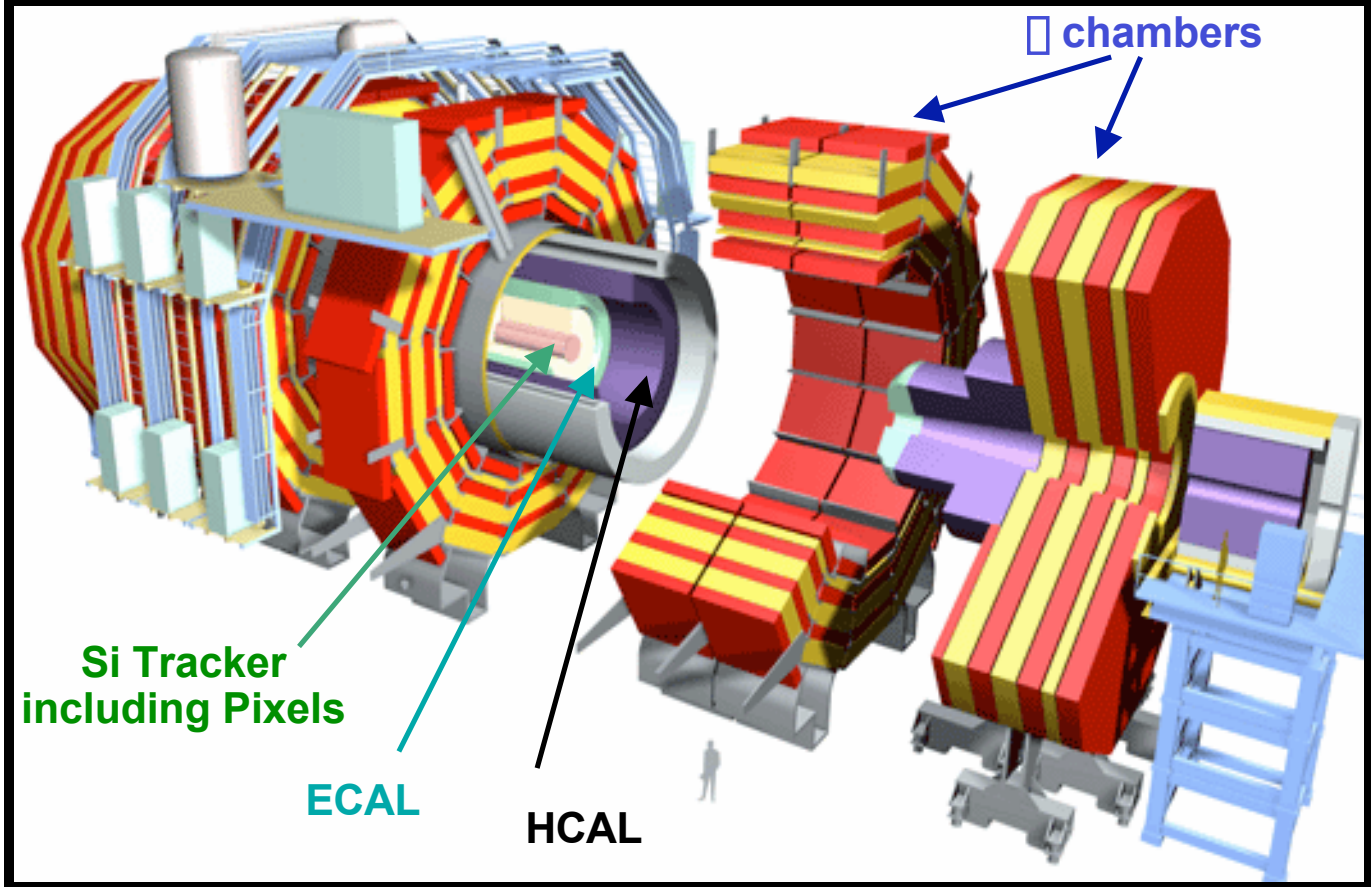
Scanning the phases of QCD with CMS

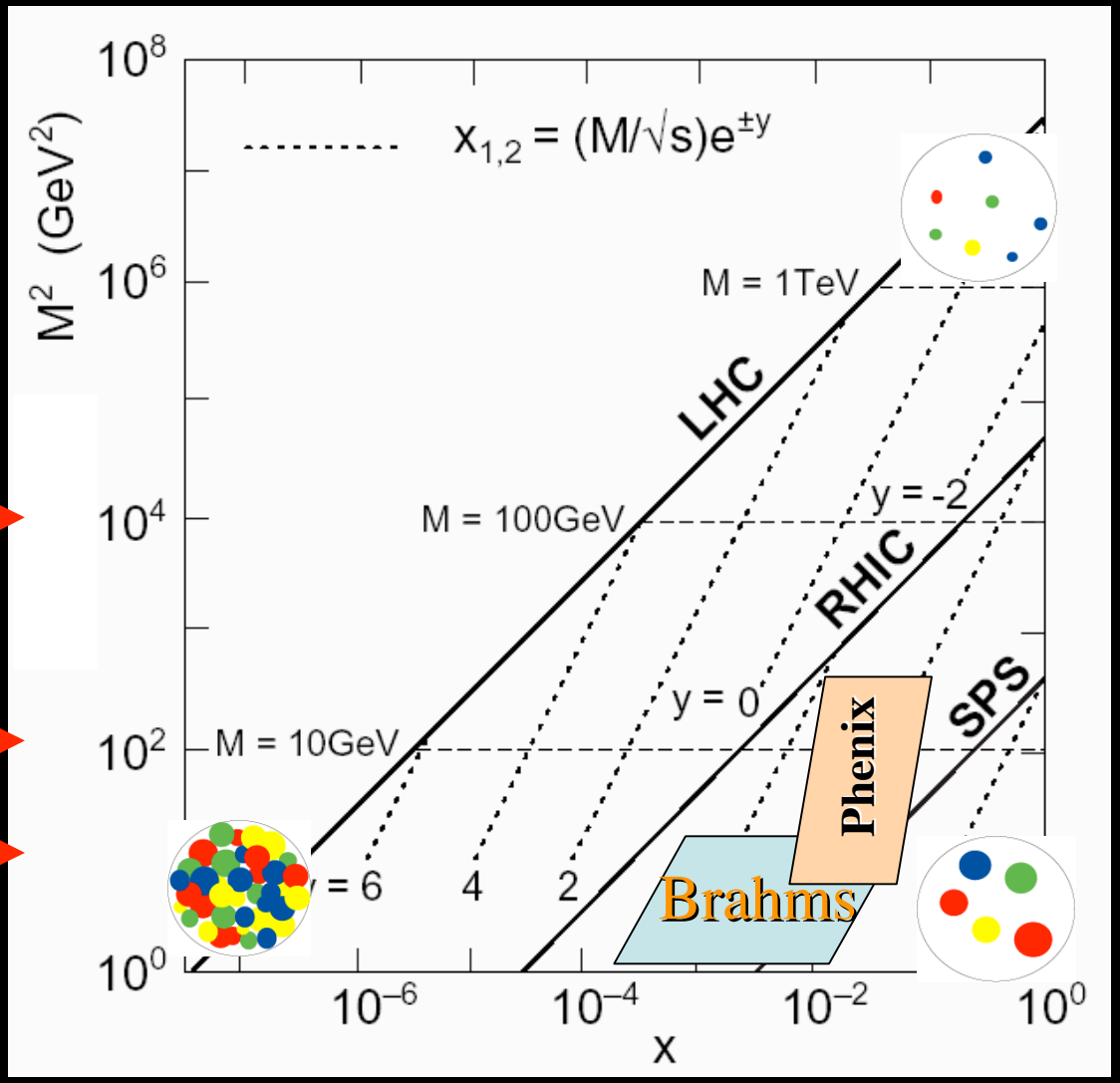


Michael Murray
University of Kansas
For the CMS Collaboration

CMS Heavy Ion Groups

Athens,Basel, Budapest, CERN, Demokritos, Dubna, Ioannina, Kiev, Kent State, Krakow, Los Alamos, Lyon, MIT, Moscow, Mumbai, N. Zealand, Protvino, PSI, Rice, Sofia, Strasbourg, U Kansas, Tbilisi, UC Davis, UI Chicago, U. Iowa, Yerevan, Warsaw, Zagreb

CMS will measure low X and high p_T



Z⁰

J/ψ

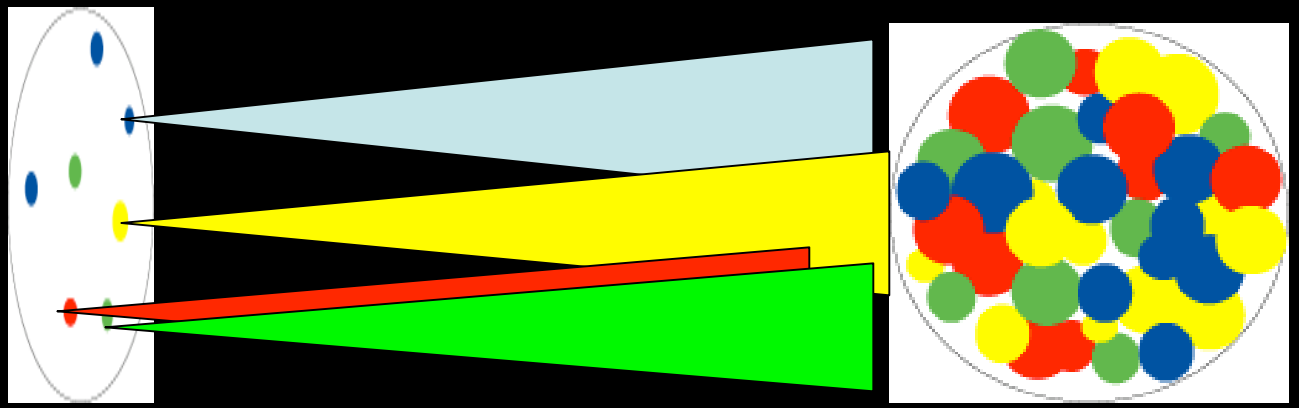
Rate & trigger

To study such a huge kinematic range we need a wide range of probes. CMS can study jets, quarkonia photons and Z

Rapidity Coverage

Low and high X physics

It is possible that low momentum gluons in large nuclei form a classical colored field. However the sources of this field are the high momentum valence quarks. Therefore it is essential to study the correlations between low and high X.

