ALICE experiment

- Physics motivation
- Experimental conditions
- Detector status
- Physics performance

Deconfinement and screening

Deconfinement ~ screening of the static potential between heavy quarks

T = 0: heavy quark bound states described by confining potential

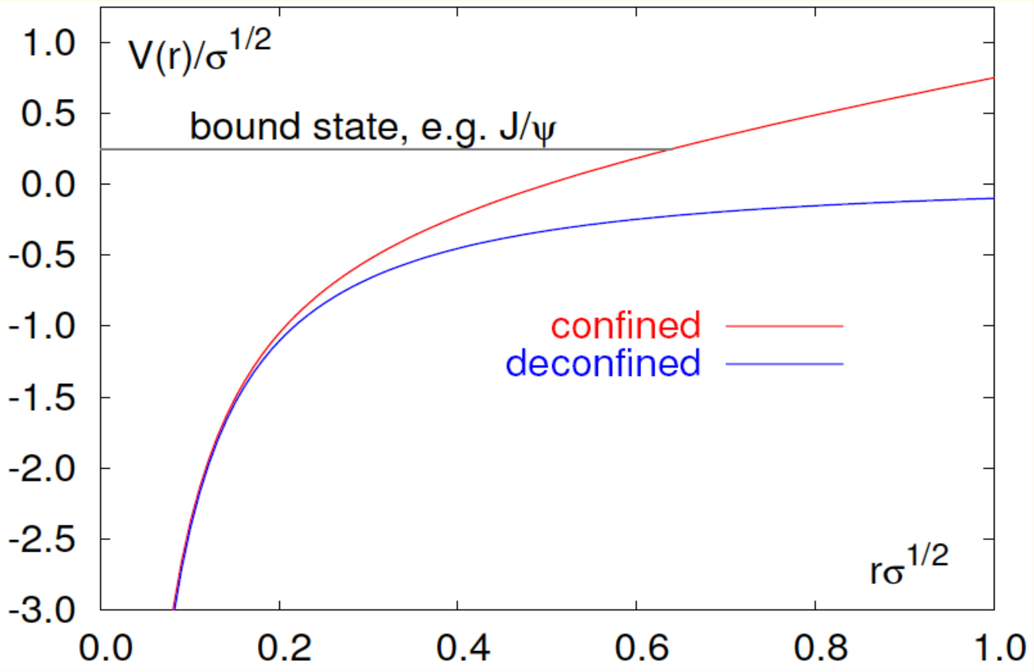
$V_{qq}(r) = - 4\alpha / 3r + \sigma r$

$\alpha = g^2(r) / 4\pi$

T > Tc: no bound state in a Debye screened potential:

$V_{qq}(r,T) \sim - \alpha / r \exp(-\mu r)$

$\alpha = g^2(T) / 4\pi$

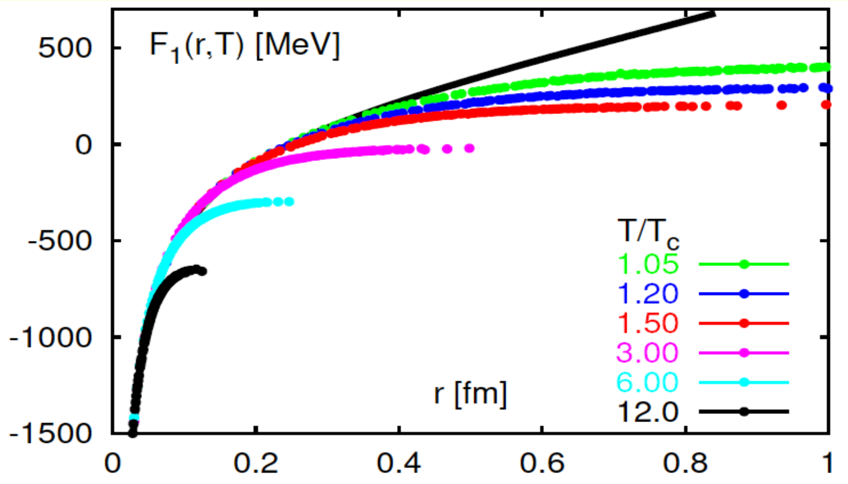


$V_{qq}(r,T) \to \infty$ confinement

$V_{qq}(r,T) < \infty$ no confinement

Heavy quark free energy - heavy quark potential (Lattice QCD)

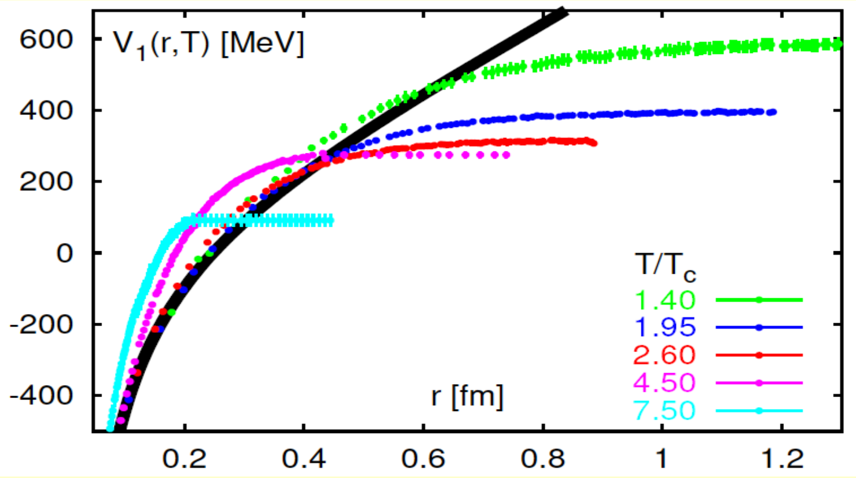
Singlet free energy $F_1(r,T)$
F.Karsch QM'04



Singlet energy <=> "potential" energy

$$V_1(r,T) = -\,T^2 \frac{\partial F_1(r,T)/T}{\partial T}$$

- *potential is "deeper": V(r,T) > F(r,T)*
- *potential "barrier" high above Tc*
- *"potential" screened at short distances*



At what temperature do heavy quark states really disappear ?

Quarkonia

- Quarkonia rates sensitive to nuclear absorption and secondary scattering, parton distributions, nuclear gluon shadowing
- Expect quarkonia in AA collisions reduced relative to pp or pA
- BUT copiously produced uncorrelated $\underline{q}q$-pairs may form final state quarkonium -> *Is there quarkonia enhancement at LHC ?*
- Reference: total charm/beauty cross section
- Charmonium ground state J/ψ, ηc (F.Karsch QM'04):
  - Still exist at 1.5 T_c, gradually disappear for T > 1.5 T_c, are gone at 3 T_c
  - Radial excitations disappear at T_c

Parton energy loss

- Parton energy loss in medium $<\Delta E> \propto \alpha_s C_R q L^2$
  - C_R Casimir coupling factor, 4/3 for quarks, 3 for gluons
  - q medium transport coefficient $\propto$ gluon density and momenta
  - L pathlength in medium
- Reduction of single inclusive high p_t particles
  - parton specific (stronger for gluons than quarks)
  - flavour specific (stronger for light quarks)
  - Identify hadrons (π,K,p,Λ) + partons (charm,beauty) at high p_t
- Suppression of mini-jets, same-side/away-side correlations
- Change of fragmentation function for hard jets (p_t >> 10 GeV/c)

Study parton energy loss

Compare p_t-distributions of leading particles in pp, pA and AA collisions

Nuclear modification factor:

$$R_{AA}(p_t) = \frac{1}{N_{coll}} \times \frac{dN_{AA}/dp_t}{dN_{pp}/dp_t}$$

Dead cone effect for heavy quarks with momenta < 20-30 GeV/c (v<<c)

- gluon radiation suppressed at angles < m_Q/E_Q
- Dokshitzer and Kharzeev: *dead cone implies lower energy loss*

⇒ D meson quenching reduced

⇒ Ratio D/hadrons (D/π^0) enhanced and sensitive to medium properties

Heavy Ions at LHC

- heavy ion experimental programs
  at SPS, RHIC, LHC

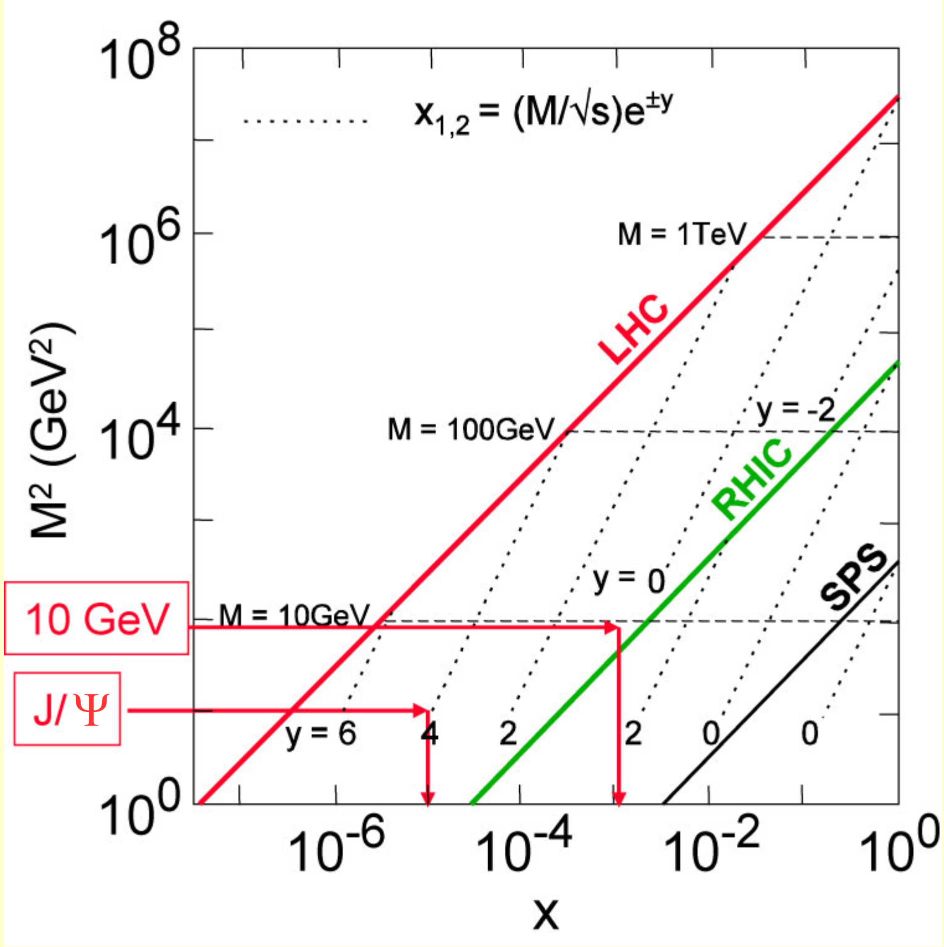
Central collisions	SPS	RHIC	LHC
$s^{1/2}$ (GeV)	17	200	5500
dN_{ch}/dy	500	850	2-8 x 10^3
ε(GeV/fm^3)	2.5	4-5	15 - 40
V_f(fm^3)	10^3	7x10^3	2x10^4
τ_{QGP}(fm/c)	< 1	1.5 - 4.0	4-10
τ_0(fm/c)	~1	~0.5	< 0.2

ε(LHC) > ε(RHIC) > ε(SPS)
V(LHC) > V(RHIC) > V(SPS)
τ(LHC) > τ(RHIC) > τ(SPS)

LHC new aspects I

-- probe initial partonic state in a novel Bjorken-x range (10^{-3} - 10^{-5})
  --> nuclear shadowing
  --> high density saturated gluon distribution (CGC)

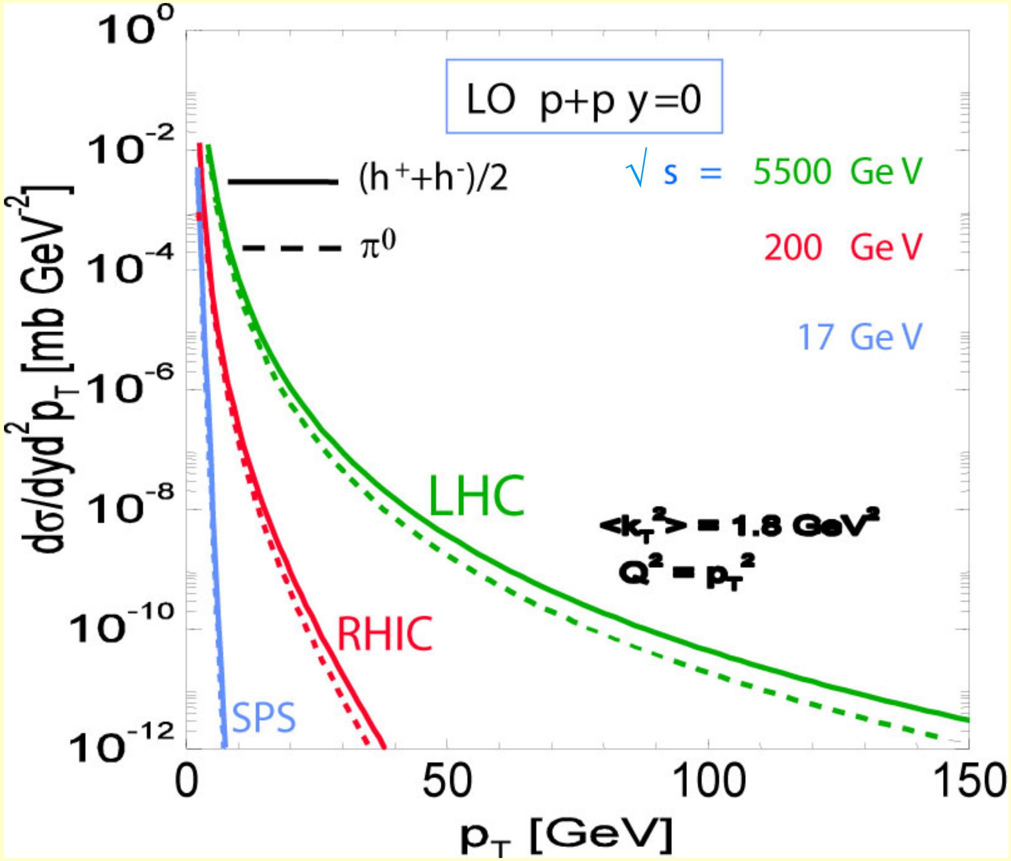
-- Larger saturation scale ($Q_s = 0.2\ A^{1/6}\ \sqrt{s}^{-\delta} = 2.7$ GeV)
  particle production dominated by saturation region



