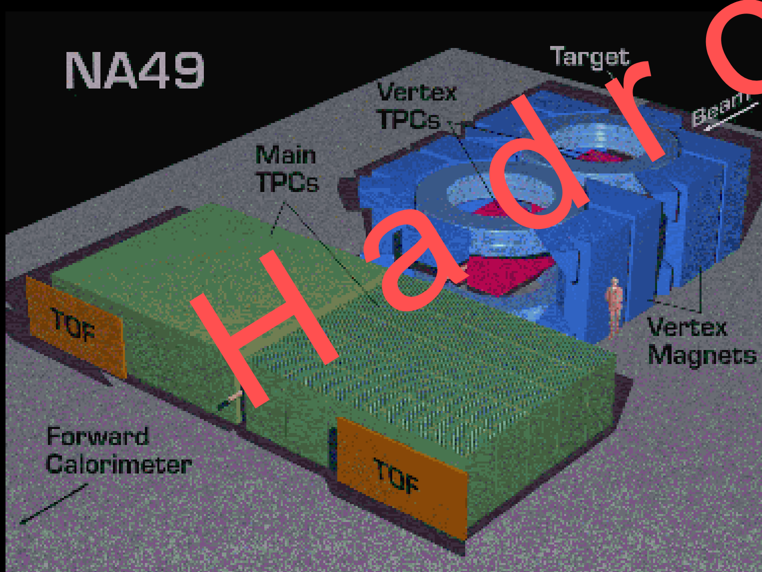
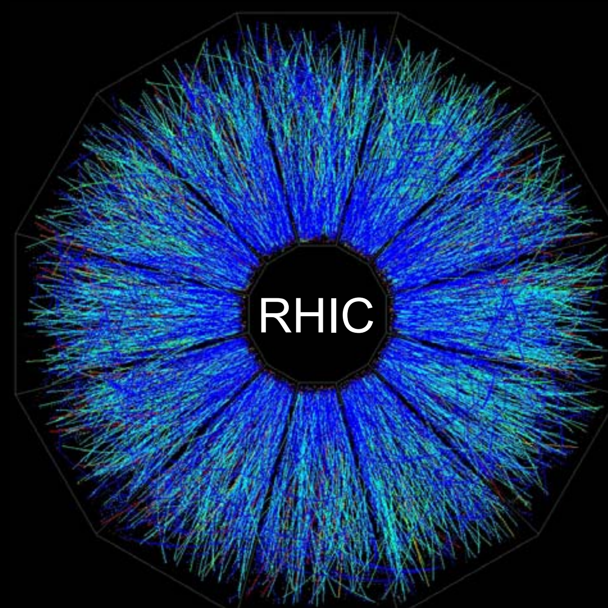
Zimanyi 75 Memorial Workshop

Hadronization

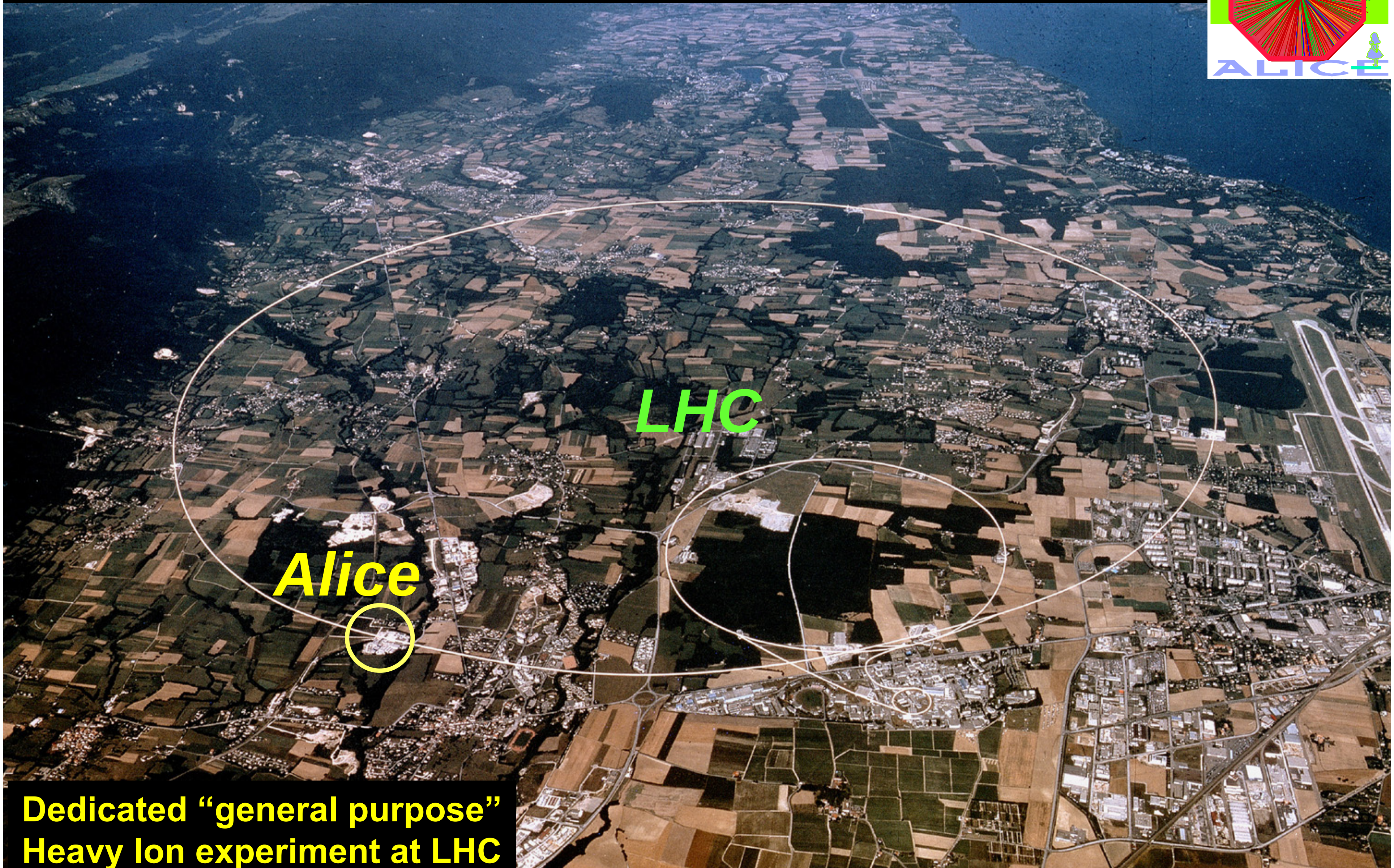
Biro TS and Zimanyi J, Nucl. Phys. A395 (1983) 525.





Biro TS, Levai P, and *Zimanyi* J, J. Phys. G27 (2001) 439 and J. Phys. G28 (2002)1561.

High p_T and Jet Physics in ALICE



Dedicated "general purpose" Heavy Ion experiment at LHC

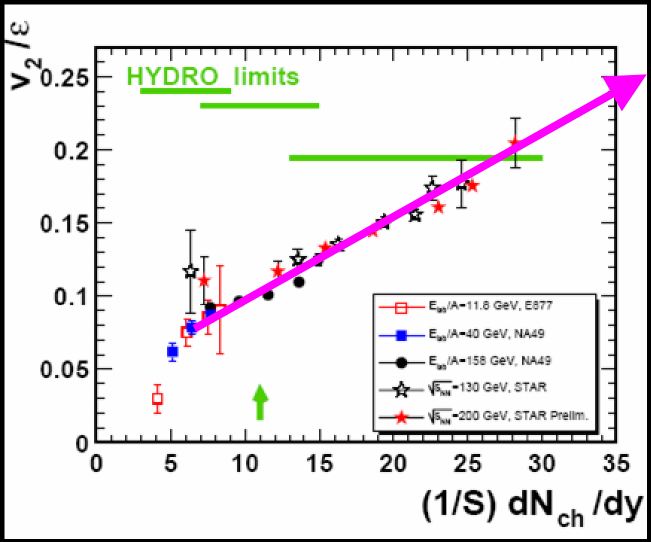
Heavy Ion Physics at the LHC

LHC Heavy Ions –

- guidance from pQCD predictions
- expectations (detector simulations) based on RHIC extrapolations and theory
- lesson from RHIC – theory guidance + versatility + **"expect the unexpected"**

Soft Physics at LHC –

- smooth extrapolation from **SPS → RHIC → LHC?**
- expansion will be different (v_2, HBT, T_{chem} & T_{kin}, strange/charm particles & resonances)