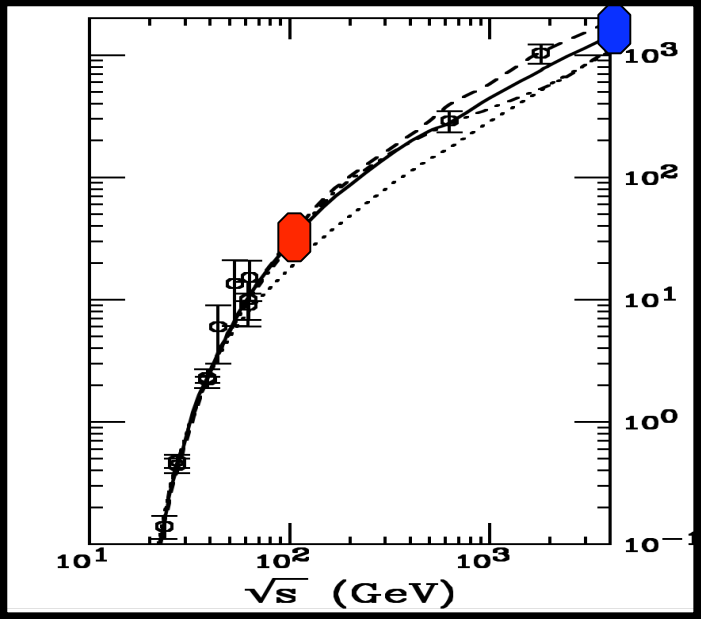


High X

Low X

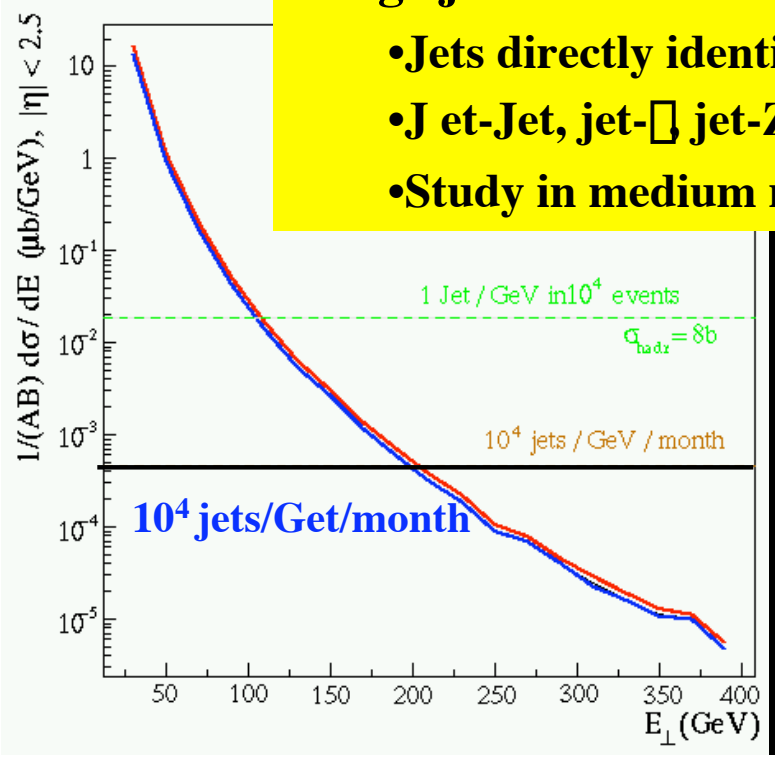
Abundant hard probes at LHC

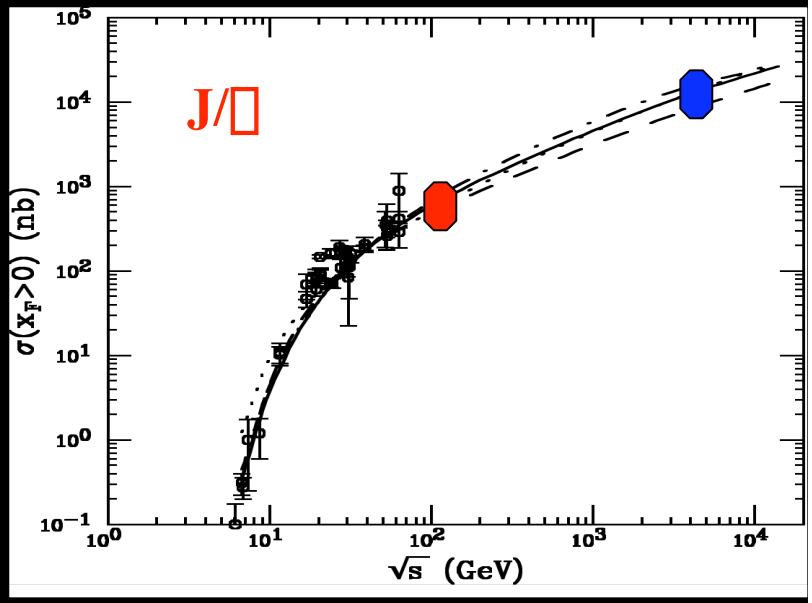
Large cross section for J/□ and .
Study the different melting of the 3 states to measure the temperature of the early system.