LHC new aspects II

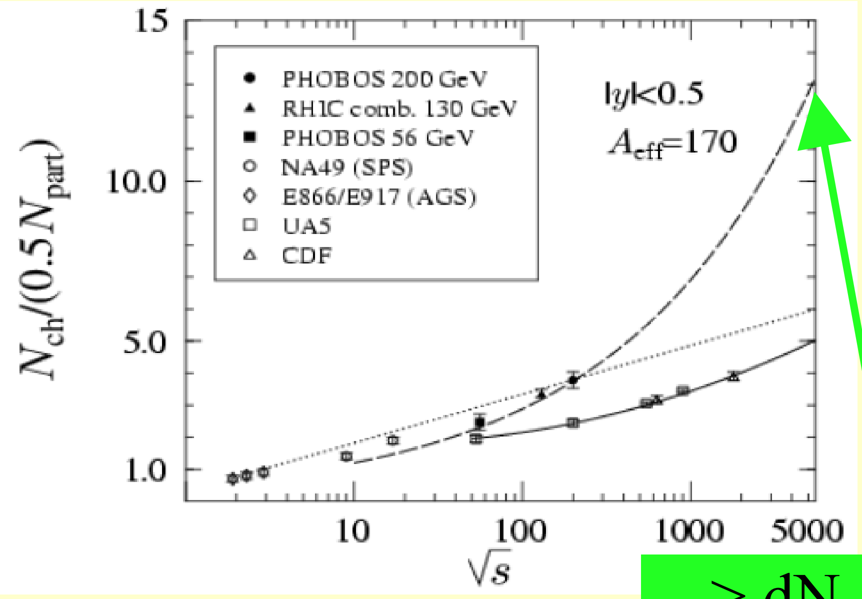
-- Hard processes contribute significantly to the total AA cross section ($\sigma^{hard}/\sigma^{tot}$ = 98 %)
--> bulk properties dominated by hard processes
--> very hard probes are abundantly produced

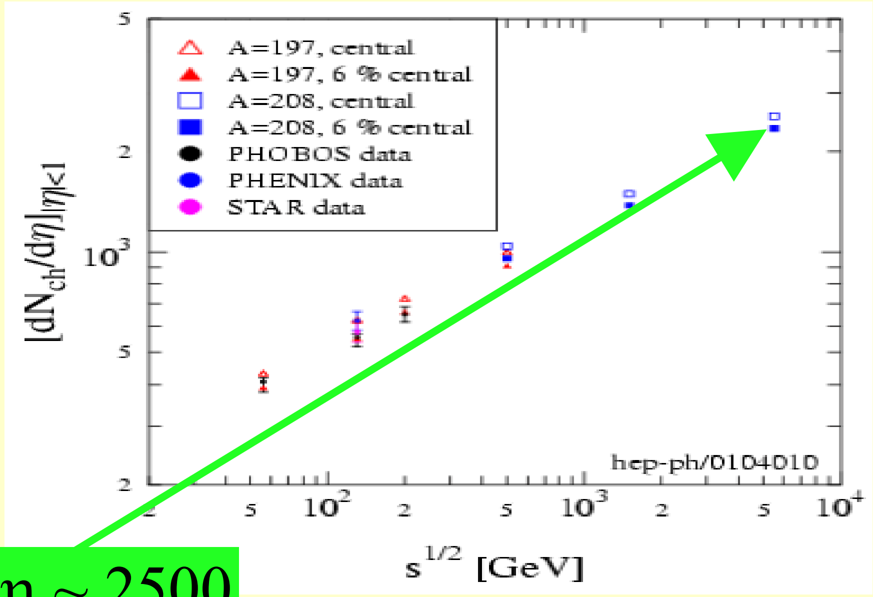
-- Weakly interacting probes become accessible (γ, Z^0, W^{+-})



Which multiplicity at LHC ?

Former estimate: dN/dy = 2000 – 8000, extrapolation from RHIC data possible
uncertainties - shadowing/saturation (decrease)
- jet quenching (increase)
- A-scaling (important soft vs. hard changes with energy)



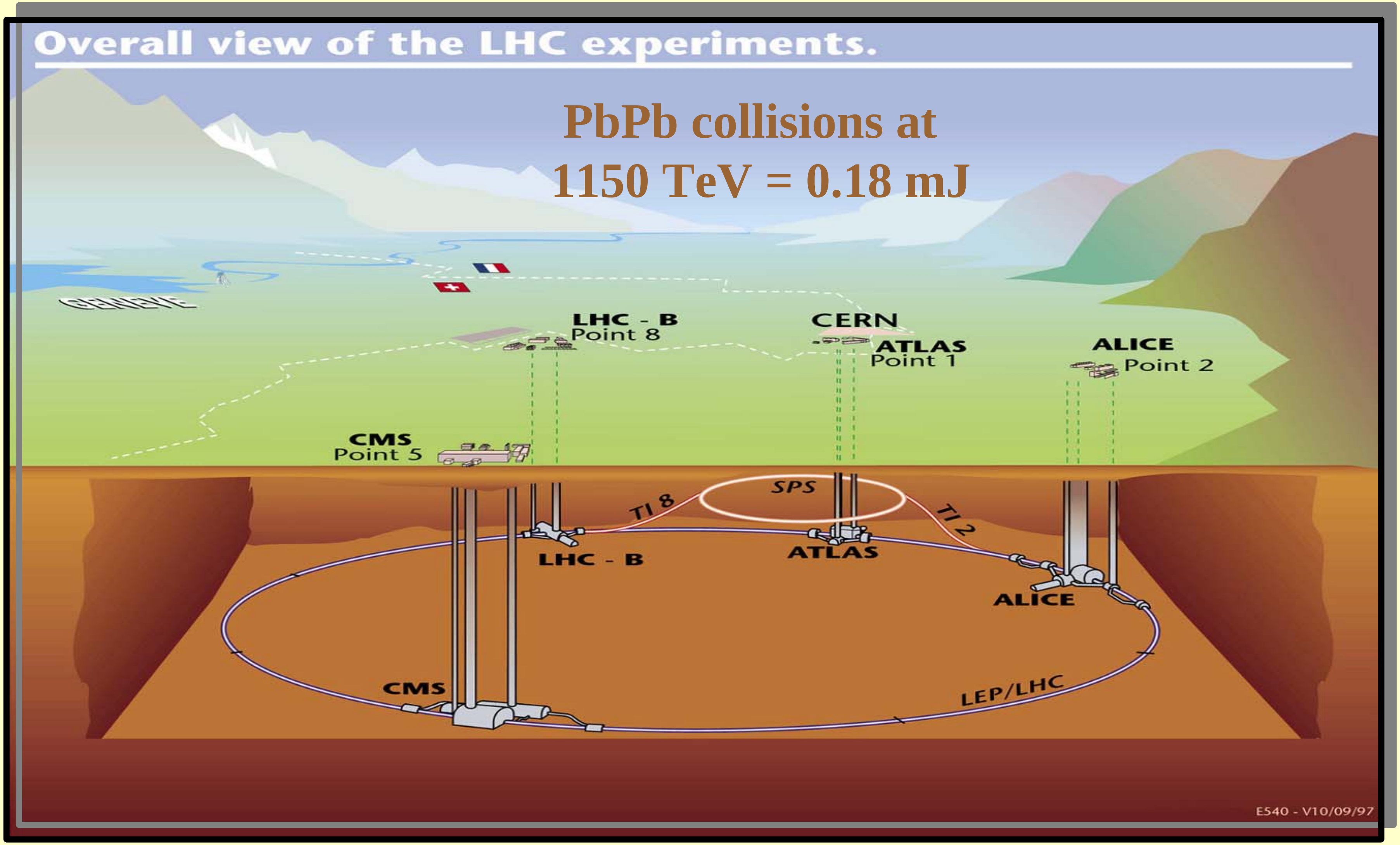


-> $dN_{ch}/d\eta \sim 2500$

(K.Kajantie, K.Eskola)

ALICE optimized for dN_{ch}/dy = 4000, checked up to 8000

ALICE @ LHC


Overall view of the LHC experiments.
PbPb collisions at
1150 TeV = 0.18 mJ
GENEVE
LHC - B
Point 8
CERN
ATLAS
Point 1
ALICE
Point 2
CMS
Point 5
SPS
TI 8
TI 2
LHC - B
ATLAS
ALICE
CMS
LEP/LHC
E540 - V10/09/97

Experimental conditions @LHC

- April 2007 start pp commissioning
- Initial Heavy-Ion programme at LHC
  - Initial few years (1HI 'year' = 10^6 effective s)
    - 2-3 years Pb-Pb — L ~ 10^{27} cm^{-2} s^{-1}
    - 1 year p-Pb 'like' (p,d or α) — L ~10^{29} cm^{-2} s^{-1}
    - 1 year light ions (eg Ar-Ar) — L ~ few 10^{27} to $10^{29}$$cm^{-2}$ s^{-1}
    - reg pp run at s = 14 TeV — L ~ 10^{29} and < $3x10^{30}$ cm^{-2} s^{-1}
- Heavy Ion running part of LHC initial programme, early pilot run expected by end of 2007

Luminosity limitations

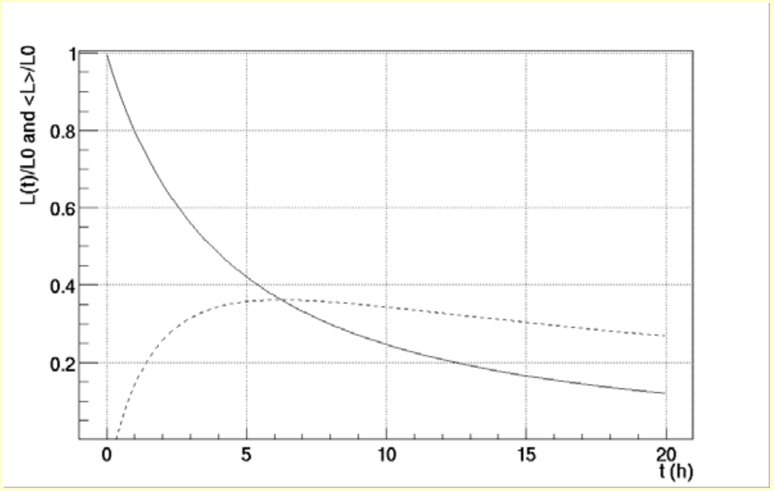
LHC Intensity Limit --> Pb losses due to electromagn. processes (500 barn!)

Limit luminosity life-time:

1 exp 6.7 h @10h $\langle L \rangle = 0.44 L_0$

2 exp 3.7 h $\langle L \rangle = 0.34 L_0$

3 exp 2.7 h $\langle L \rangle = 0.28 L_0$

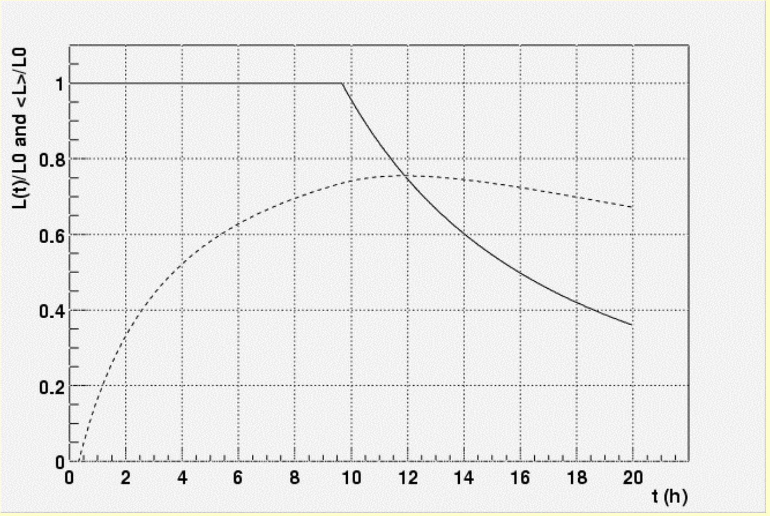


SPS bunch intensity limit close to nominal luminosity (limits possible schemes to improve ratio <L>/L)