Heavy Ion Physics at the LHC

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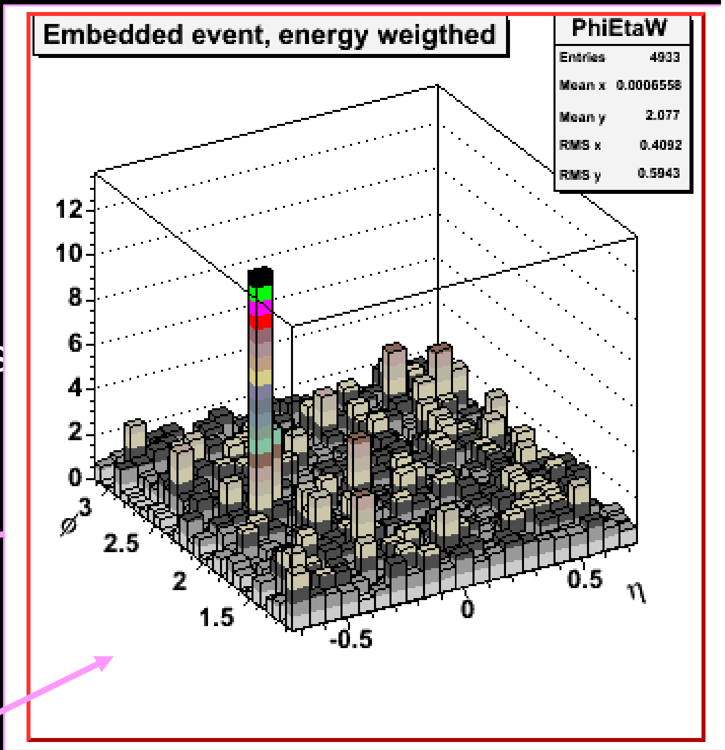
Hard Probes at LHC –

- **significant increase in hard cross sections**

  → $\sigma_{hard} / \sigma_{total}$ ~ 2% at SPS, 50% at RHIC, 98% at LHC

  - “real” jets, large p_T processes
  - abundance of heavy flavors
  - probe early times, calculable → **precision studies!**

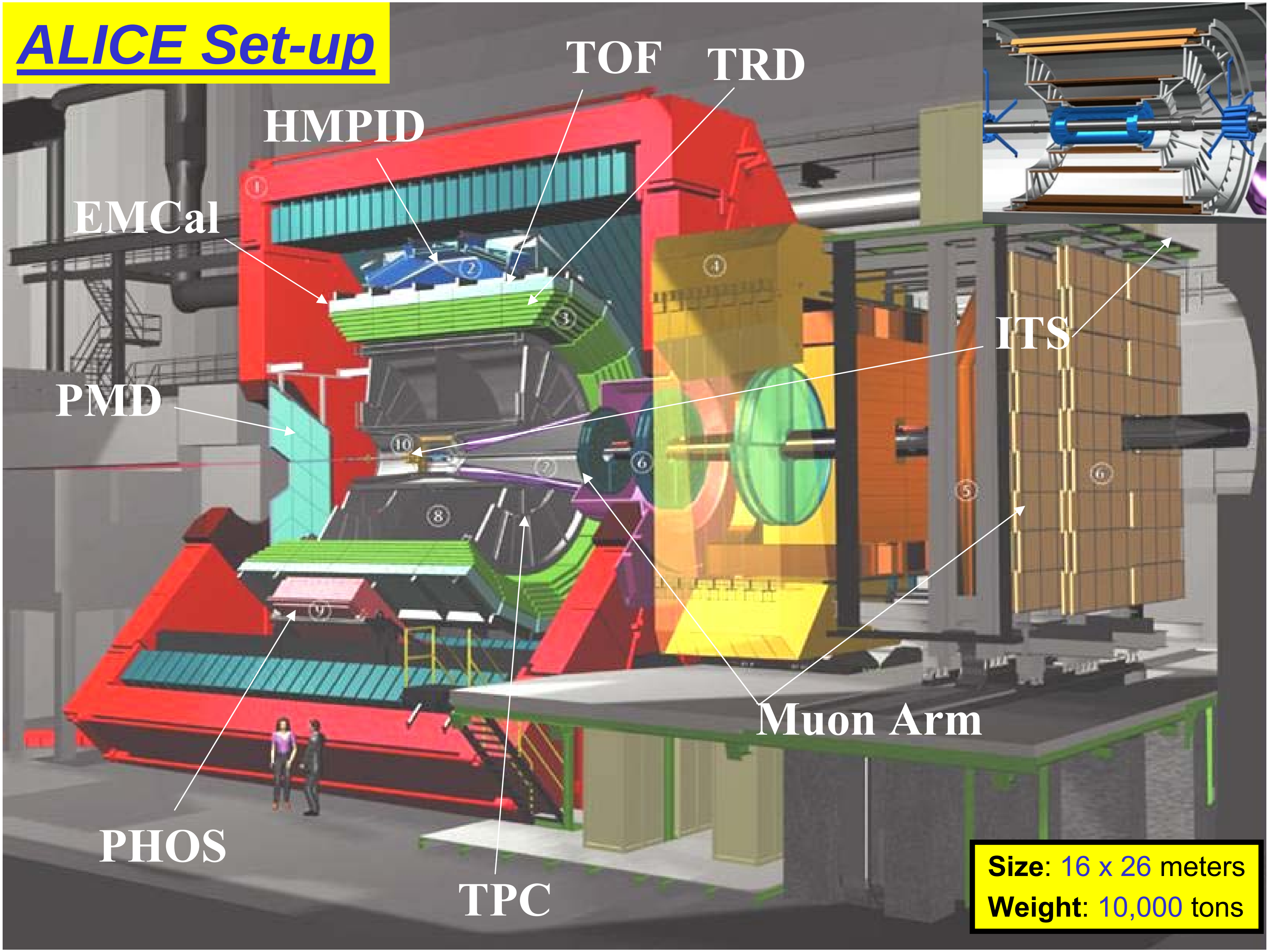


σ_{bb} (LHC) ~ 100 σ_{bb} (RHIC)

σ_{cc} (LHC) ~ 10 σ_{cc} (RHIC)

ALICE Overview

ALICE Set-up



TOF
TRD
HMPID
EMCal
PMD
ITS
Muon Arm
PHOS
TPC
Size: 16 x 26 meters
Weight: 10,000 tons

ALICE Detectors & Acceptance

central barrel ***-0.9 < η < 0.9***

- $\Delta\phi = 2\pi$ tracking, PID **(TPC/ITS/ToF)**
- single arm RICH **(HMPID)**
- single arm e.m. cal **(PHOS)**
- jet calorimeter **(EMCal)**

forward muon arm ***2.4 < η < 4***

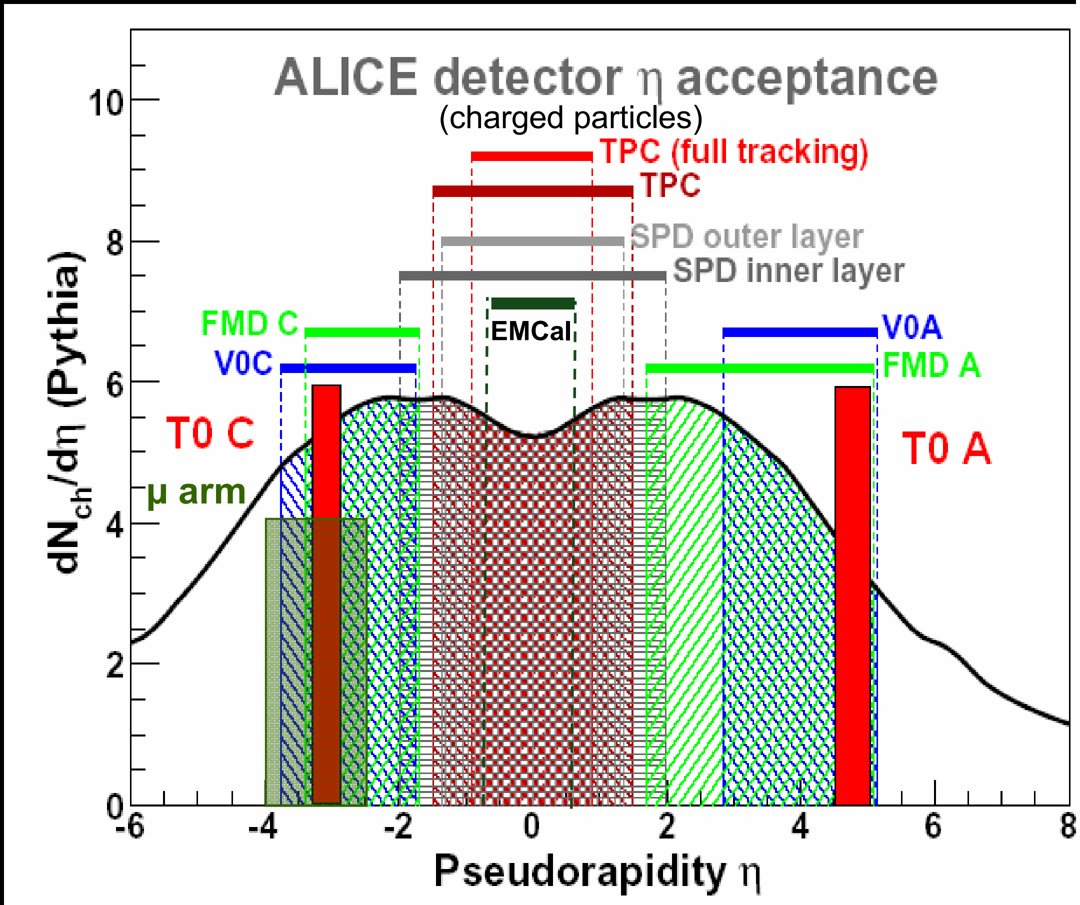
- absorber, 3 T-m dipole magnet
10 tracking + 4 trigger chambers

multiplicity detectors ***-5.4 < η < 3***

- including photon counting in **PMD**

trigger & timing detectors

- 6 **Zero Degree Calorimeters**
- **T0:** ring of quartz window PMT's
- **V0:** ring of scint. Paddles