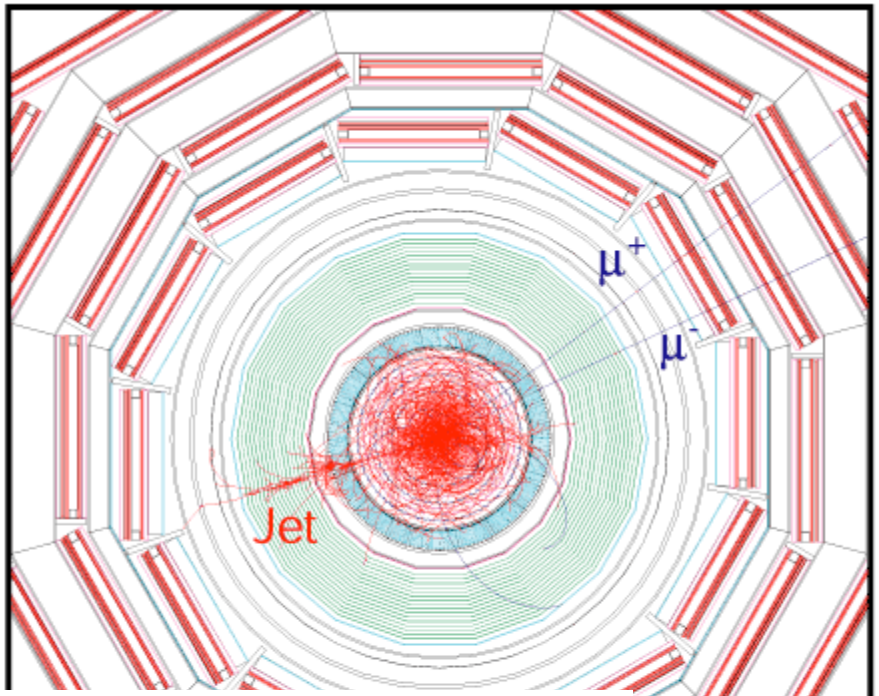
Large jet cross section

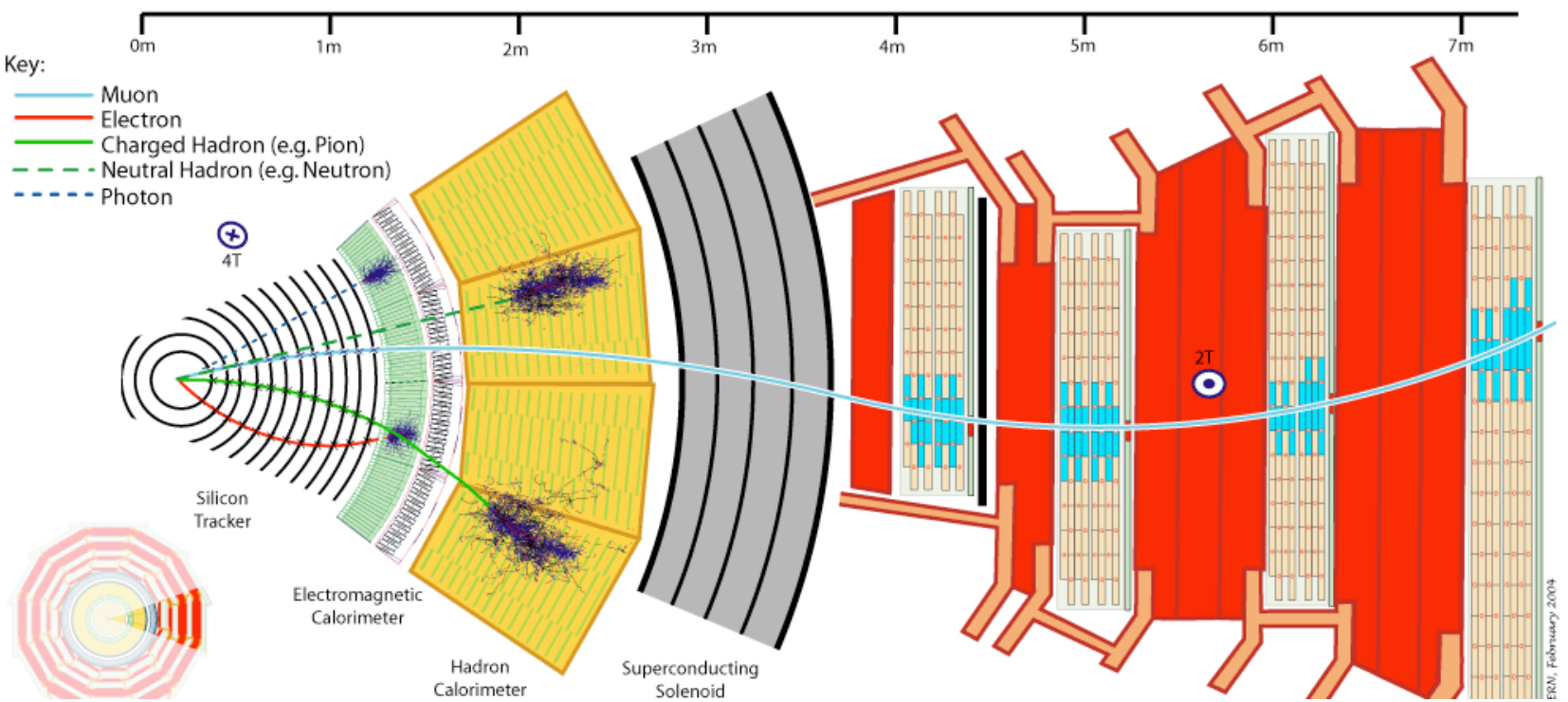
- **Jets directly identifiable**
- **J et-Jet, jet-□, jet-Z_0 correlations**
- **Study in medium modifications**