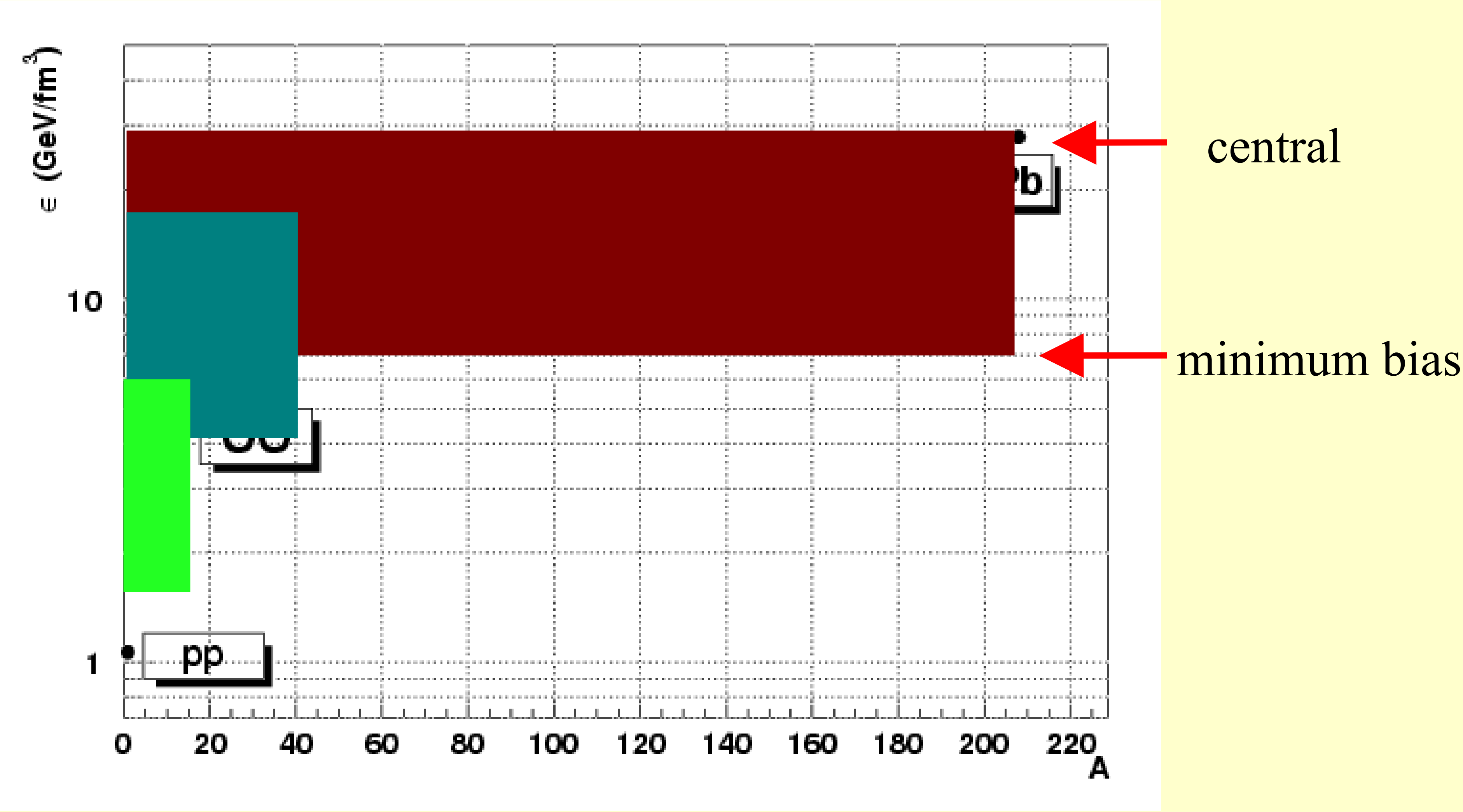
L_0 Max = $1.0 * 10^{27}$ for Pb-Pb

$0.6 * 10^{29}$ for Ar-Ar

$2.0 * 10^{29}$ for O-O



Energy densities for different ions



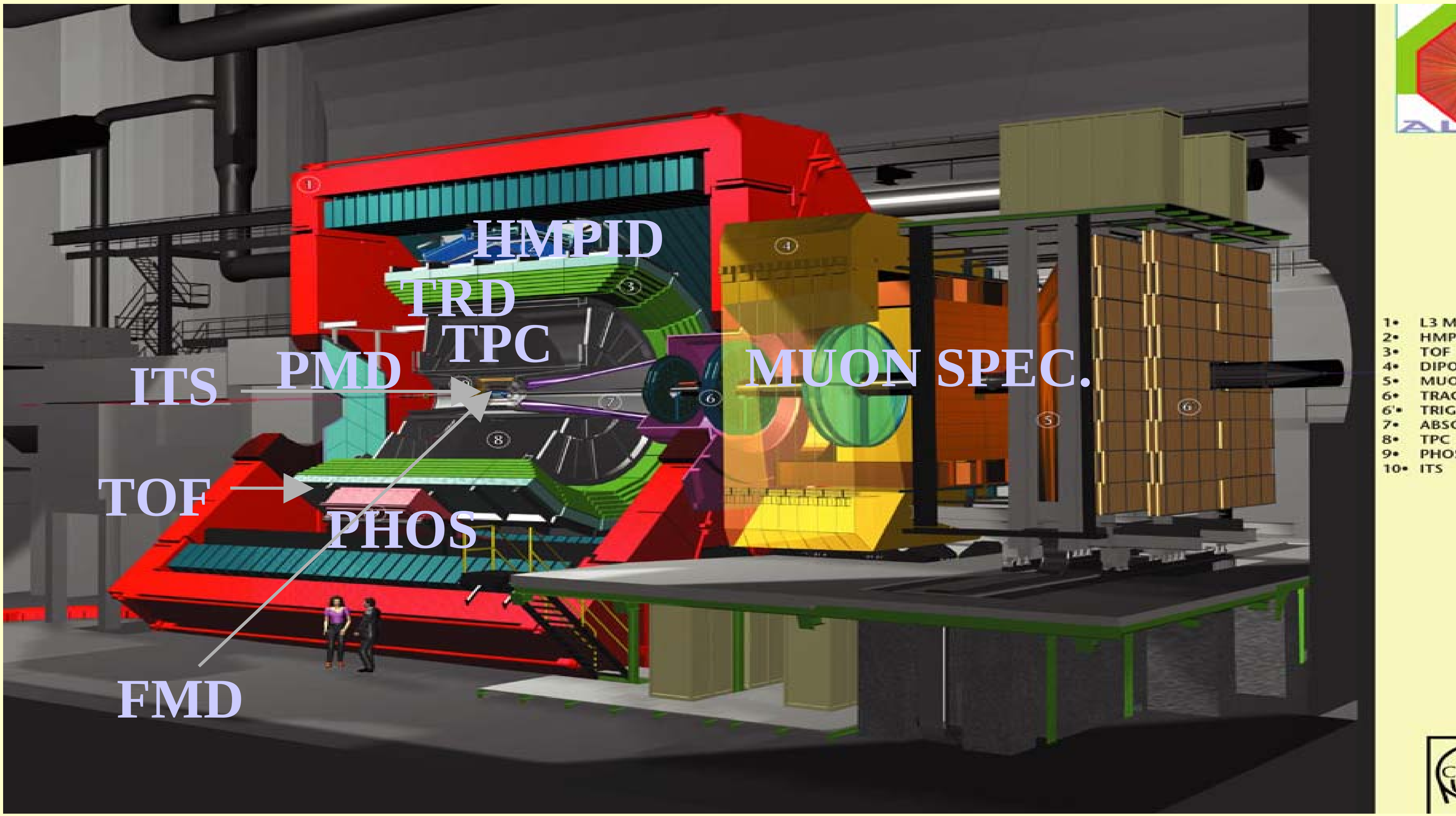
ALICE physics goals

Global observables: *- multiplicities, η-distributions*
Degrees of freedom as function T: *- hadron ratios and spectra, dileptons, direct photons*
Early state signal collective effects: *- elliptic flow*
Parton energy loss in deconfined state: *- jet quenching, high pt spectra, open charm & beauty*
Study of deconfinement: *- charmonium and bottomonium spectroscopy*
Study of chiral symmetry restoration: *- neutral to charged ratio, resonance decays*
Fluctuation signals – critical behaviour: *- event by event particle composition, spectra*
Geometry of emitting source: *- HBT, impact parameter by zero degree energy flow*
Study of pp collisions in energy domain

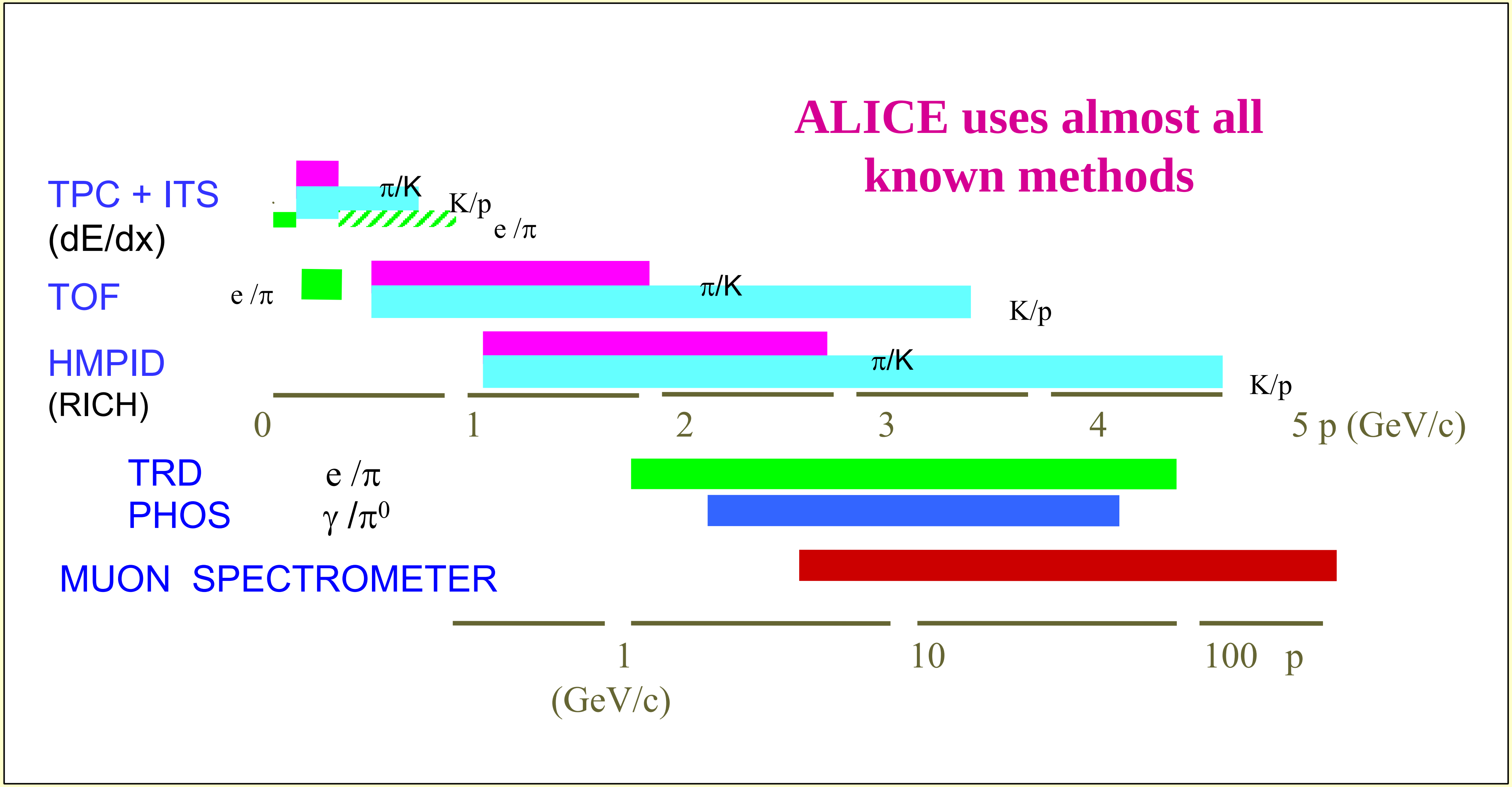
-> Large acceptance
-> wide momentum coverage
-> good secondary vertex reconstr
-> good tracking capabilities
-> PID of hadrons and leptons
-> Photon detection

