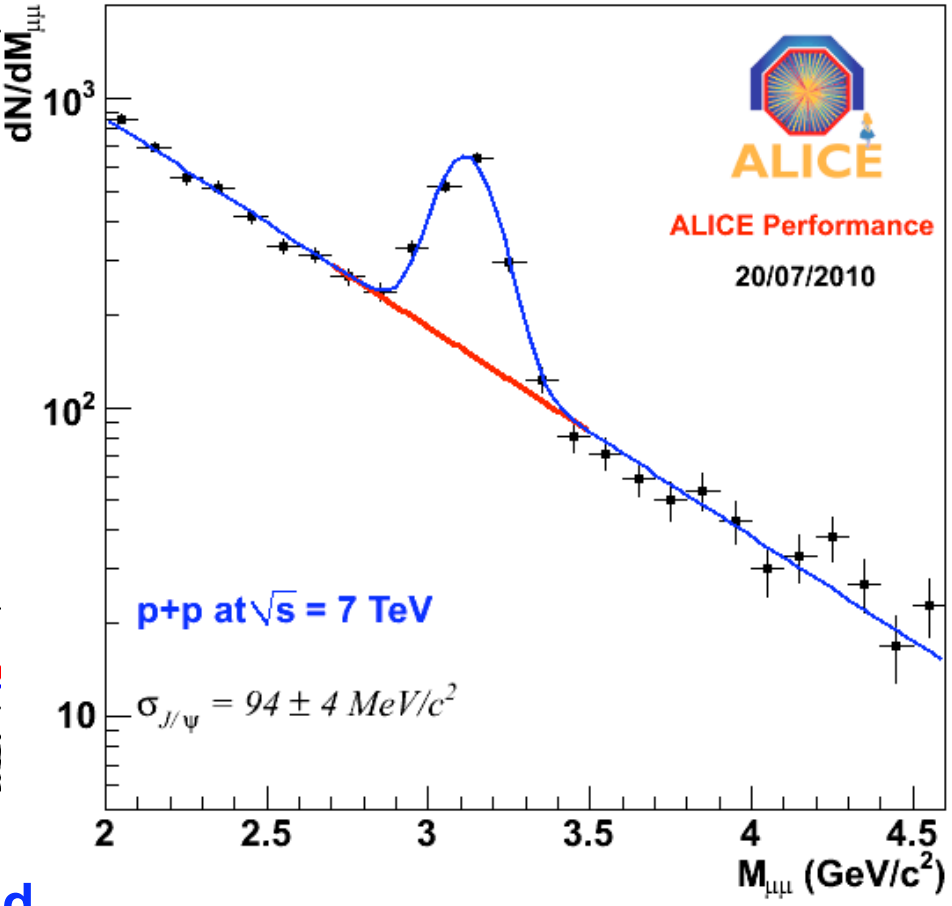


J/Ψ at p+p 7 TeV

$J/\Psi \rightarrow e^+e^-$ $|y| < 1$