Particle Identification in ALICE

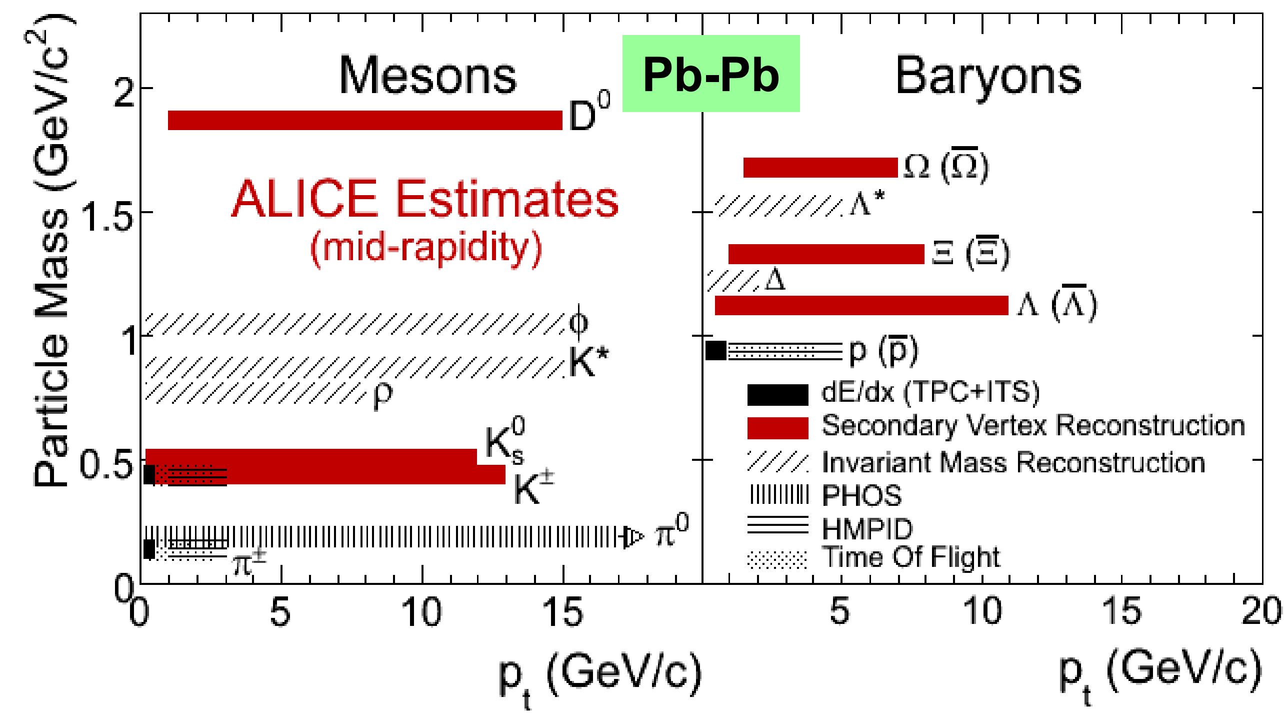
PID capabilities unique to ALICE!
Global tracking (ITS-TPC-TRD)
dE/dx (low p_T + relativ. rise)
TOF, HMPID, PHOS

} π, K, p: 0.1- 0.15 → 50 GeV

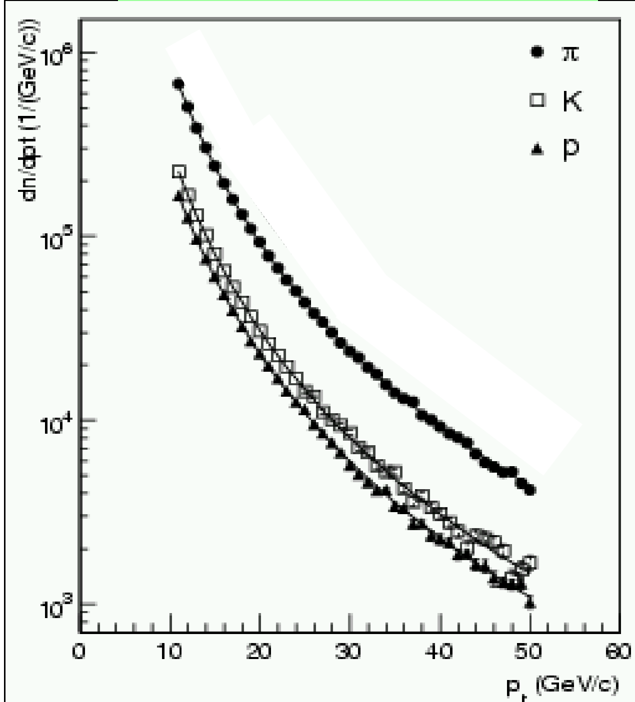
Topological reconstruction
Invariant mass