→ ***Variety of experimental techniques***

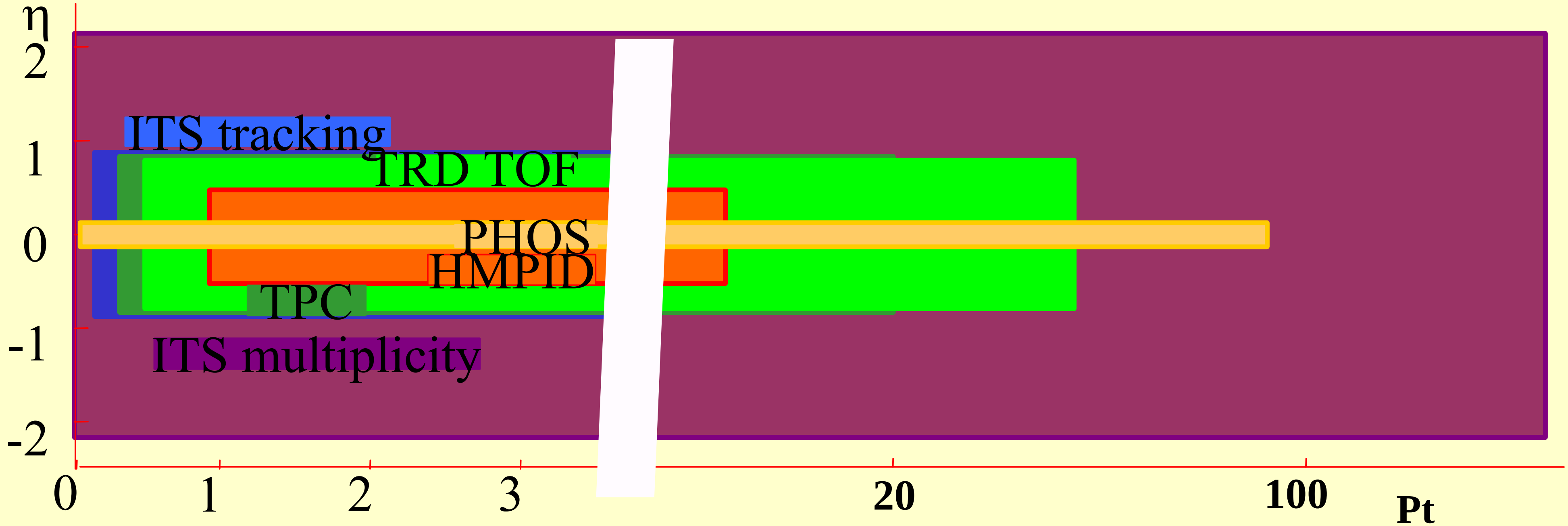
The ALICE experiment



PID in ALICE

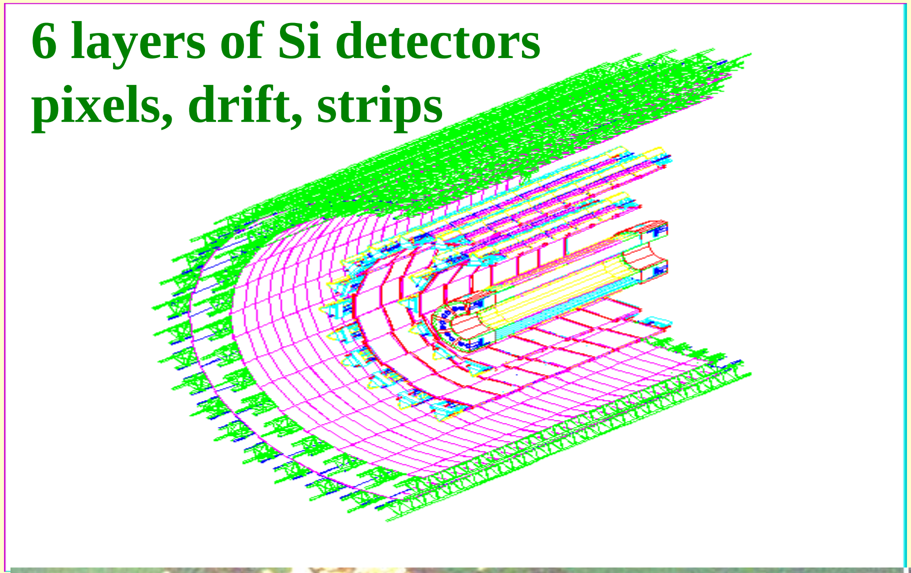

ALICE uses almost all
known methods
TPC + ITS
(dE/dx)
π/K
K/p
e /π
TOF
e /π
π/K
K/p
HMPID
(RICH)
π/K
K/p
0
1
2
3
4
5 p (GeV/c)
TRD
e /π
PHOS
γ /π0
MUON SPECTROMETER
1
10
100 p
(GeV/c)

ALICE acceptance

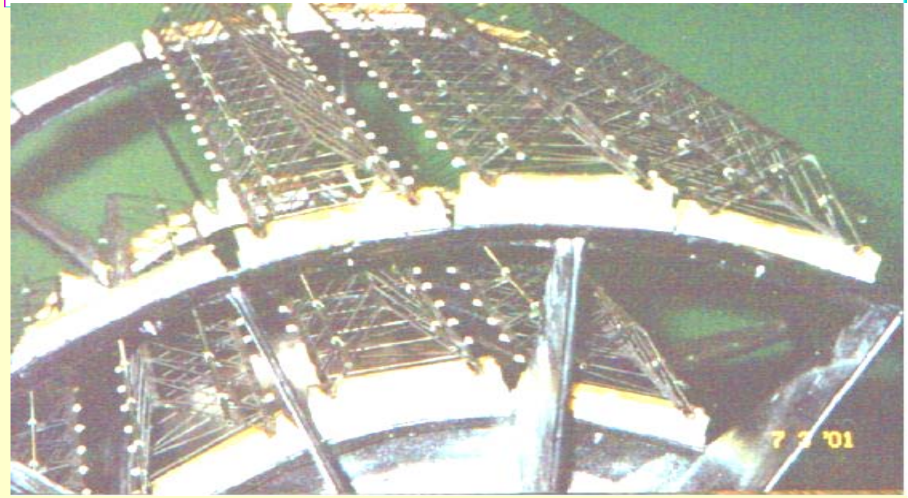


Muon arm 2.4 < η < 4
PMD 2.3 < η < 3.5
FMD -5.4 < η < -1.6
1.6 < η < 3

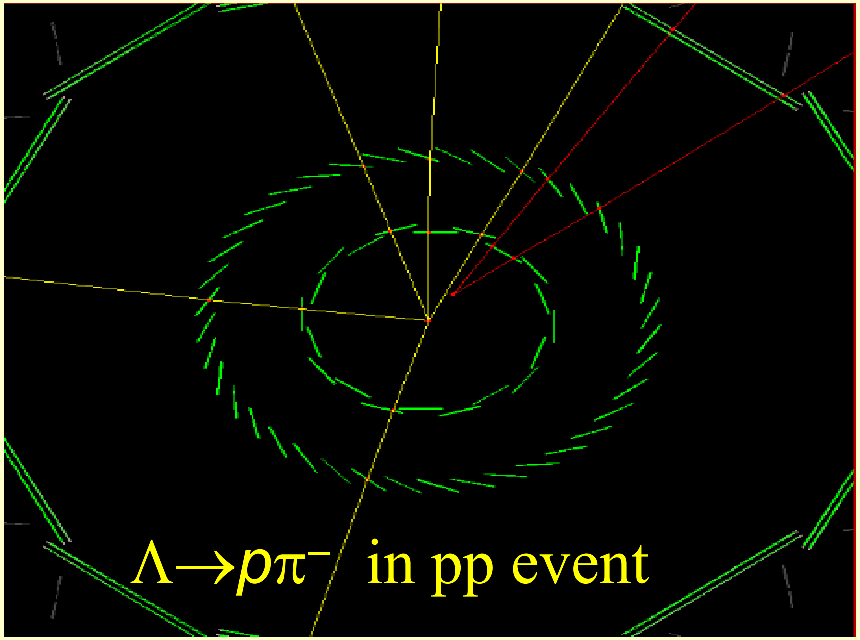
Inner tracking system ITS

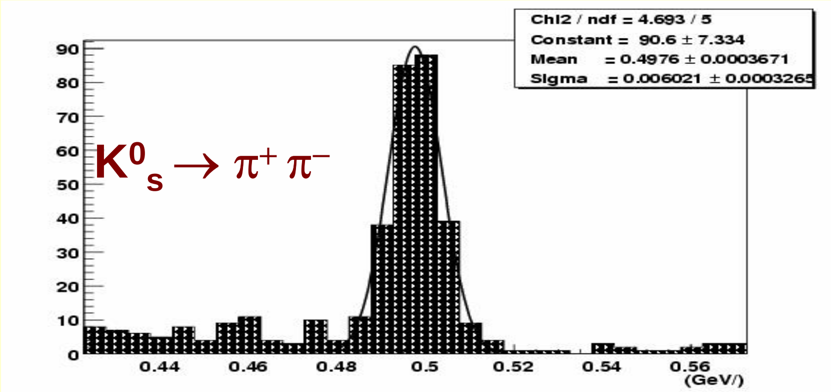


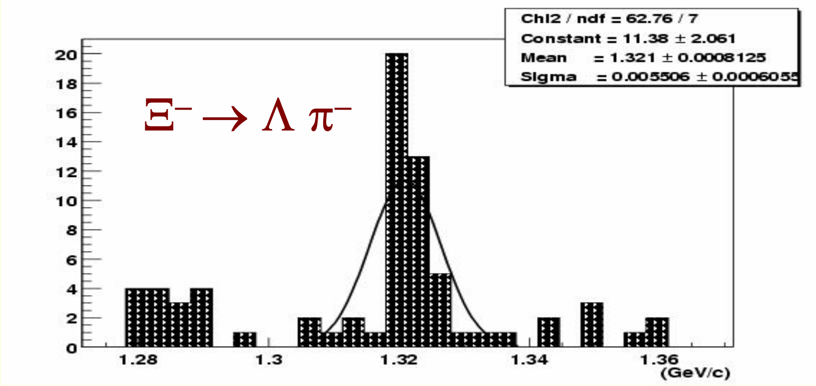
vertex reconstruction
(primary and secondary)
PID via dE/dx
$-0.9 < \eta < 0.9$
multiplicity and η reconstruction
$-2 < \eta < 2$



ITS secondary vertices







For the moment restricted inside the beam pipe R < 2.5cm

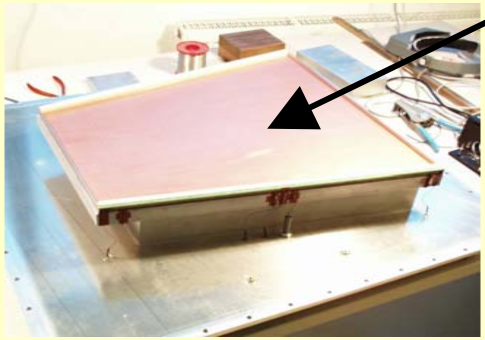
Loss due to vertexing itself only 1%

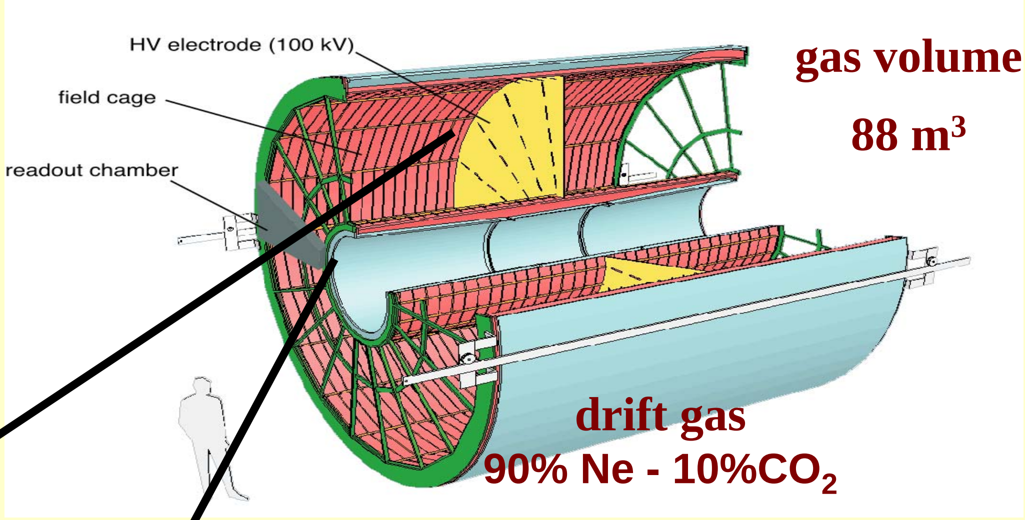
B = 2 T	Position resolution	Mass resolution	Momentum resolution	Efficiency
K^0_s	200-300 μm	6-8 MeV	1.5-1.8%	21-25%
Λ	~ 500 μm	3-4 MeV	1.3%	15%