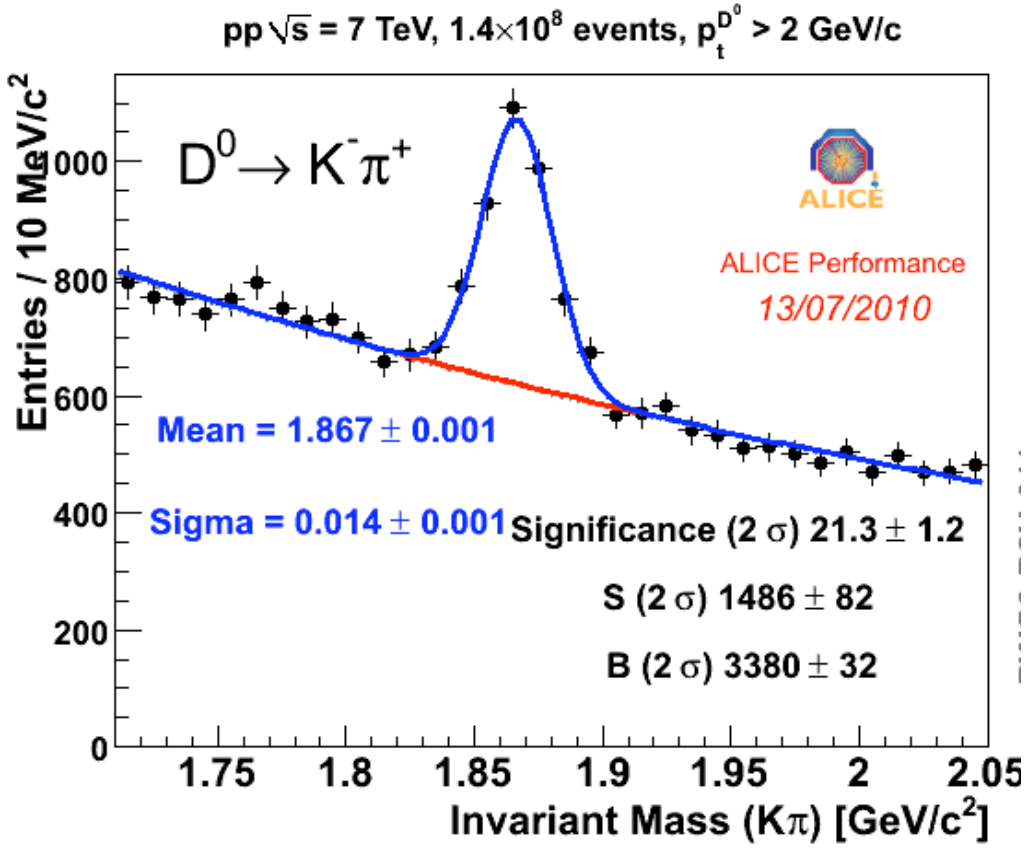


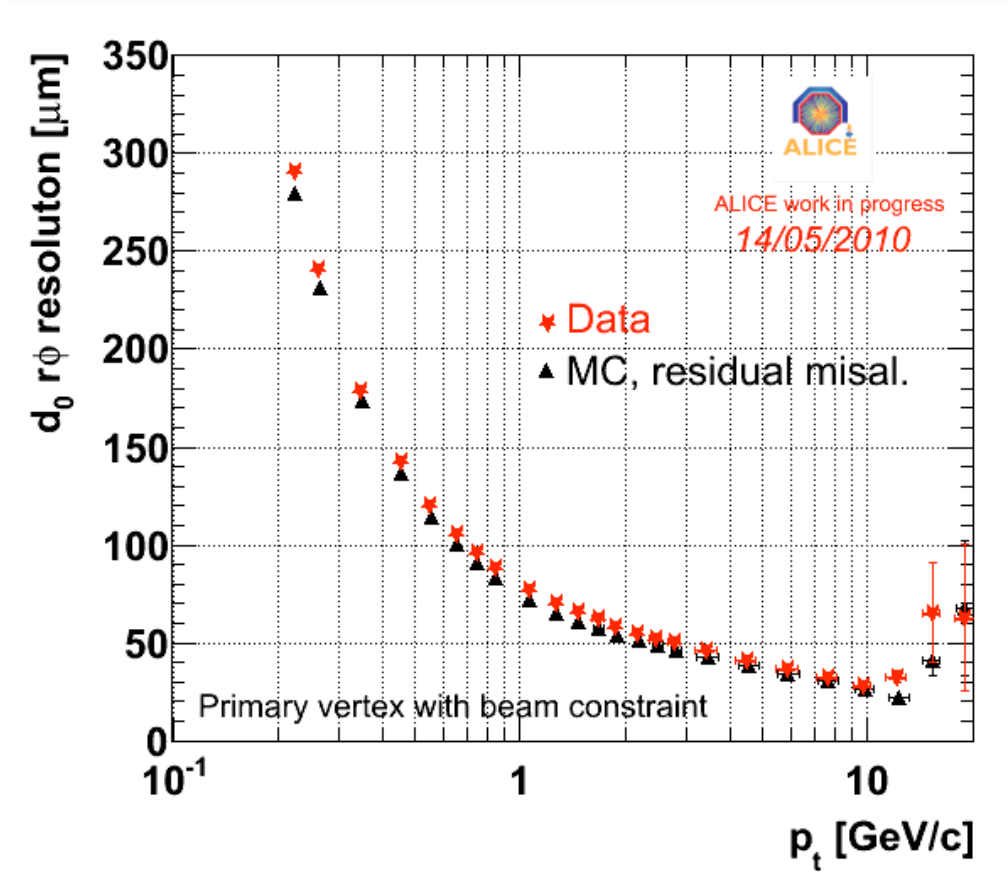
$J/\Psi \rightarrow \mu^+\mu^-$, y = 2.5 - 4 1