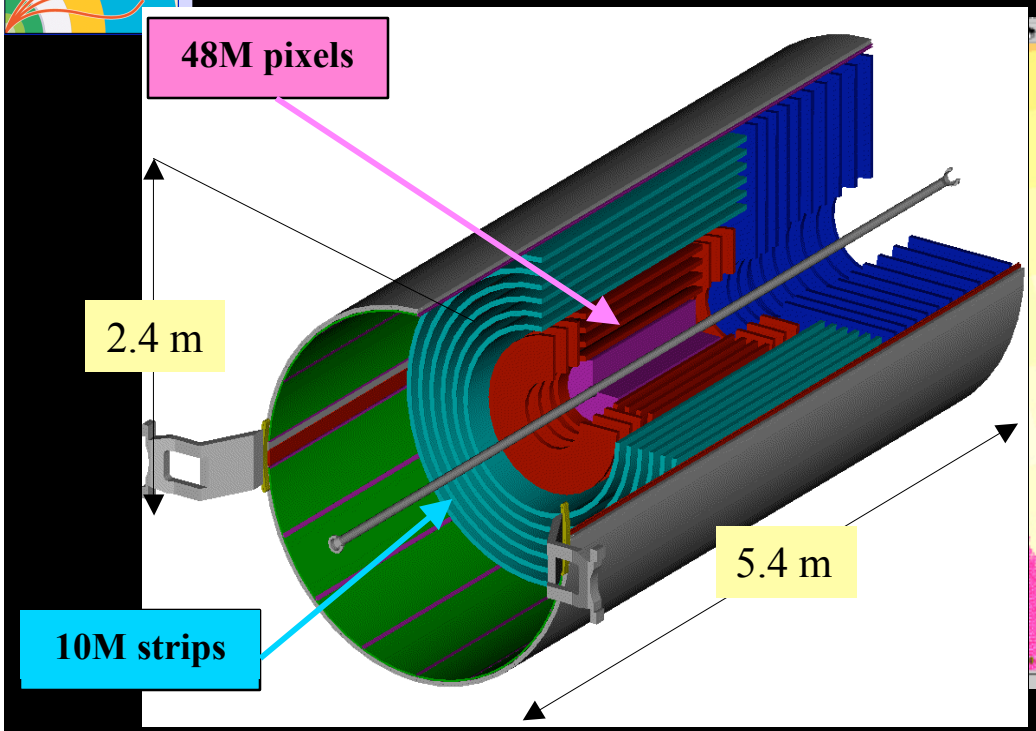


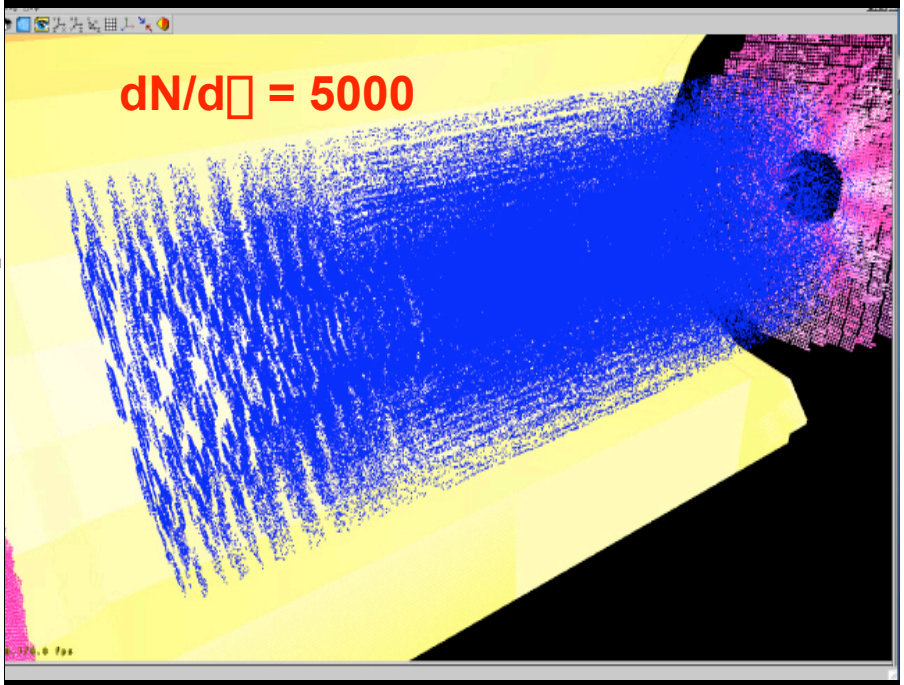
Measure electrons, muons, photons, Z, charged & neutral hadrons