Time Projection Chamber

for tracking and PID via dE/dx

$-0.9 < \mu < 0.9$





gas volume

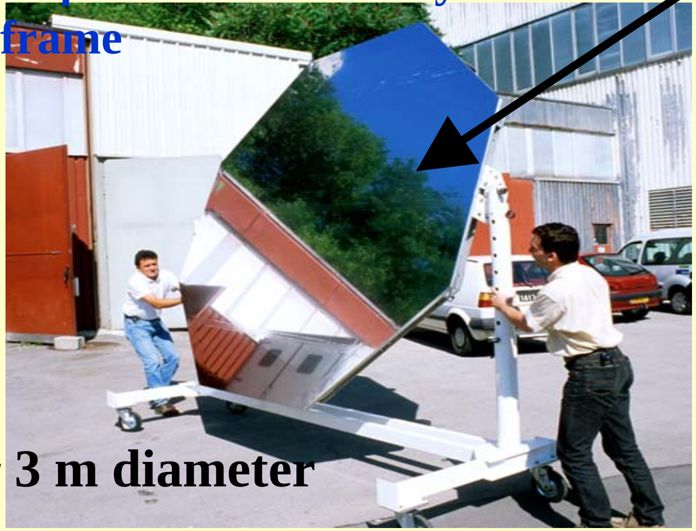
88 m^3

drift gas

90% Ne - 10%CO_2

Central Electrode Prototype

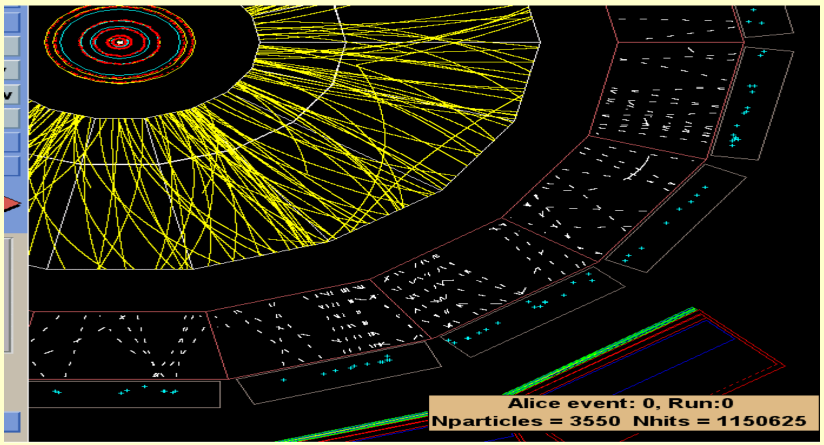
25 μm aluminized Mylar on Al frame

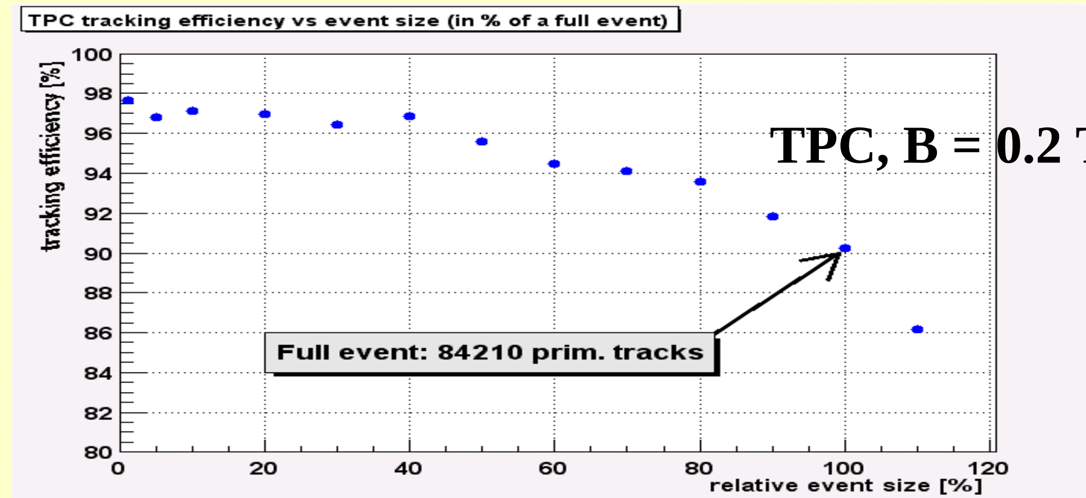


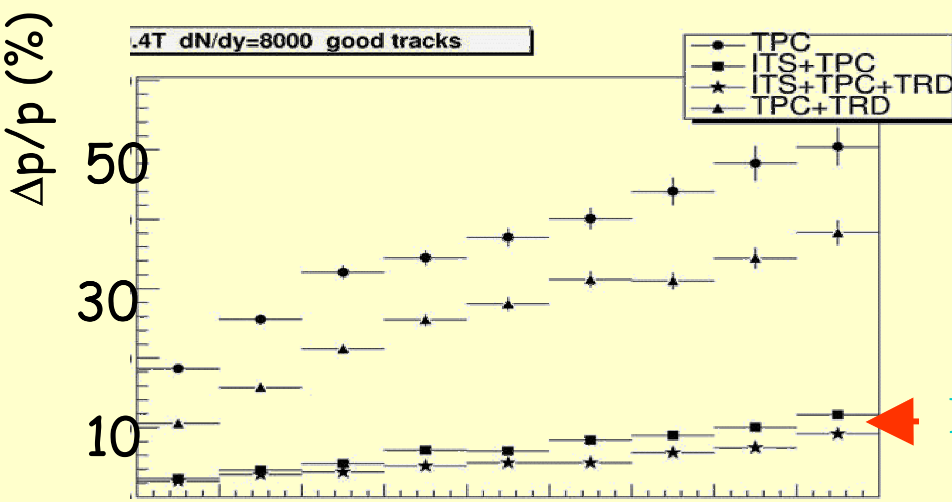
~ 3 m diameter

Field Cage
Inner Vessel

Tracking



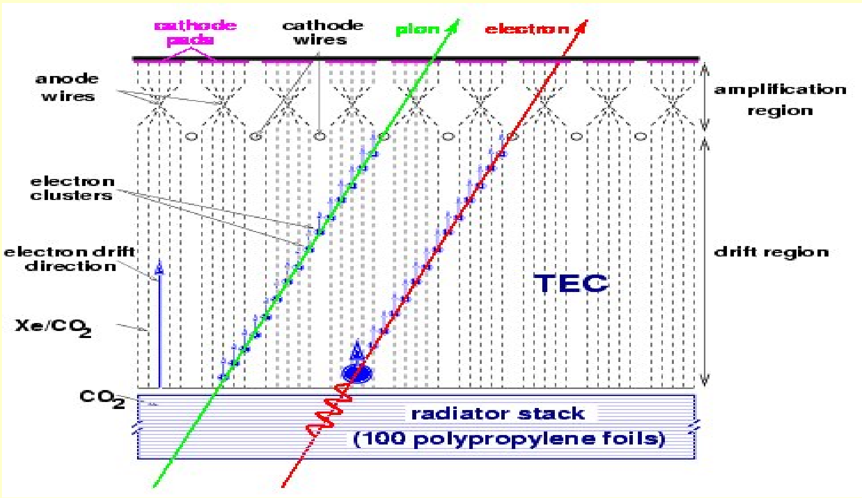




δp/p (%)	< p_t >		p_t > 5 GeV/c	
Magnetic field (T)	0.2	0.5	0.2	0.5
TPC	2.4	1.2	8.5	5.8
TPC+ITS	1.6	0.7	3.4	1.4