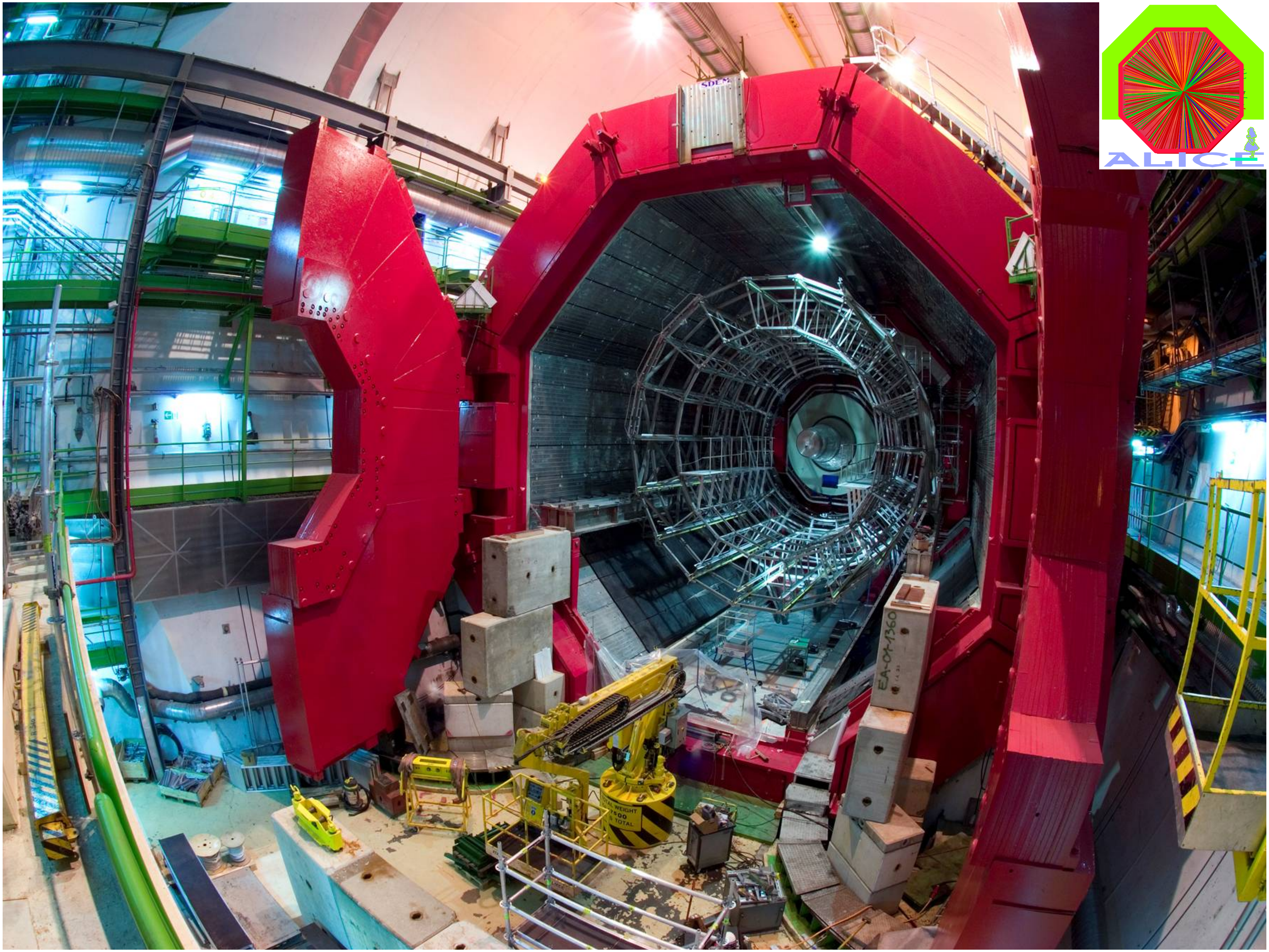
} Decay particles: → 10 - 15 GeV

p_T range (PID/stat. limits) in 10^9 pp or 10^7 central Pb-Pb



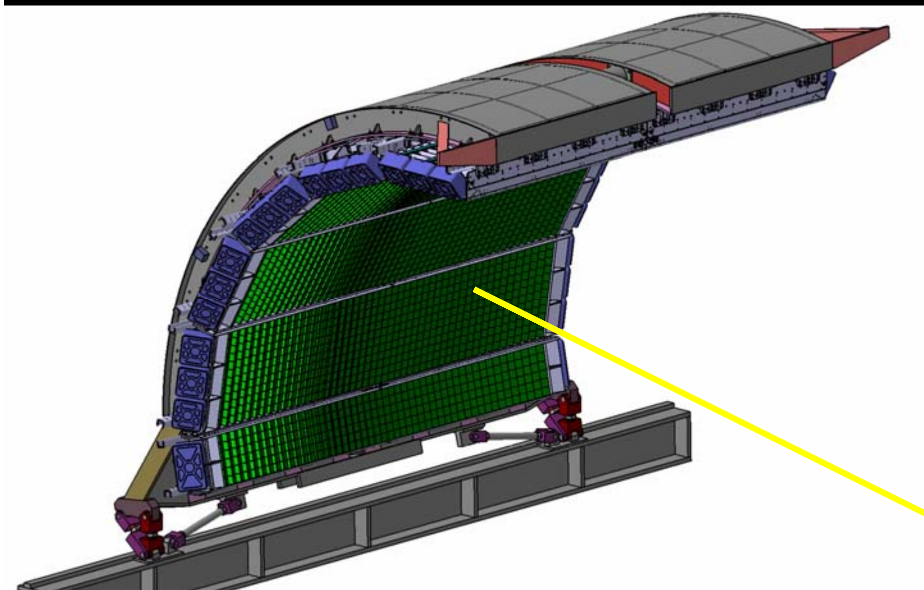
PID in relativistic rise





ALICE

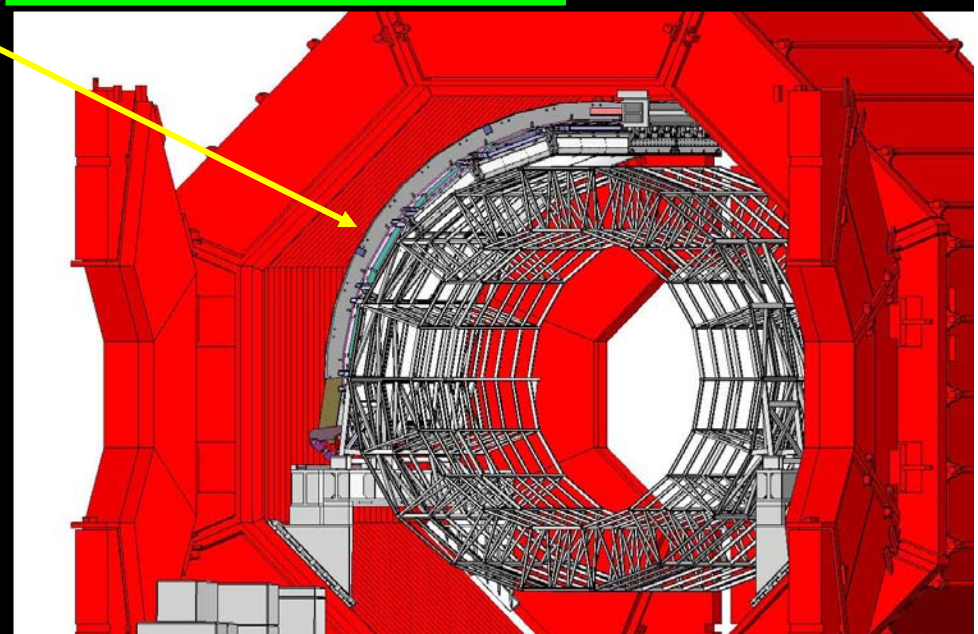
ALICE EMCal



Approved by LHCC 9/28/06

10+1/2+1/2=11 super-modules
8 SM from US
3 SM from France, Italy

Allows Jet Measurements / Triggering with ALICE



Lead-scintillator sampling calorimeter
$\Delta\eta = 1.4$, $\Delta\phi = 110^o$

Shashlik geometry, APD photosensor
~13K towers ($\Delta\eta$ x $\Delta\phi$ ~ 0.014 x 0.014)

Energy resolution $\leq 15\%/\sqrt{E} + 2\%$
over-takes tracking above 30 GeV

π^o/γ discrimination to p_T ~ 30 GeV

Jet Capabilities of ALICE (with EMCal)

EMCal improves detector capabilities:

- Fast trigger ~10 -100 enhancement of jets
- Allows jet reconstruction (with TPC)
- Good γ/π^0 discrimination

  increases coverage

- Good electron/hadron discrimination

EMCal extends the physics of ALICE:

10^4 / year in minbias Pb+Pb:

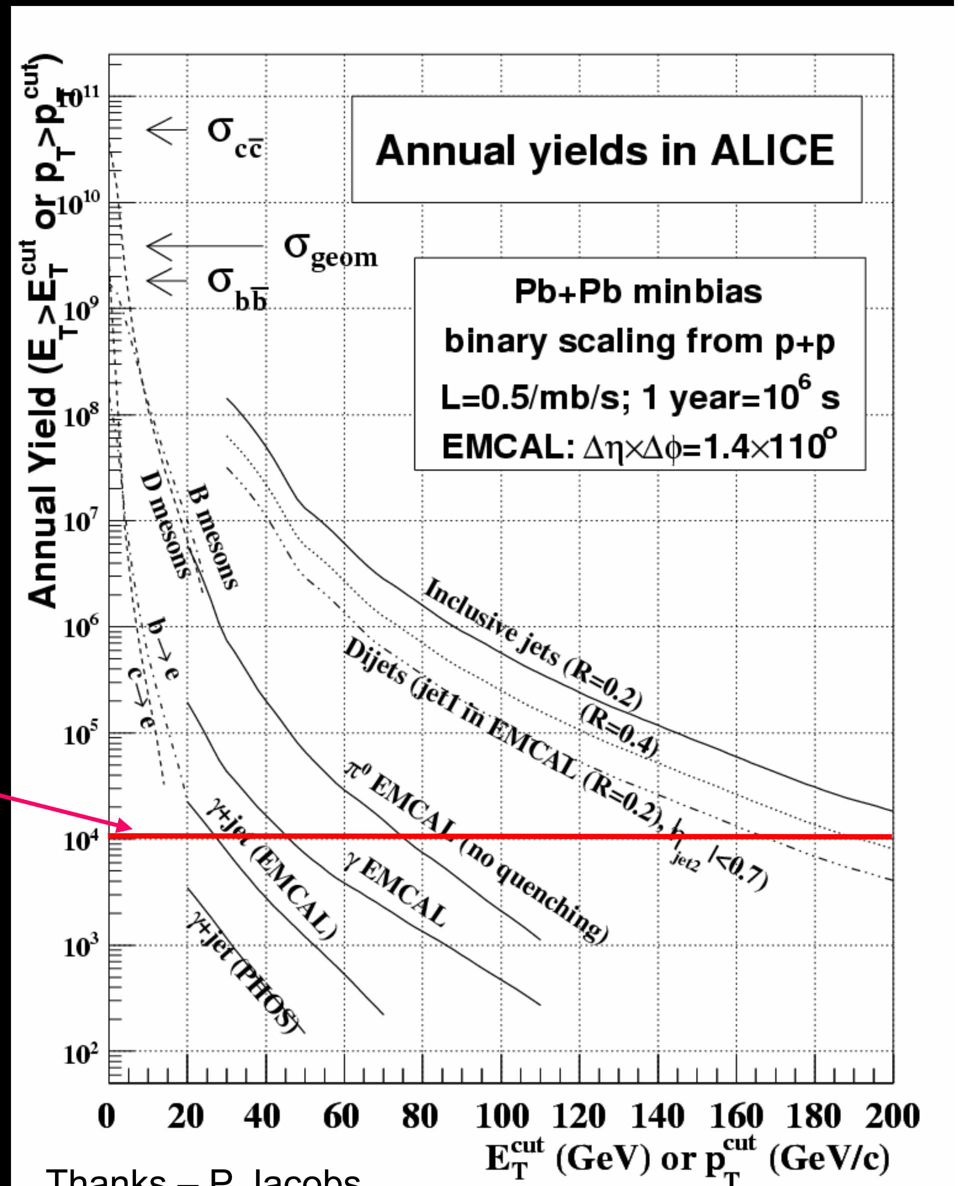
inclusive jets: $E_T \sim 200$ GeV

dijets: $E_T \sim 170$ GeV

π^0: $p_T \sim 75$ GeV

inclusive γ: $p_T \sim 45$ GeV

inclusive e: $p_T \sim 30$ GeV



Thanks – P.Jacobs

Synopsis of ALICE Physics

Soft Probes – "ala RHIC"

- ALICE – important soft physics measurements ala RHIC (+ extended PID)
- Expansion dynamics different from RHIC (note - timescales, densities)
- Day 1 physics + ….. (unexpected…)

Heavy Quarks

- Displaced vertices ($D^o \rightarrow K^- \pi +$) from TPC/ITS (charm and beauty)
- Electrons in Transition Radiation Detector (TRD)

Quarkonia (forward muon arm)

- J/ψ, Υ, Υ' (excellent), Υ''(2-3 yrs), ψ' (very difficult!)