Tracker Covers |□|<2.4



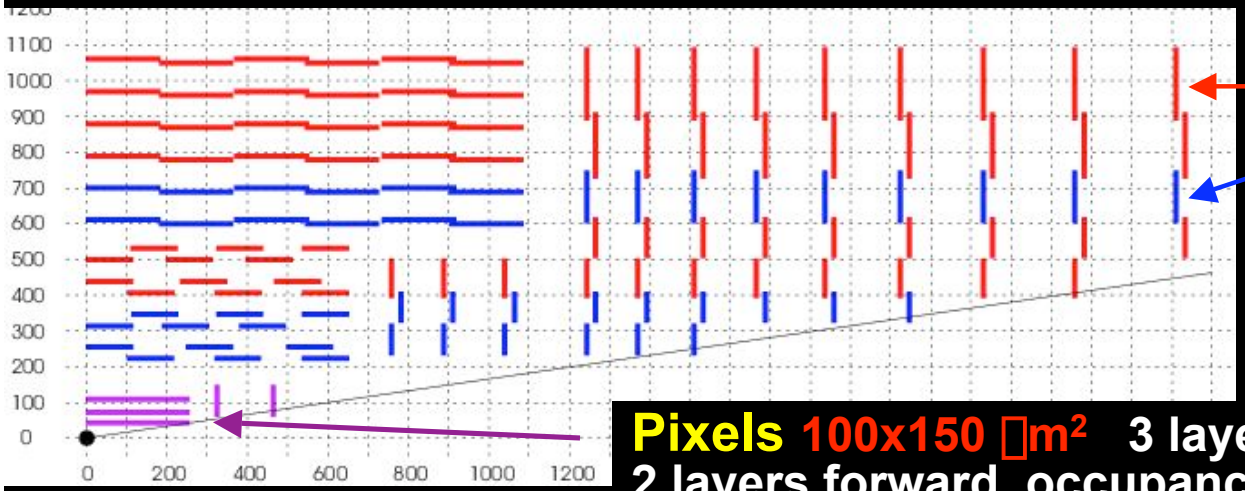


Strips 10 layers in barrel

9 layers forward

single and double-sided

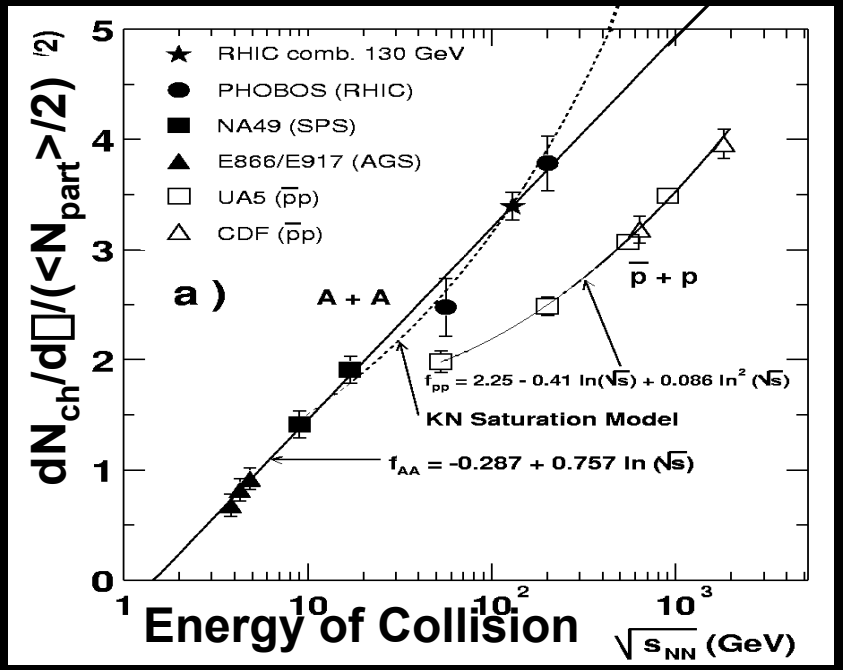
Analog readout useful for HI



Pixels 100x150 □m² 3 layers in barrel,
2 layers forward, occupancy: 2%

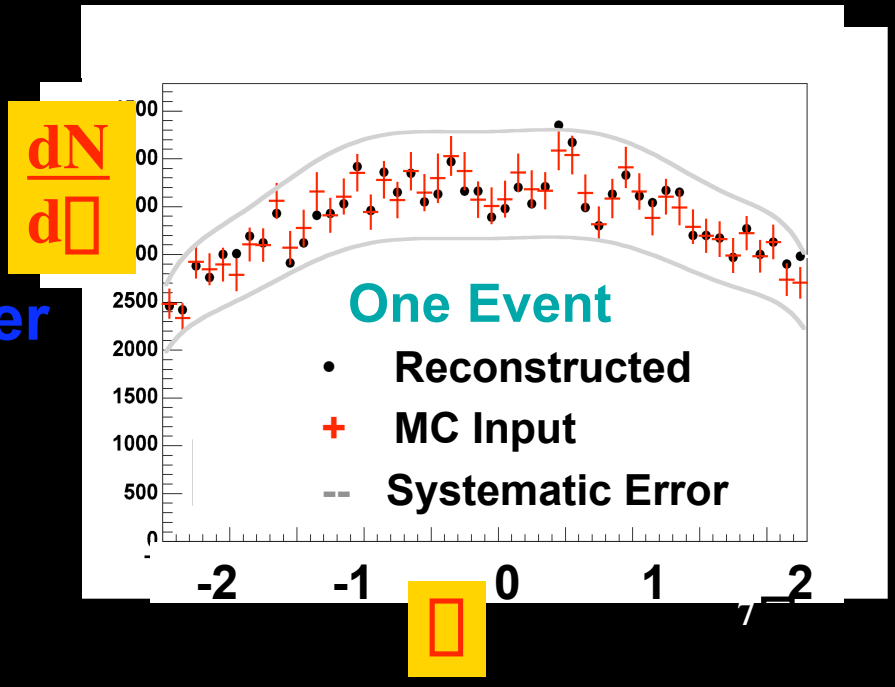
Bulk Properties

?



Charged Particle Multiplicities

- Predictions vary by a factor of 4!
- dN/dy ~ 1200 – 7000
- (RHIC extrapolation vs. HIJING)