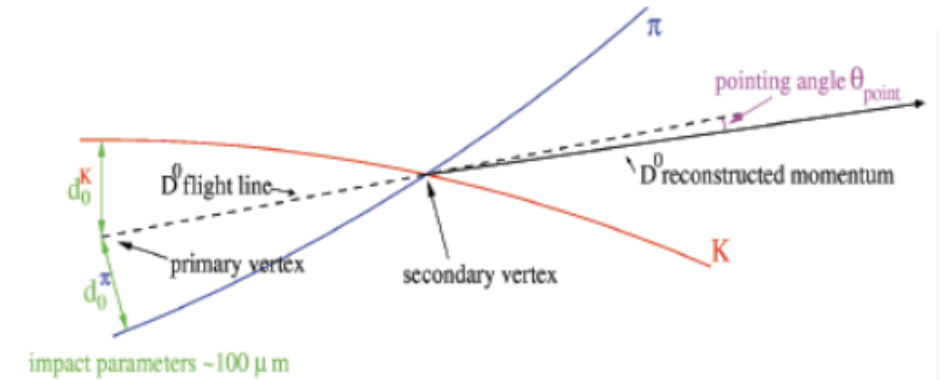


Mass resolution ~50 MeV even with low field, due to low material budget

Charm at p+p 7 TeV



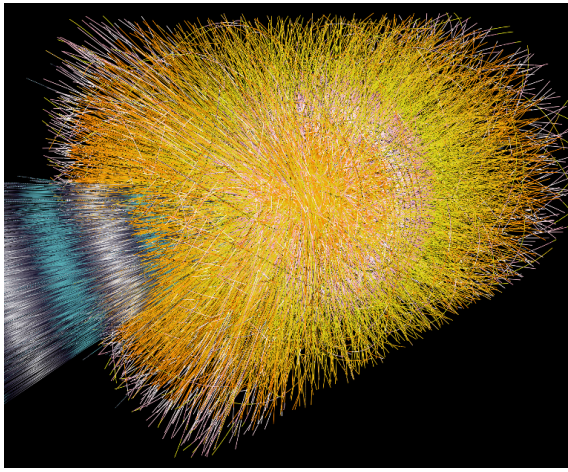




Impact Parameter Resolution vs p_T

80 μm @ 1 GeV

Prospects for Pb+Pb



What will be luminosity for November 2010?

- Design luminosity for Pb+Pb: 10^{27} $cm^{-2}s^{-1}$
  - ~ /10 from number of bunches
  - ~ /10 from increased beam size (lower energy, less focussing)
- Most probable value → **10^{25} cm^{-2} s^{-1}** [J. Jowett]

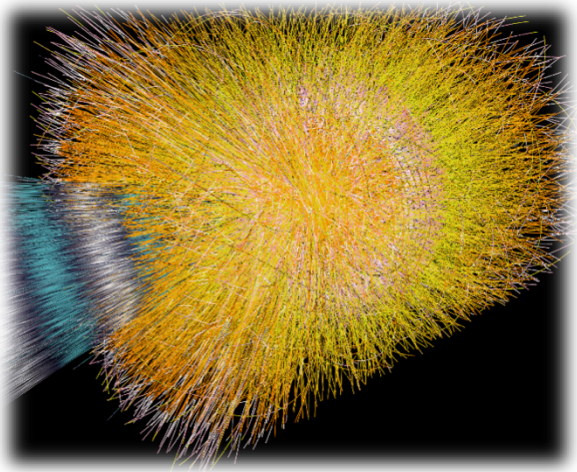
What is expected amount of data sample?

- Depends critically on overall duty factor and number of days
- e.g.: 20 days at 50 Hz min bias at 20% overall duty factor

  → ~ **1.5 x 10^{7} min bias events** (as opposed to target of a few 10^{7} central!)

Summary

- ALICE detector is fully operational since the first collision.
- p+p (mainly 7 TeV):
  - Re-discovering “standard model” and particle zoo.
  - Providing an important reference data to the heavy ion data.
- Pb+Pb:
  - Will start the 2.76 TeV Pb+Pb run on Nov. 2010.
- Exciting moment, new regime of QCD matter, and discoveries !!




Wow !
it's not liquid,
it's QGP gas…


ALICE
Thank you for your attention.