EMCal

measure $e^{\pm}$ with p_e > 10 GeV supplementing TRD

Jet Quenching & Medium Response

- Leading particles to intermediate p_T (range of intermediate p_T at LHC?)
- Away-side

trigger on leading π^0

trigger on / measure jets

6x increased acceptance for γ's with respect to PHOS

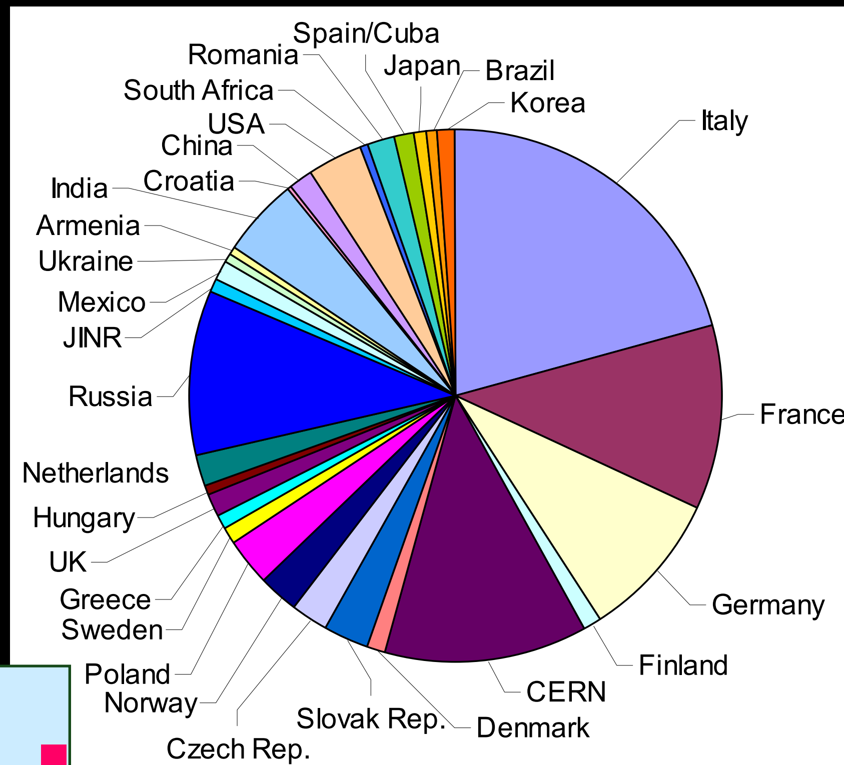
ALICE Collaboration

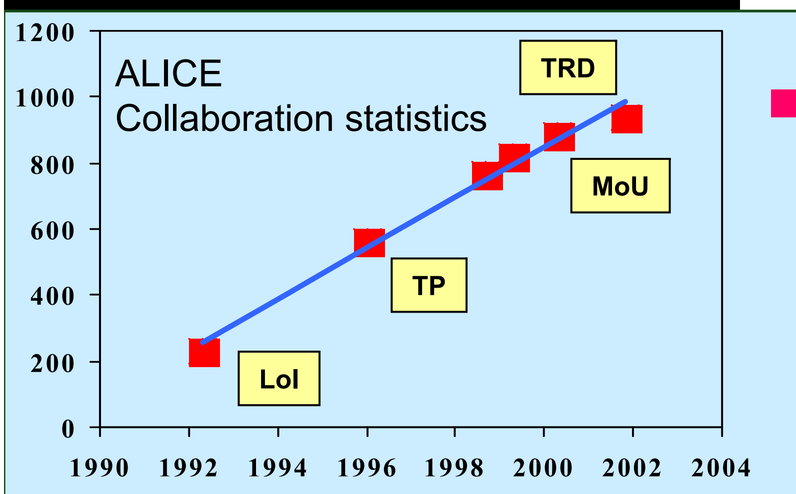
~ 1000 Members
(~ 500 M&O PhDs)
63% CERN States
~ 8% expected US

~ 30 Countries

~ 100 Institutes

~ 150 M CHF capital
(+ L3 magnet)





Jet Physics with ALICE EMCal

Jet Physics in ALICE (with EMCal)

Utilize Initial Hard Parton Scattering

- High energy jets, photons and heavy flavors → requires EMCal and triggering

  Exploit large kinematic range of jets at LHC

  Measure jet structure & medium-induced jet modification

  Investigate energy loss mechanism with

  quark-tagged jets (heavy flavor decays)

  gluon jets (light hadron leading)

  γ – jet coincidences

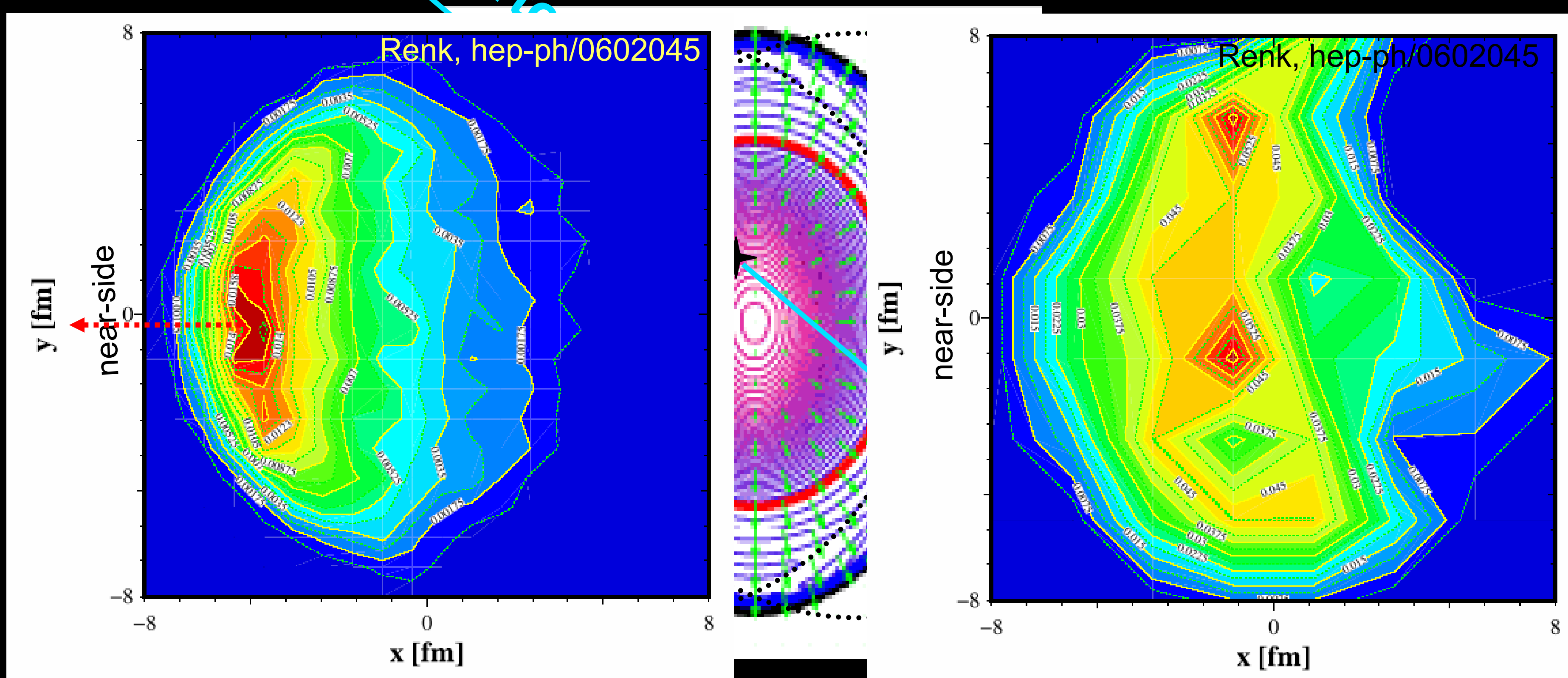
- Low energy particles correlated with trigger or quenched jet

  → requires ALICE acceptance, robust tracking, & PID to low/high p_T

  Investigate energy propagation in medium to determine medium properties

Start of Detailed "Tomography" of the QGP

$$F_{QGP}(\rho_g^{QGP}) = f_{initial}(\sqrt{s}, A_1+A_2, b, x_1, x_2, Q^2) \cdot f_{QGP}(p_T^{\gamma}, y^{\gamma}, \phi^{\gamma}, p_T^{jet}, y^{jet}, \phi^{jet}, \text{flavor}^{jet}, \phi^{flow})$$



Extensive di-hadron measurements from PHENIX (hep-ex/0605039) & STAR (nucl-ex/0510002):

Di-hadron fragmentation functions exhibit only a weak sensitivity to medium!