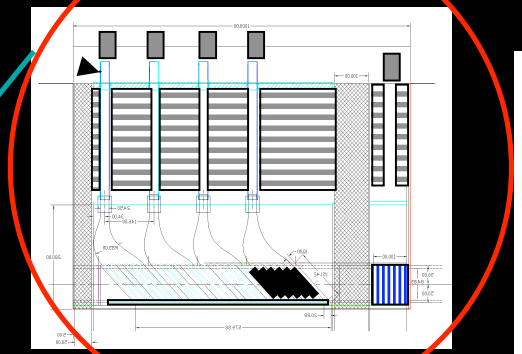
Hit counting in the first pixel layer

- Needs few events O(1000)
- Few seconds of data taking

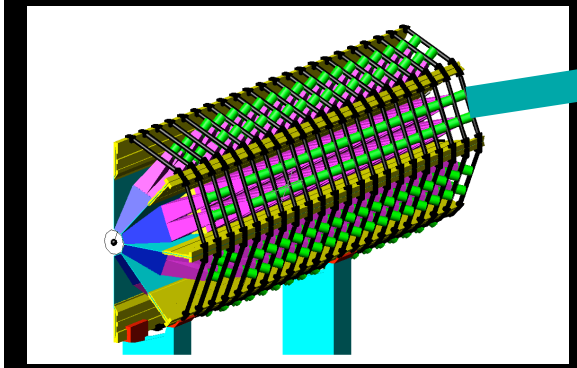
Forward detectors for pp, pA & AA

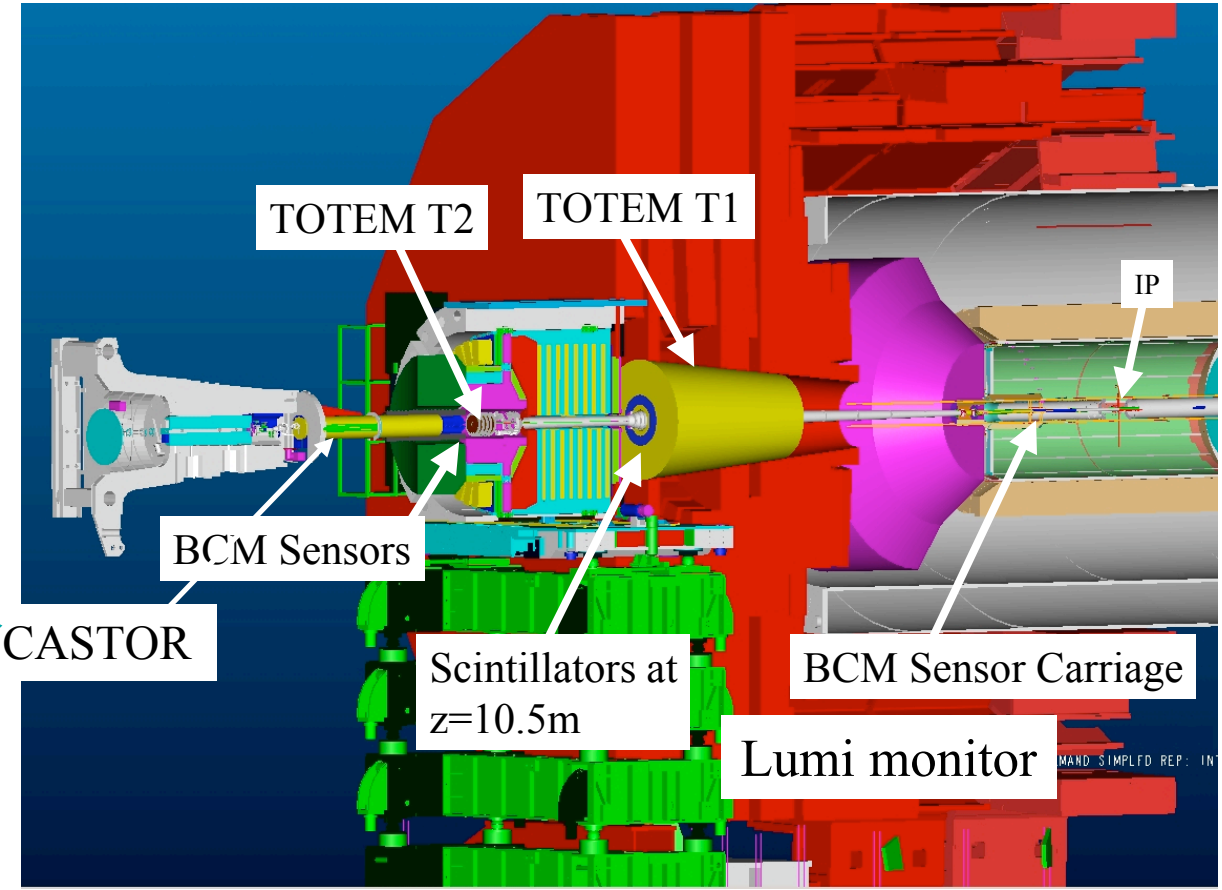
Hermetic calorimetry up to |□|<7 plus zero degree neutral energy. T1 and T2 are multiplicity detectors