Resolution 9% at 100 GeV/c

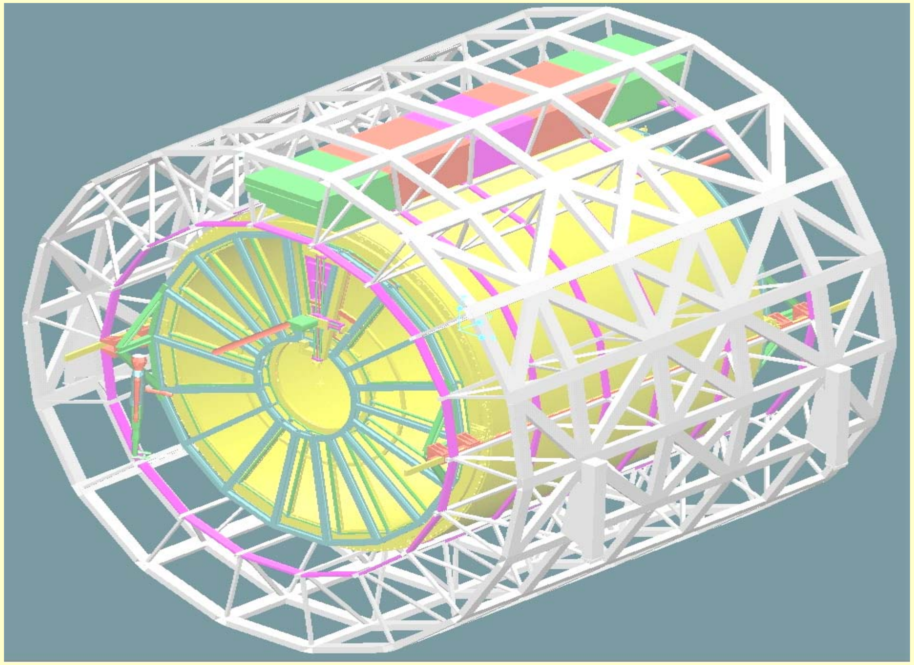
Transition radiation detector



for e PID, p>1 GeV/c
for e and high pt trigger, p>3 GeV/c
-0.9 < η < 0.9

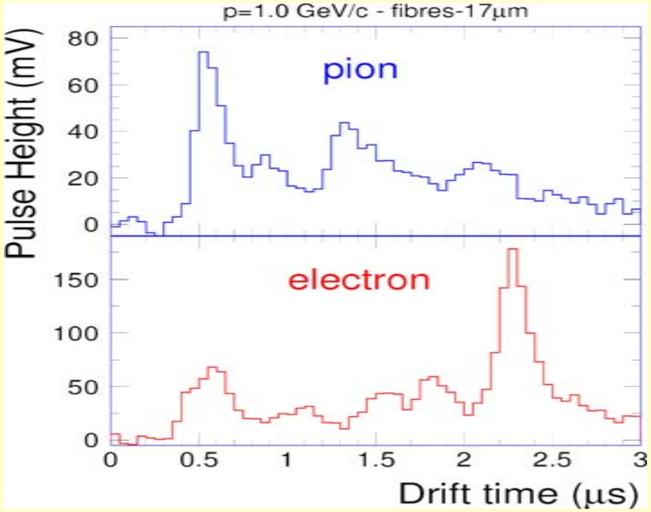
Full scale prototype

Supermodule in space frame

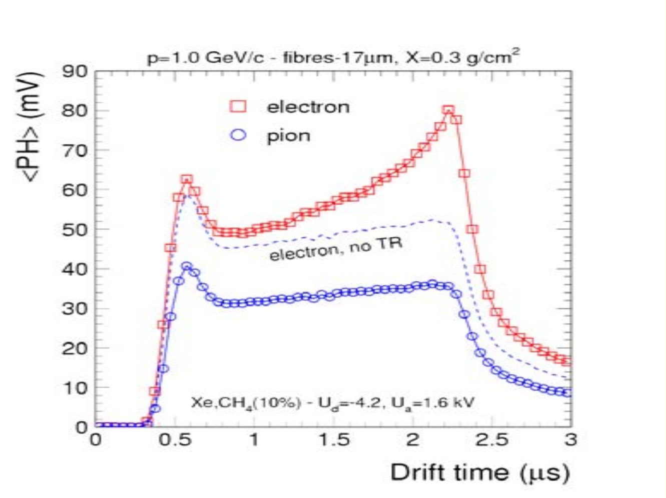


TRD signals: pions, electrons

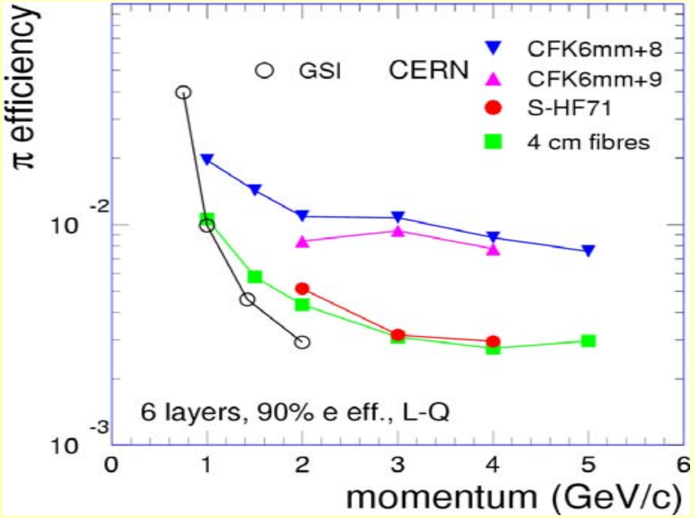
Pulse height distribution π,e



<pulse height> distribution π,e

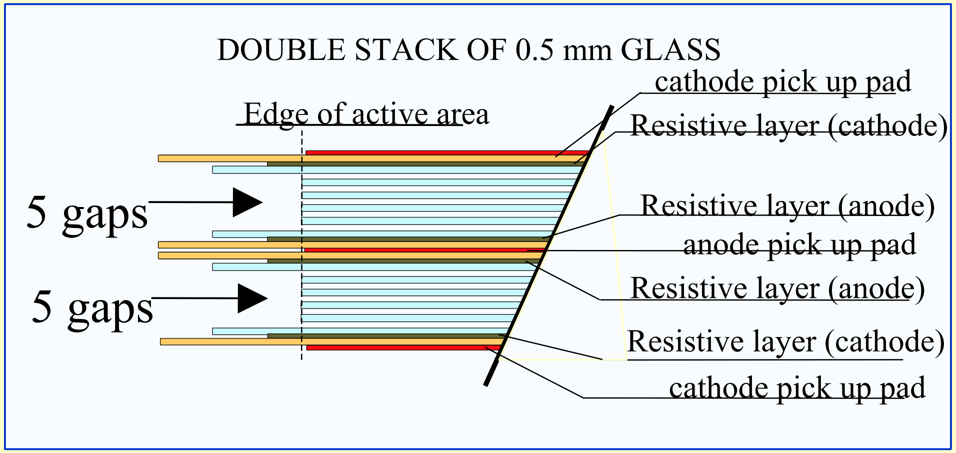


π-efficiency

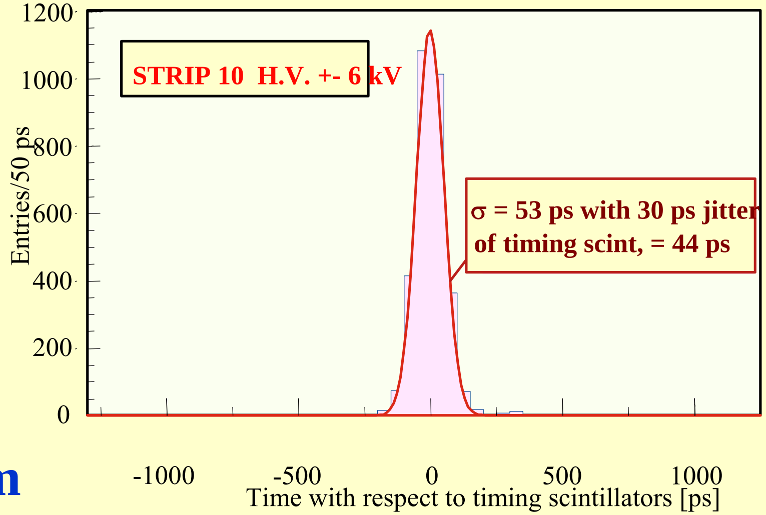


Time-Of-Flight

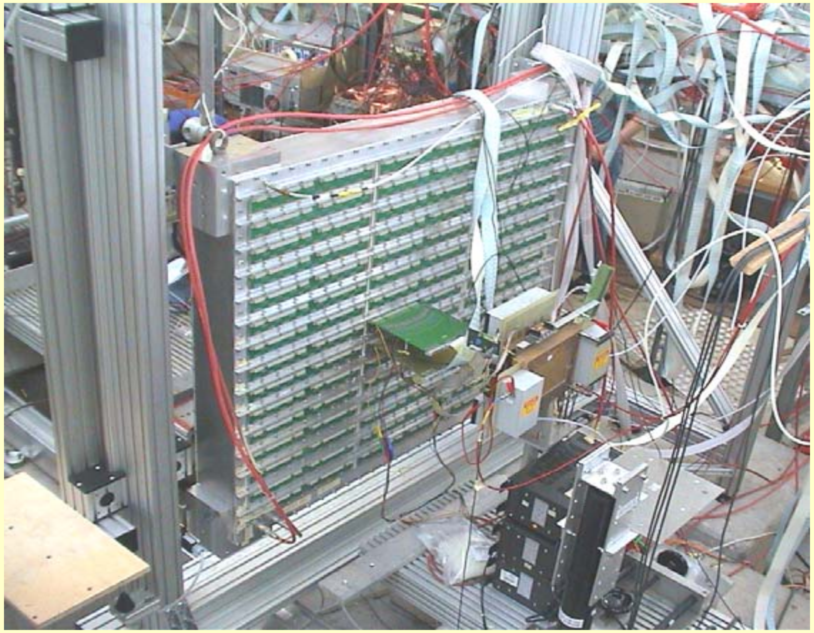
Resistive plate chambers



Time spectrum



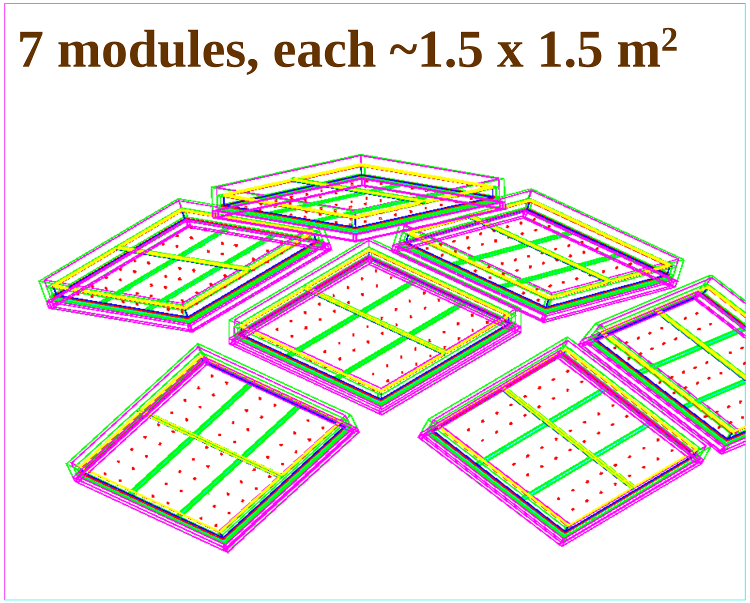
PID for π, K, p
π, K for p < 2 GeV/c
p for p < 4 GeV/c
$-0.9 < \eta < 0.9$

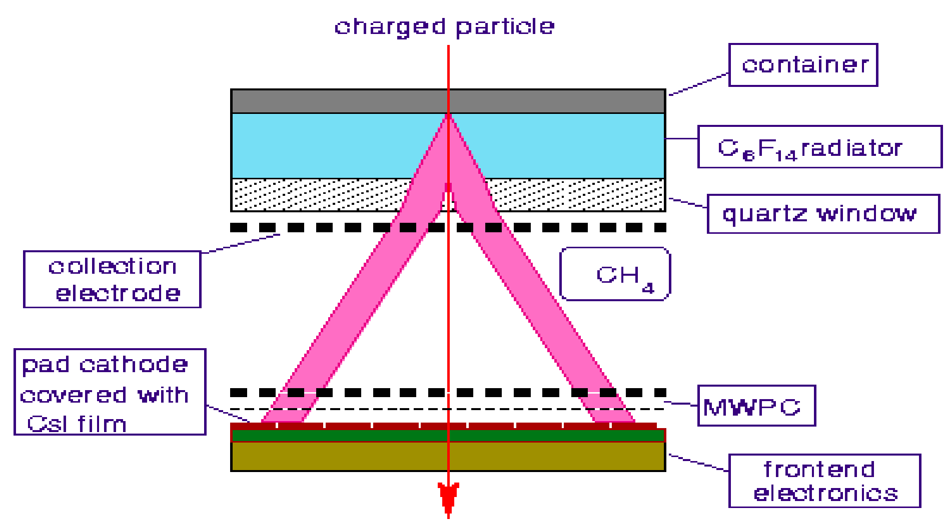


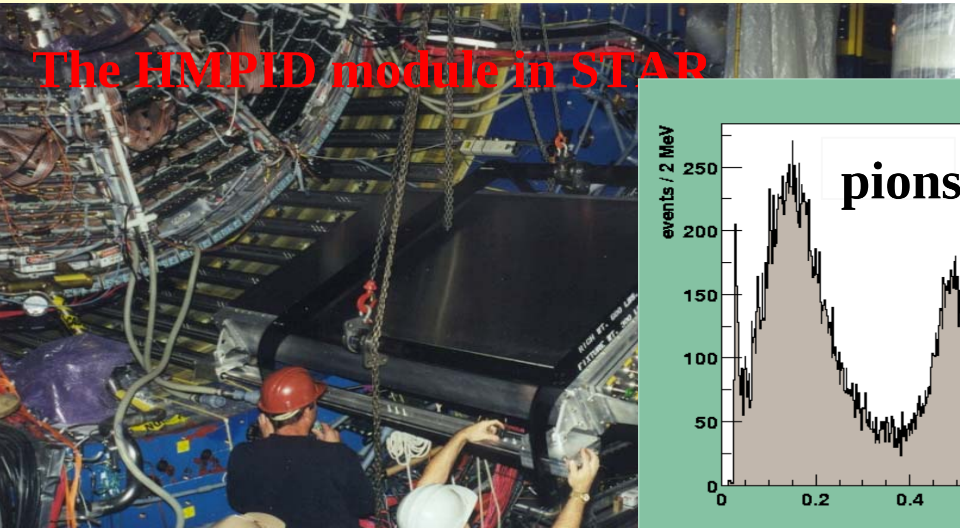
2 full size TOF modules under test

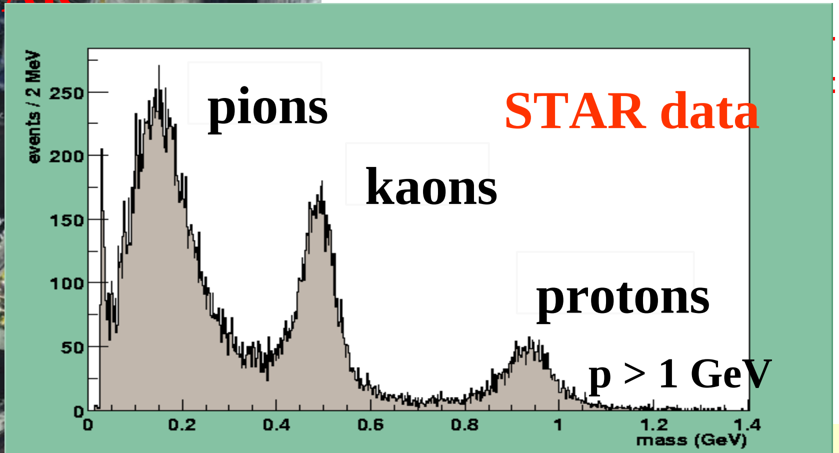
High Momentum Particle Identification

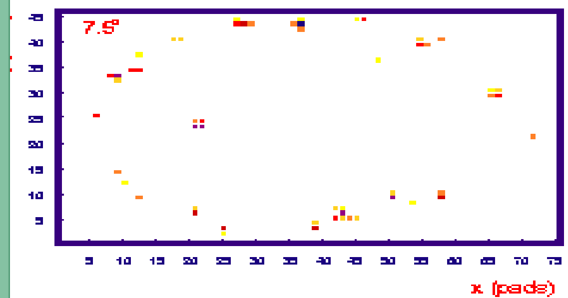
7 modules, each ~1.5 x 1.5 m^2



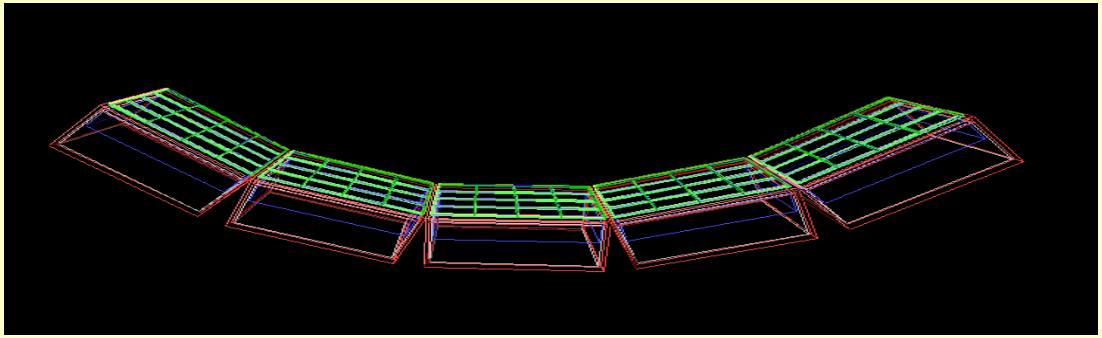


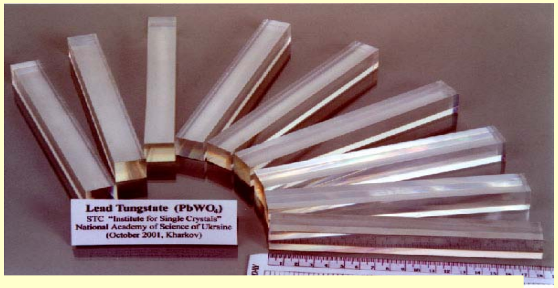




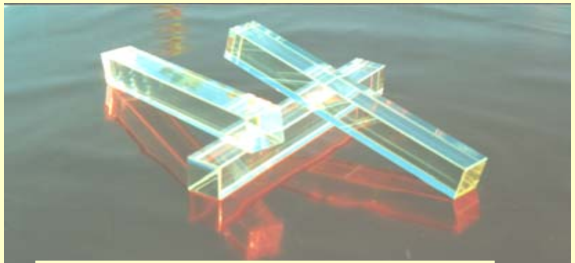


Photon spectrometer





Ukranian crystals

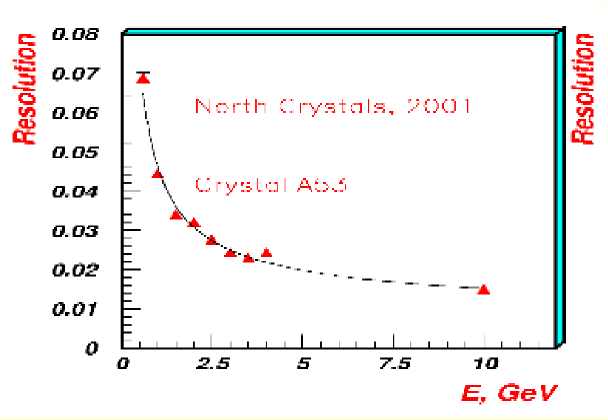


Apatity PWO crystals

$PbWO_4$ crystals

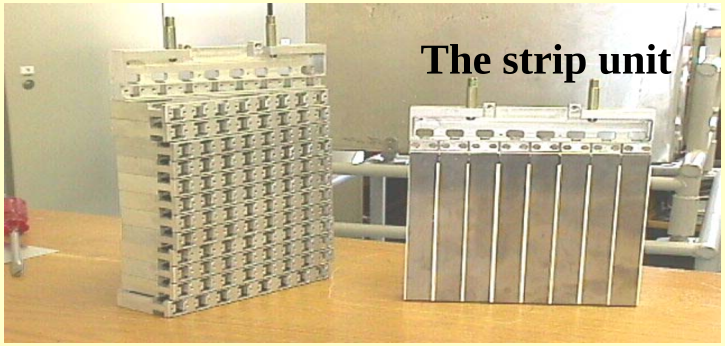
Excellent energy resolution:

stochastic	$2.7\%/E^{1/2}$
noise	$2.5\%/E$
constant	1.3%



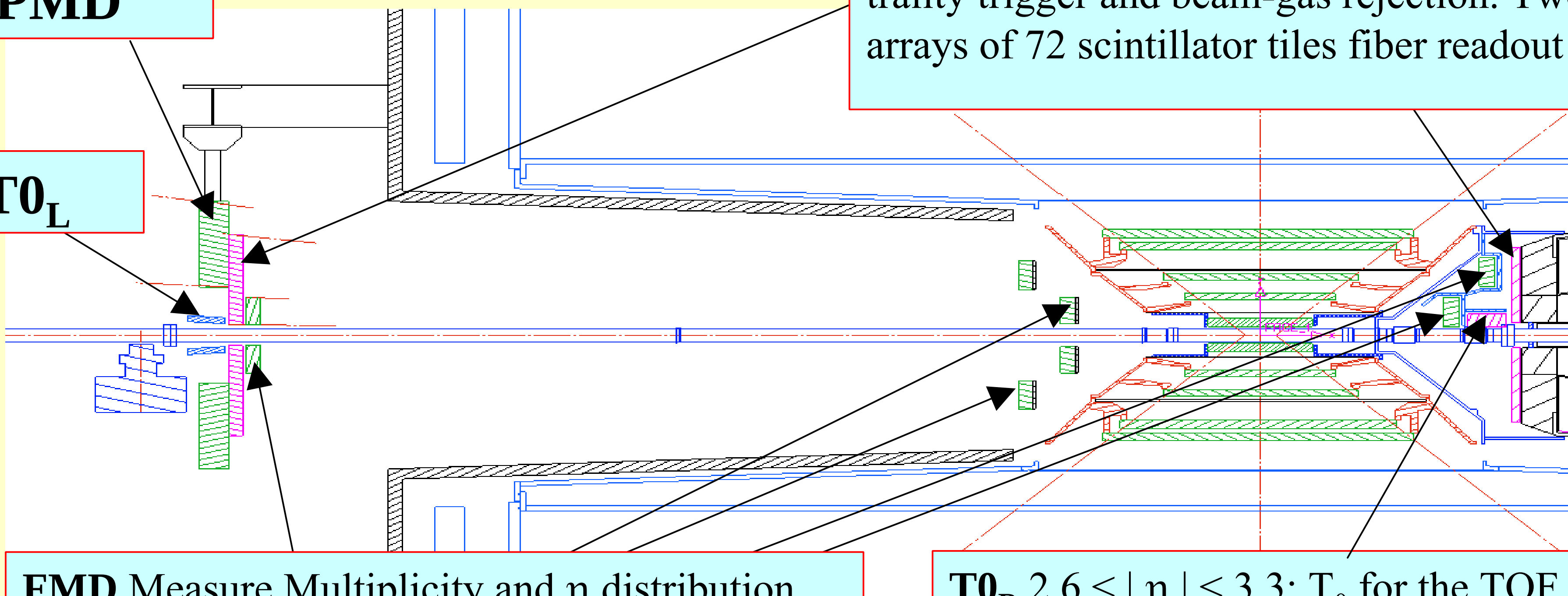
For photons, neutral mesons and γ–jet tagging $-0.5 < \mu < 0.5$

PHOS 256-Channel Prototype



The prototype with the CPV-detector mounted on top of it.

Forward Detectors



PMD

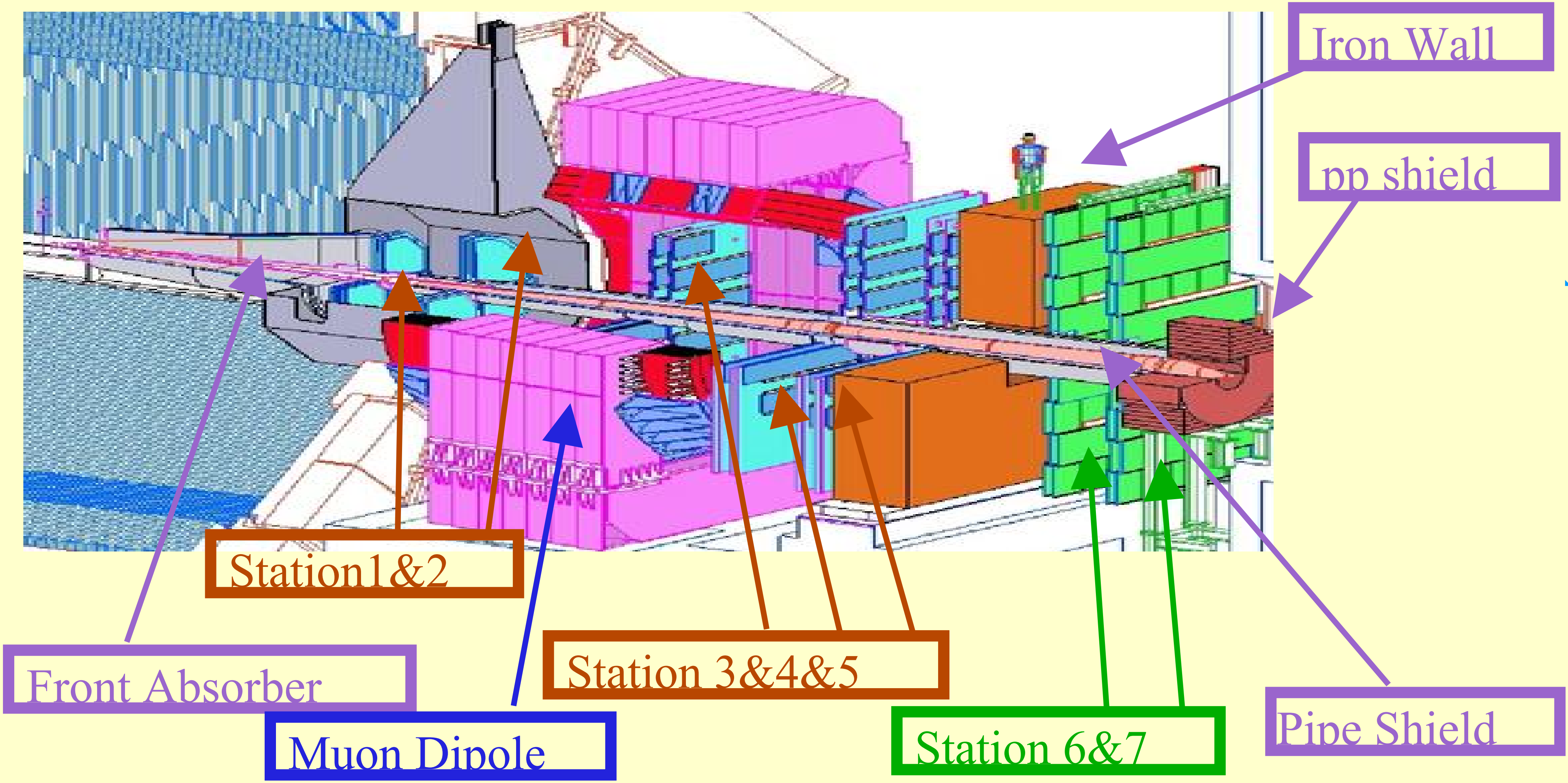
T0$_L$

V0 1.6 < | η | < 3.9 Interaction trigger, centrality trigger and beam-gas rejection. Two arrays of 72 scintillator tiles fiber readout

FMD Measure Multiplicity and η distribution. Over 1.6 < η < 3, -5.4 < η < -1.6 ; Silicon pad detector disks (slow readout) with 12k analog channels (occ.>1)

T0$_R$ 2.6 < | η | < 3.3; T_0 for the TOF (~ 50 ps time res.) Two arrays of 12 quartz counters. Also backup to V0

Muon spectrometer

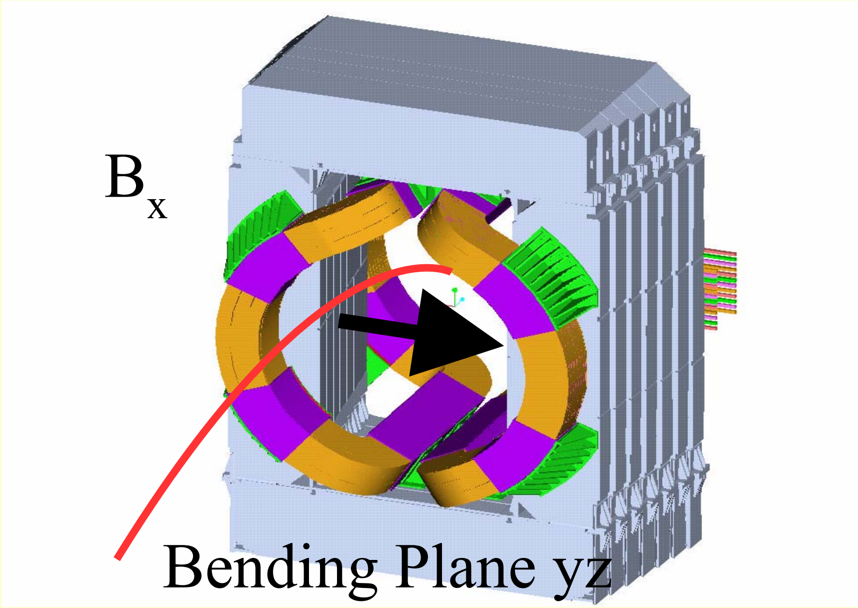


Muon absorber

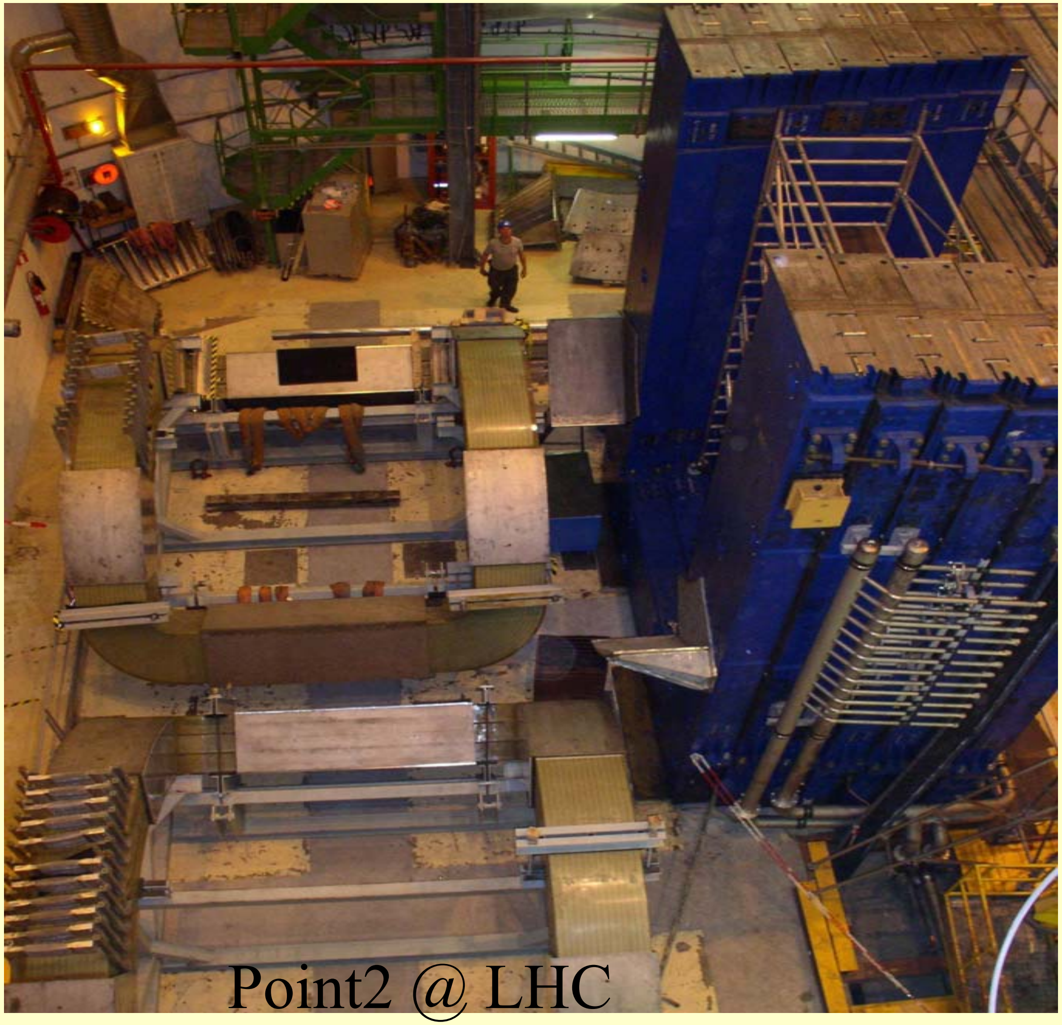
- Front Absorber ($2.5 < \mu < 4$, $\lambda_I \sim 10$):
  - **Reducing forward flux of charged particles (100).**
  - **Decreasing the hadronic muon background (limit of 90 cm to IP due to the central barrel).**
  - **Minimizing multiple scattering.**
- Beam shield ($4 < \mu < 7$):
  - **Reducing low energy background from the pipe**
- Iron wall ($2.5 < \mu < 4$, $\lambda_I \sim 7.2$):
  - **Reducing low energy background in the trigger chambers which are less constrained by multiple scattering.**