γ - jet and full jet (better jet energy) measurements necessary

Tagging Jets with Photons

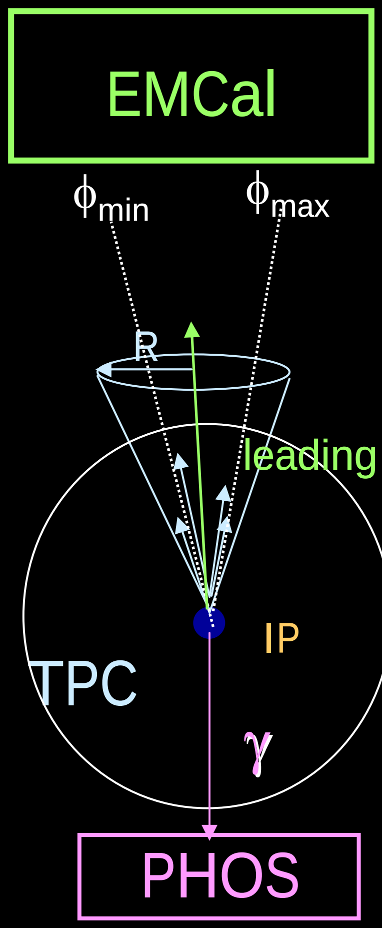
Strategy (event by event):

Search for identified prompt photon (in PHOS) with largest p_T ($E_\gamma > 20$ GeV)

Search for leading particle :

$\phi_\gamma - \phi_{leading} \sim 180°$

$E_{leading} > 0.1\ E_\gamma$



Reconstruct the jet :

Particles around leading with $p_T > 0.5$ GeV/c, inside a cone of R = 0.3.

2 configurations:

charged and neutral hadrons (TPC+EMCAL) and charged only (TPC).

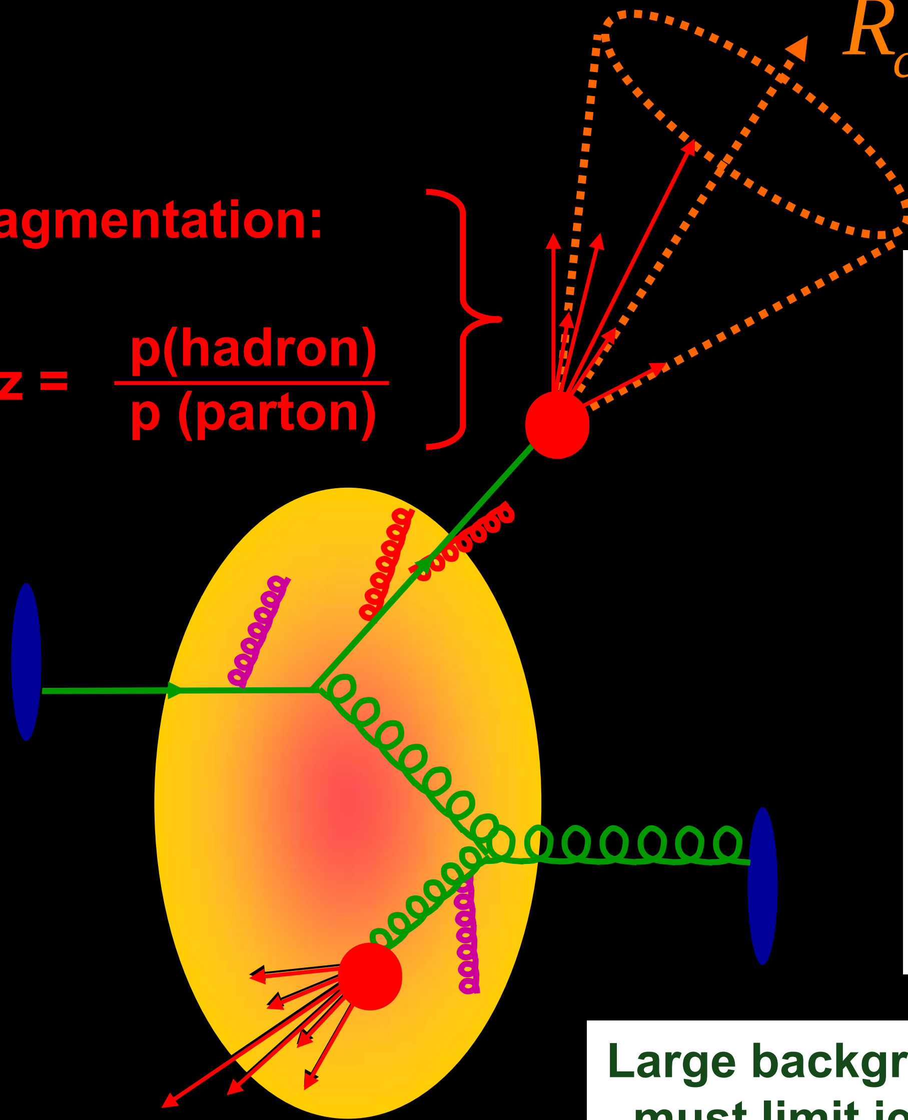
Thanks - Gustavo Conesa Balbastre – INFN Frascati

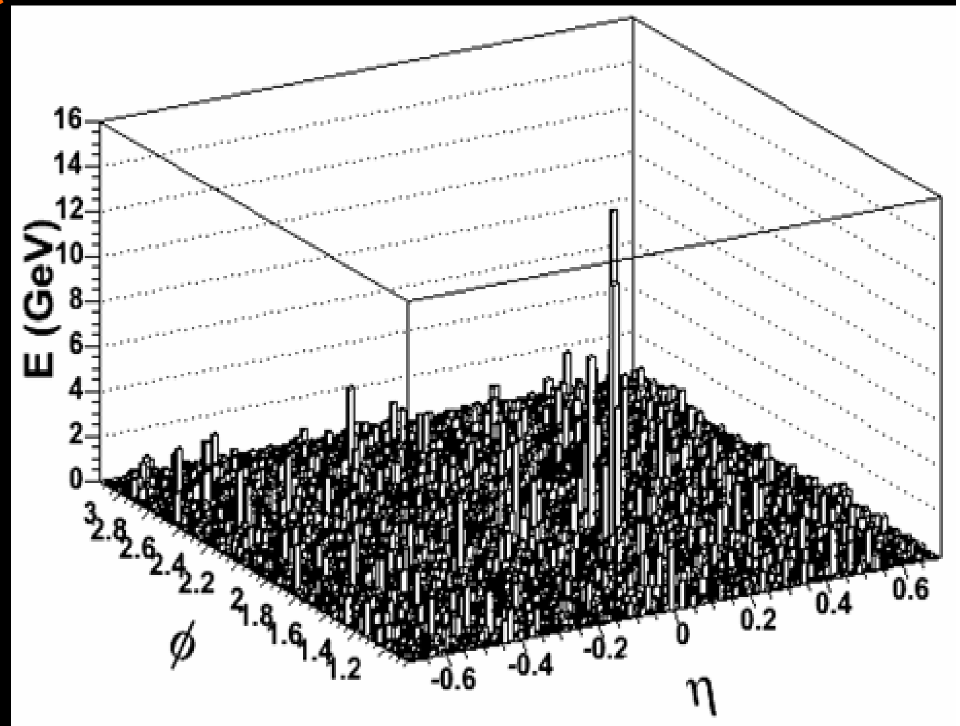
Jet Reconstruction

$R_{cone} = \sqrt{(\Delta\phi^2 + \Delta\eta^2)}$

Fragmentation:

$z = \frac{p(\text{hadron})}{p\ (\text{parton})}$



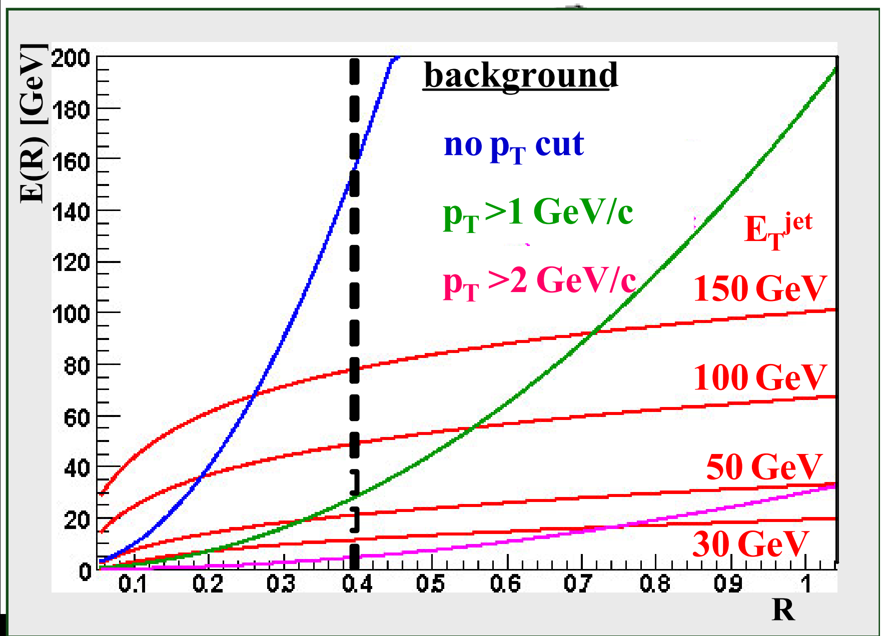


Large background in RHI Collisions –
must limit jet cone radius R, track p_T cut
⇒ only measure fraction of parton energy - calibrate