Physics: Centrality, Low-x, Limiting fragmentation, strangelets, DCC



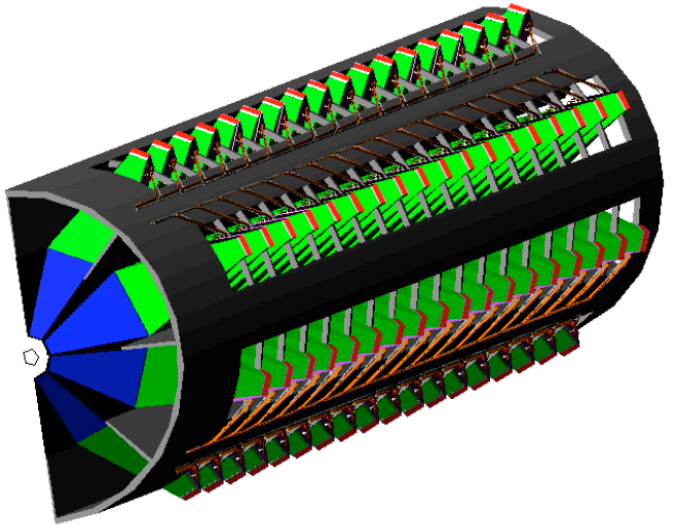
ZDC @ 140 m

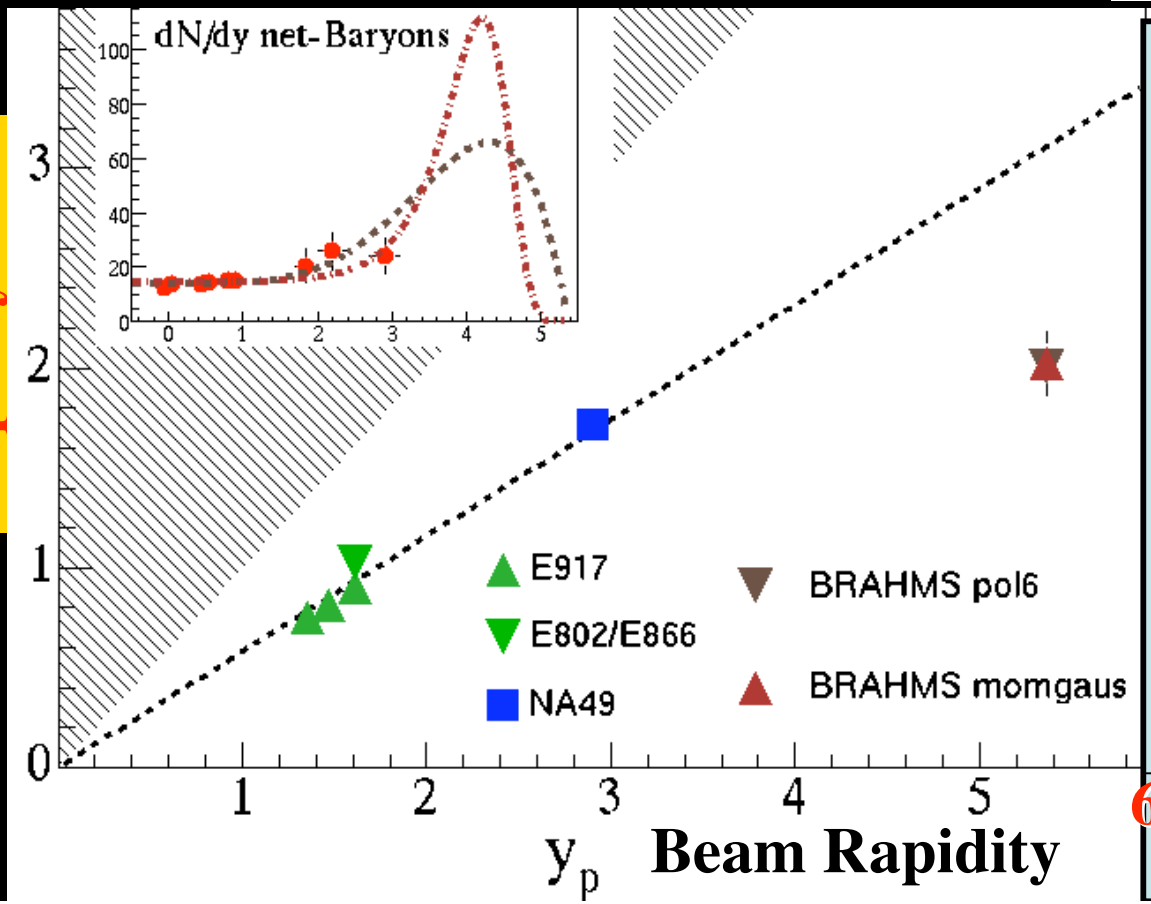




How much energy is available for particle production?

CASTOR covers 5.3< □<6.9

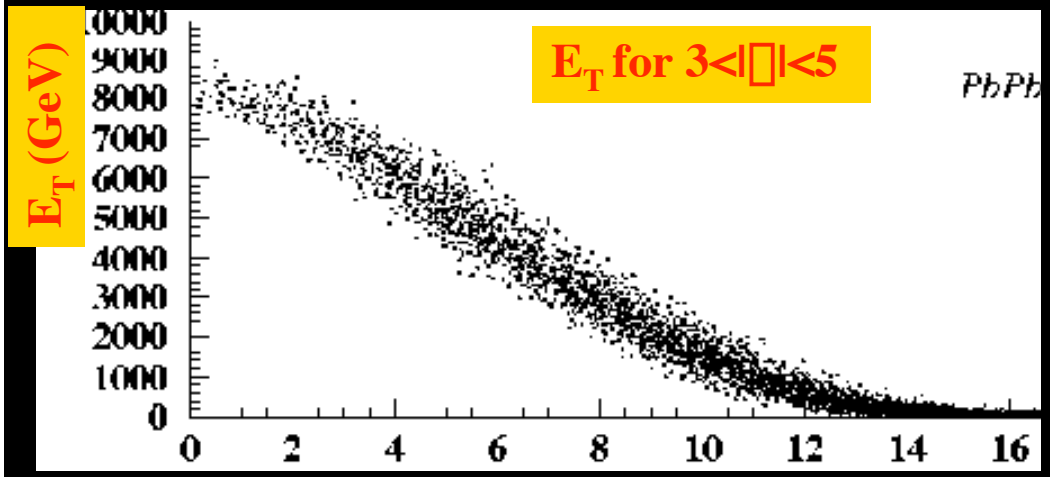


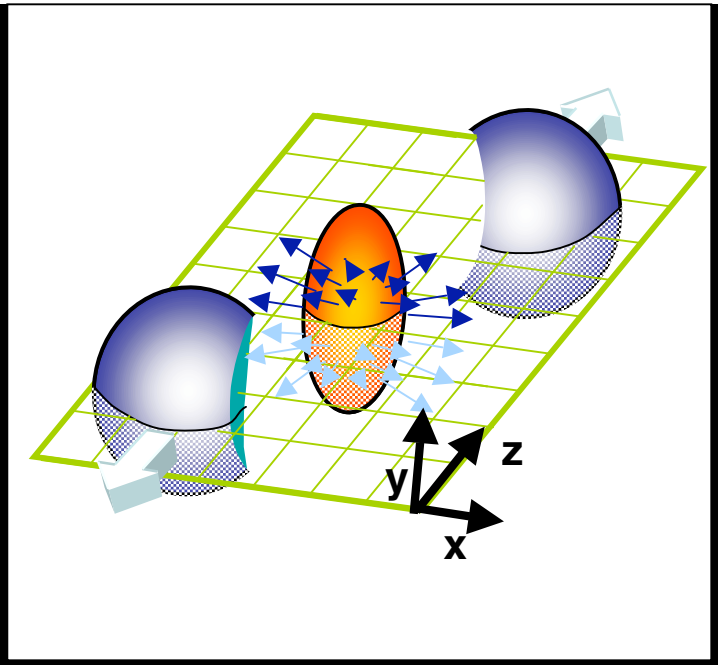


Estimate rapidity loss of incoming nucleons from dE/dy measurements.