Muon magnet

- 820 tons
- Warm dipole (~4MW)
- $B=0.7$ T, $\int Bdl \sim 3$ Tm



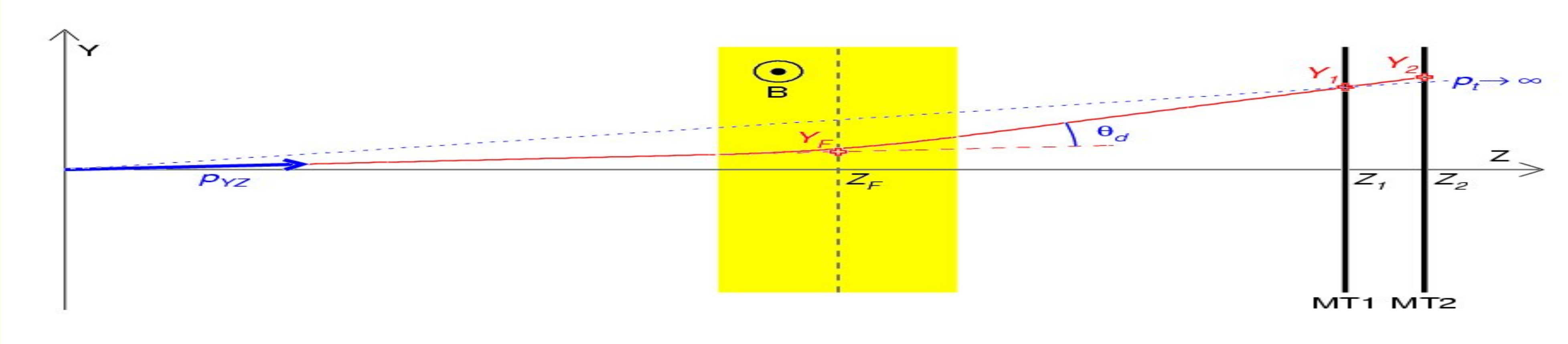
Non-Bending Plane xy



Point2 @ LHC

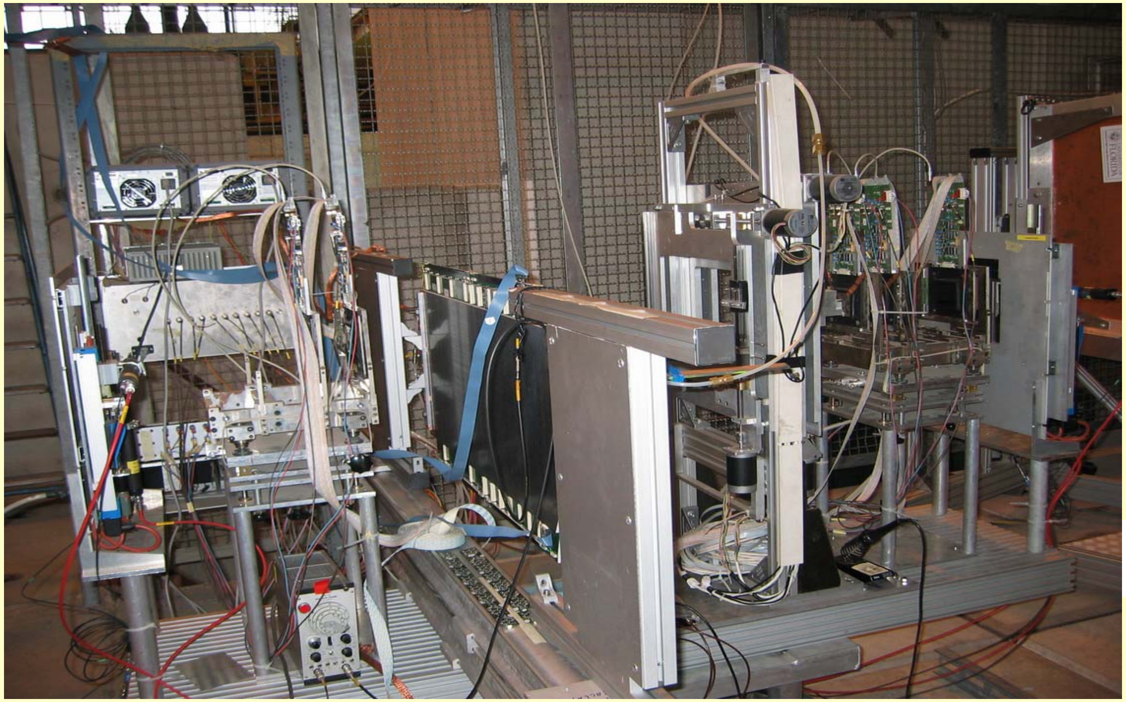
Muon trigger system

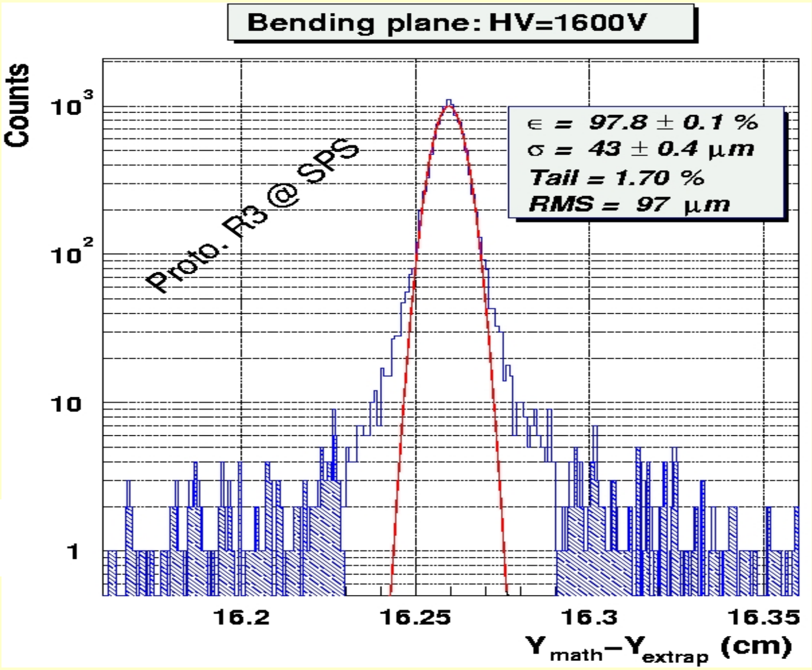
- Fast decision (<1 μs) for p_t cut:
  - Low p_t (~1 GeV/c) for J/Ψ, High p_t(~2 GeV/c) for Y's
- Reducing trigger rates below 1kHz:
  - PbPb @ LHC ~ 8 kHz, CaCa @ LHC ~30 kHz
- Compromise between quarkonia efficiency and background rejection:
  - Hadronic muons, soft-background, open heavy flavor decay.



CPC for stations 3,4,5

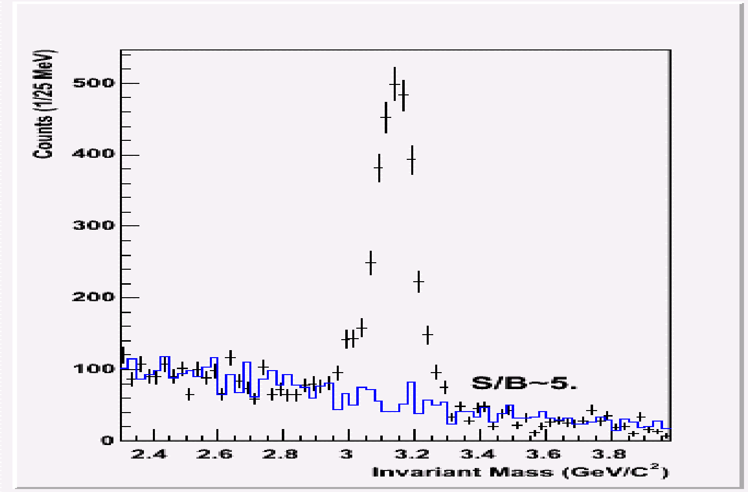
- Lengths from 80 cm to 2.4 m
- 140 CPC slats (19 types)
- Different densities 5x25 mm^2 to 5x100 mm^2.

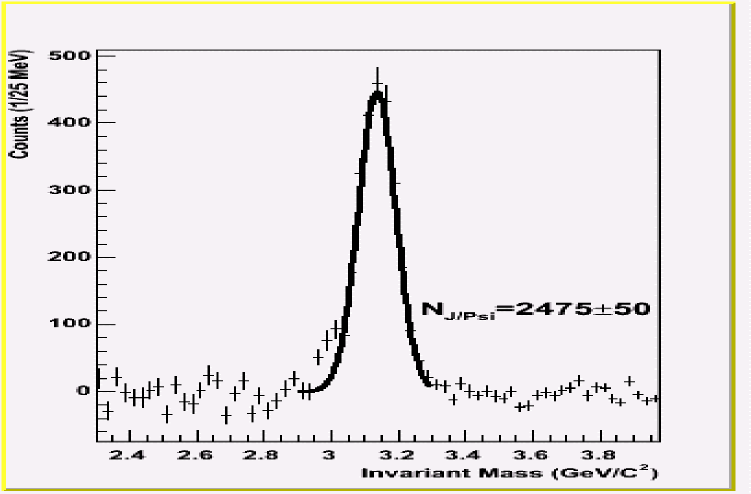




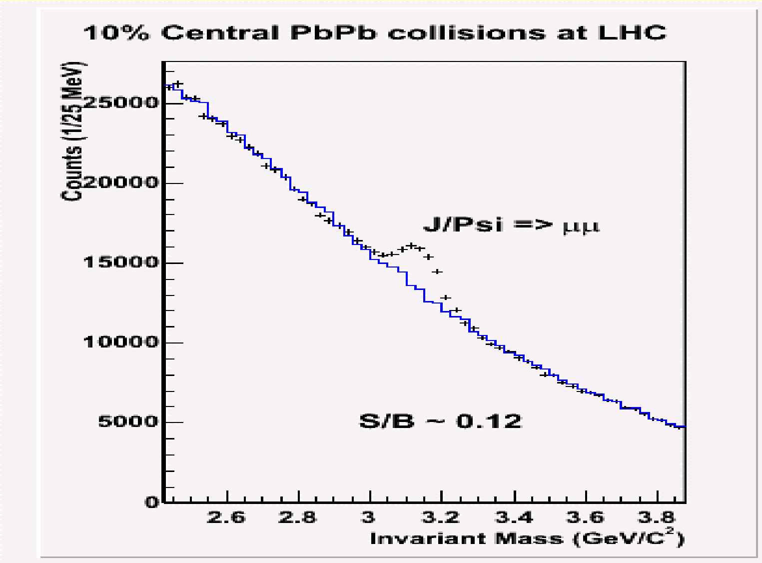
Muon signal $J/\Psi \rightarrow \mu^+\mu^-$

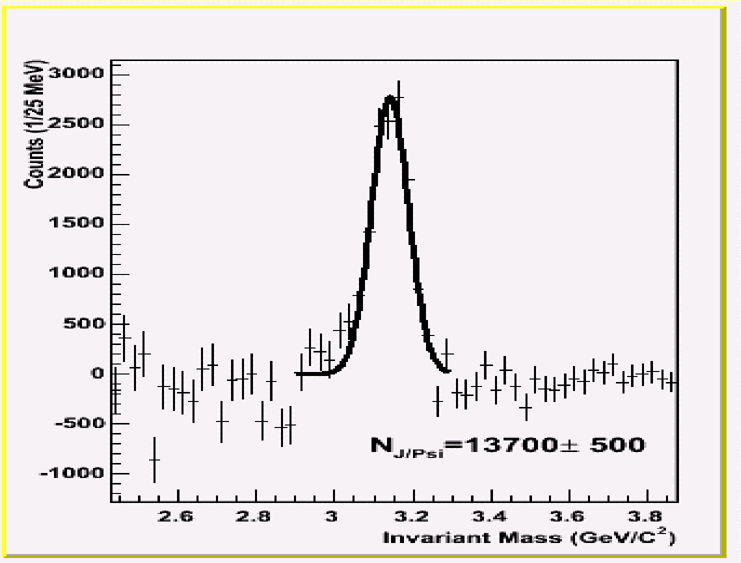
Full PbPb
LHC run statistics





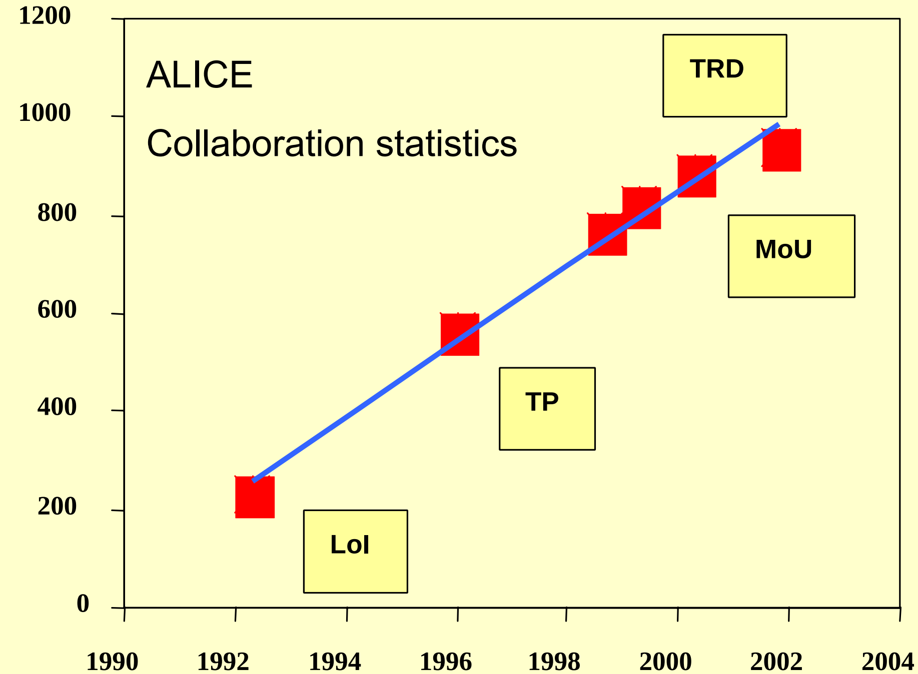
~5% of full statistic
PbPb LHC run





The ALICE collaboration

After more than 10 years of life, still healthy and growing !



- 937 members
- 77 Institutions
- Discussion with China,Japan US