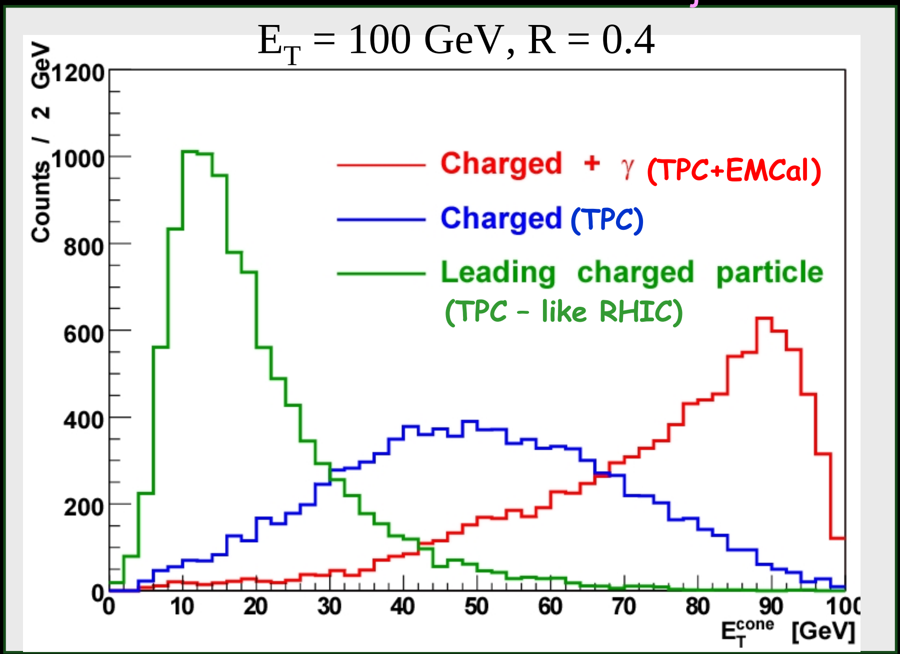
John Harris (Yale)

Soft Background in Jet Cones

Large cone radius
→ large background
Radius cut of .4
+ p_T cut
→ lowers background
→ > 80% of E_{jet}

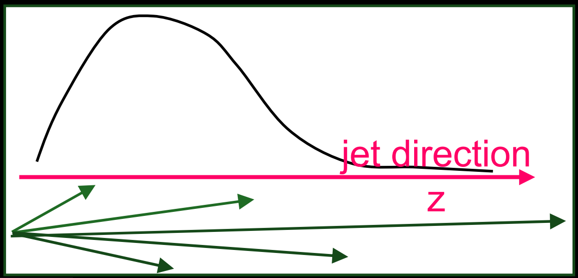


Cone radius $R=\sqrt{(\Delta\eta^2+\Delta\Phi^2)}$

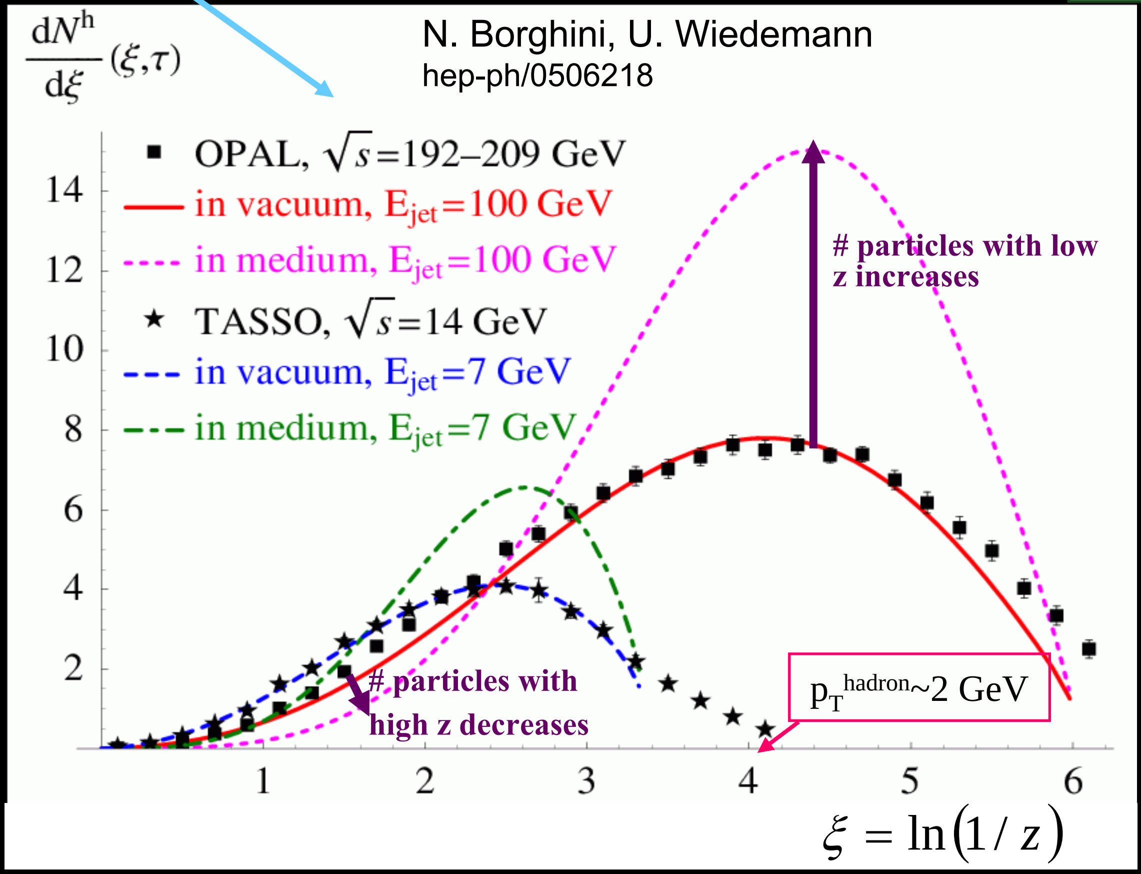


Medium Modification of Jet Fragmentation

Fragmentation along jet axis: $z = p_{hadron} / p_{parton}$



Introduce $\xi = \ln(E_{jet} / p_{hadron}) \sim \ln(1/z)$:

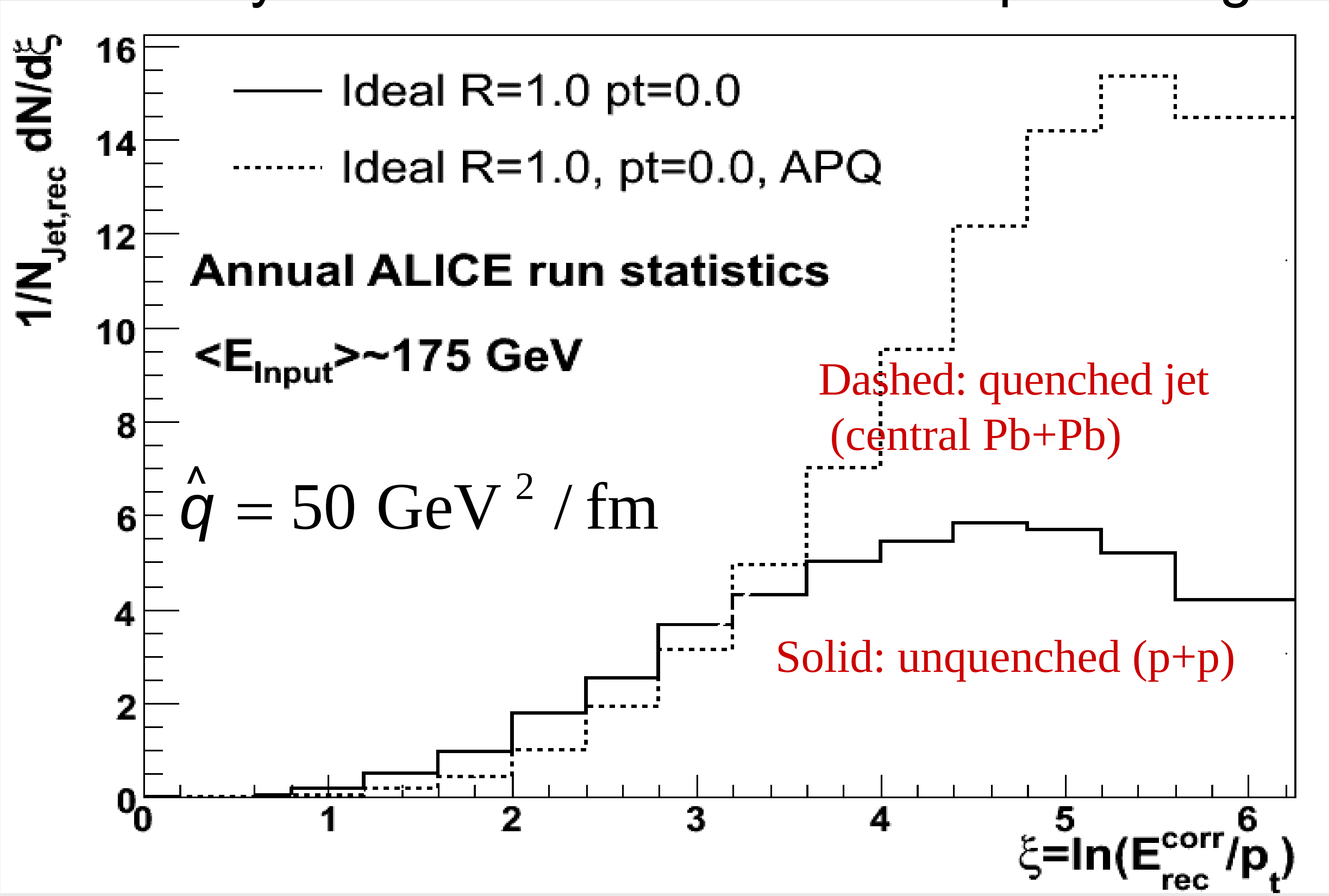


$\hat{q}_{LHC} \sim 7 \times \hat{q}_{RHIC} \sim 50\ \mathrm{GeV}^2/\mathrm{fm}$

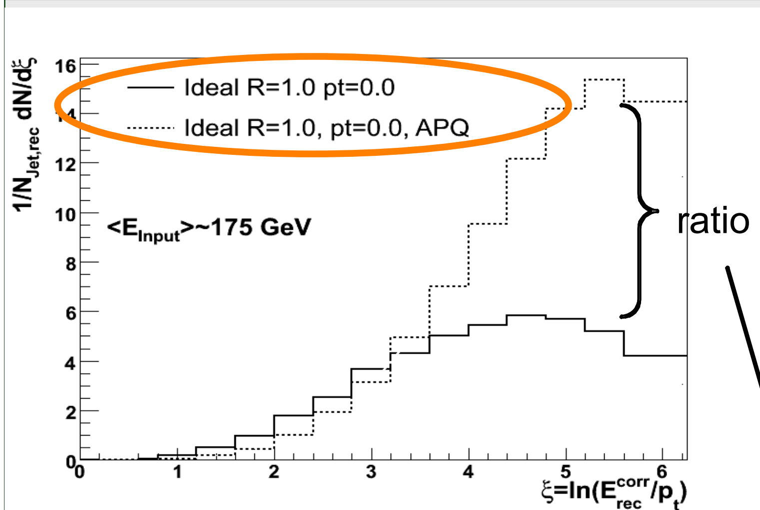
Thanks – Joern Putschke

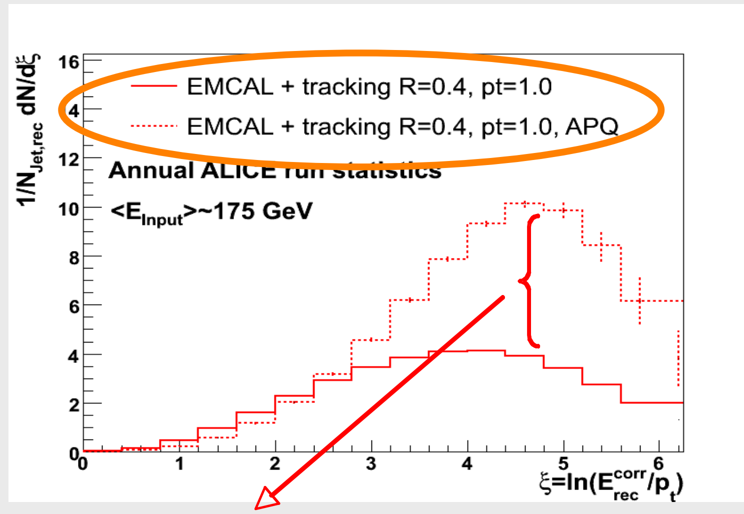
Ideal Case for Pb + Pb and p + p

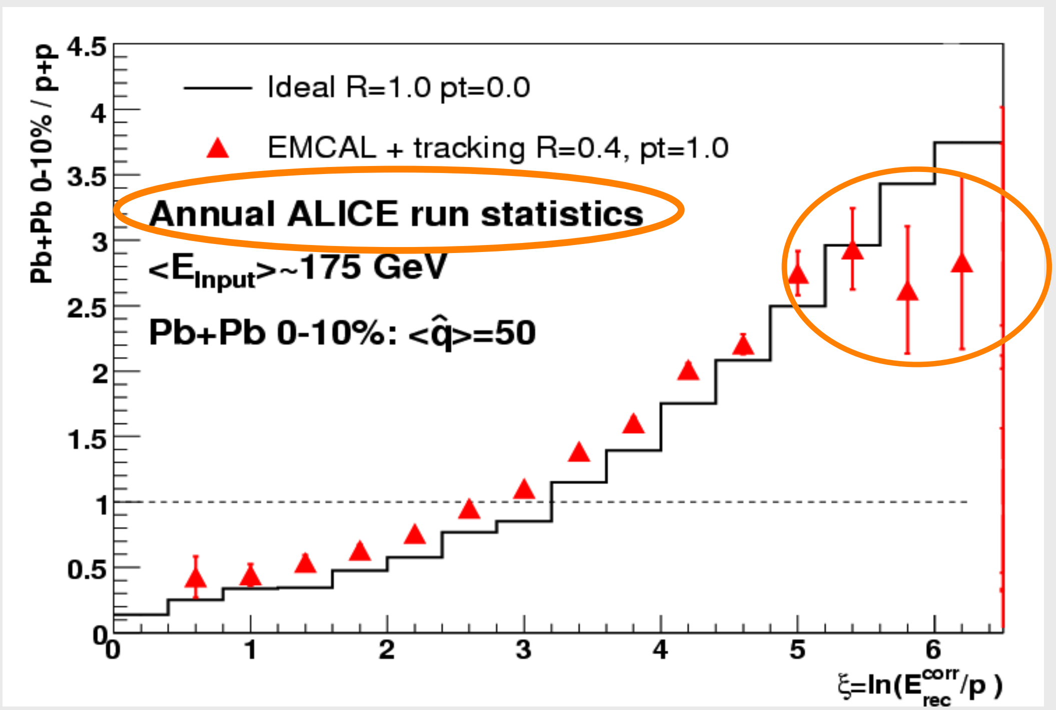
Pythia-based simulation with quenching

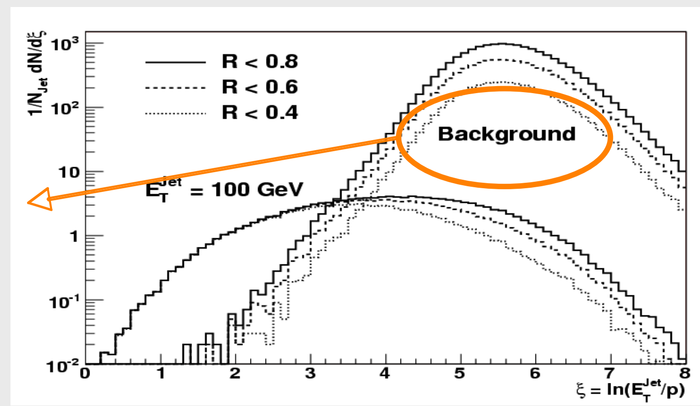


Jet Quenching in ALICE with EMCAL in 1 Year









Jet Yields per LHC Year & Jet Trigger Enhancements

Jet yield in 20 GeV bin

System	jet trigger?	N_{jets} (125 GeV)	N_{jets} (175 GeV)
Pb+Pb cent	y	1.1×10^4	1700
	n	2100	320
Pb+Pb periph	y	410	62
	n	8	1
p+Pb 8.8 TeV	y	2.7×10^4	4200
	n	250	40
p+p 14 TeV	y	6.9×10^5	1.0×10^5
	n	1200	190

Large gains due to jet trigger

Large variation in statistical reach for different reference systems

Jet Trigger Enhancements vs Reference System

Compare central Pb+Pb to reference measurements:

- **Pb + Pb peripheral: vary system size and shape**
- **p + A: cold nuclear matter effects**
- **p + p: no nuclear effects**

Systematic study involves all reference systems

Jet trigger

(includes acceptance, efficiency, dead time, energy resolution)

System	$\sqrt{s_{NN}}$ (TeV)	L_{mean} ($cm^{-2}s^{-1}$)	Time (s)	DAQ rate (Hz)	EMCal Trigger gain
p+p	5.5	$5 \cdot 10^{30}$	10^6	500	110
p+p	14	$5 \cdot 10^{30}$	10^7	100	550
p+Pb	8.8	$1 \cdot 10^{29}$	10^6	500	110
Pb+Pb					
cent 10%	5.5	$5 \cdot 10^{26}$	10^6	20	5.3
periph 60-80%	5.5	$5 \cdot 10^{26}$	10^6	20	53

Also e,γ cluster trigger enhancement
factors 10 – 100
for Pb-Pb to p-p

L1 jet "patch" trigger
$\Delta\eta \times \Delta\phi = 0.4 \times 0.4$

Summary and Concluding Remarks

ALICE - versatile, general purpose heavy ion detector at LHC

- will contribute significantly to understanding of HI physics
  - soft physics
  - high p_T physics

ALICE EMCal provides significant high p_T and jet physics to LHC

- measures and triggers on jets, photons, pi-zeros
- heavy quark jet tags
- triggered jets $\rightarrow$ response of medium in lower p_T sector

Work continues to

- develop best jet algorithm for heavy ions
  - deal with background, jet-splitting & jet-merging
- develop heavy flavor (quark) tag algorithms

Need detailed theoretical/simulation approach at parton level

Special thanks for contributors:

Joern Putschke

Gustavo Conesa Balbastre

Marco van Leeuwen

Peter Jacobs

Andreas Morsche