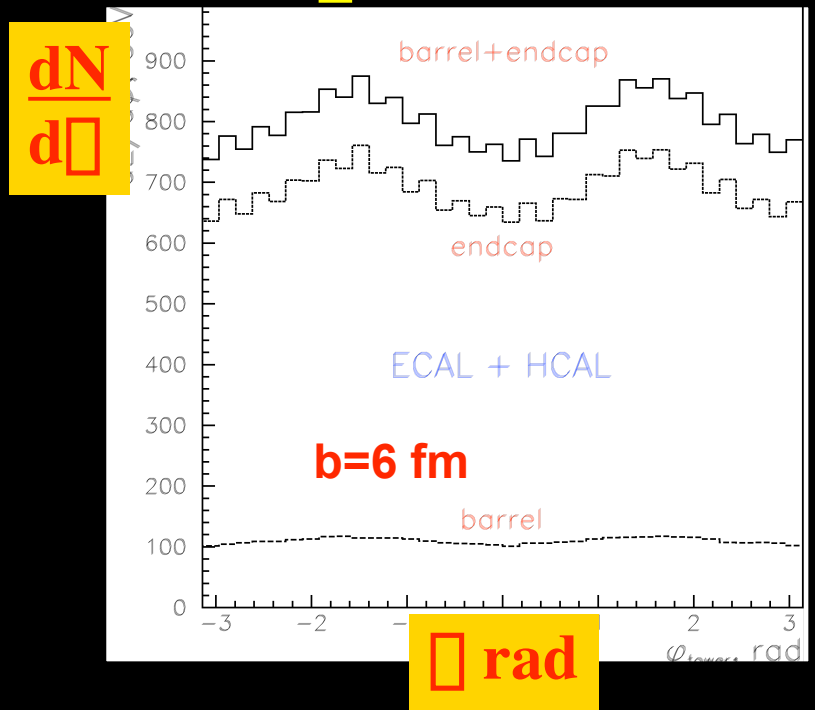
6 7 8 9

Forward detectors give reaction geometry





□ = 0.1 radians

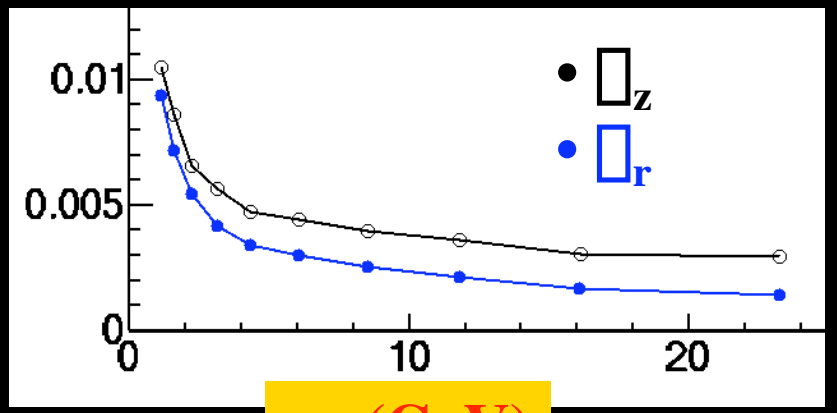


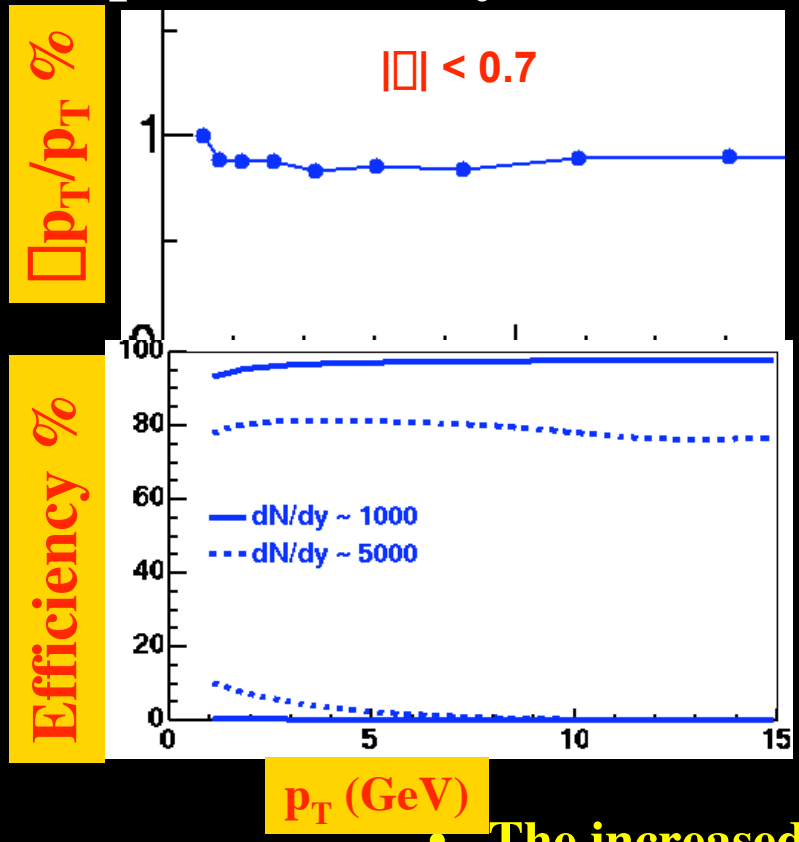
Large □ range helps us avoid auto-correlations with other measurements.

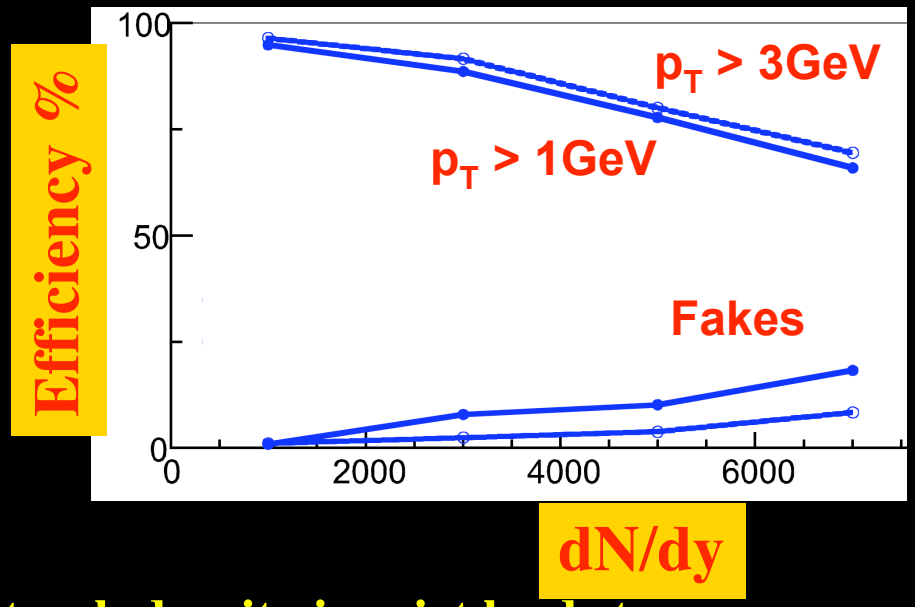
Tracking within a heavy ion event

Match reconstructed tracks to MC input on a hit by hit basis

Impact parameter resolution



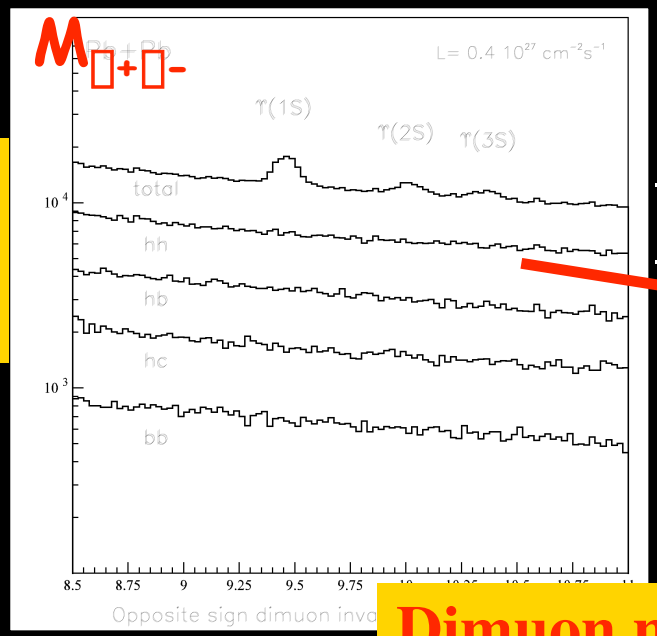




- The increased track density in a jet leads to a local decrease in efficiency of ~ 5-10%.
- This an be corrected for since jets will be reconstructed by the calorimetry

Quarkonia in CMS

Family region

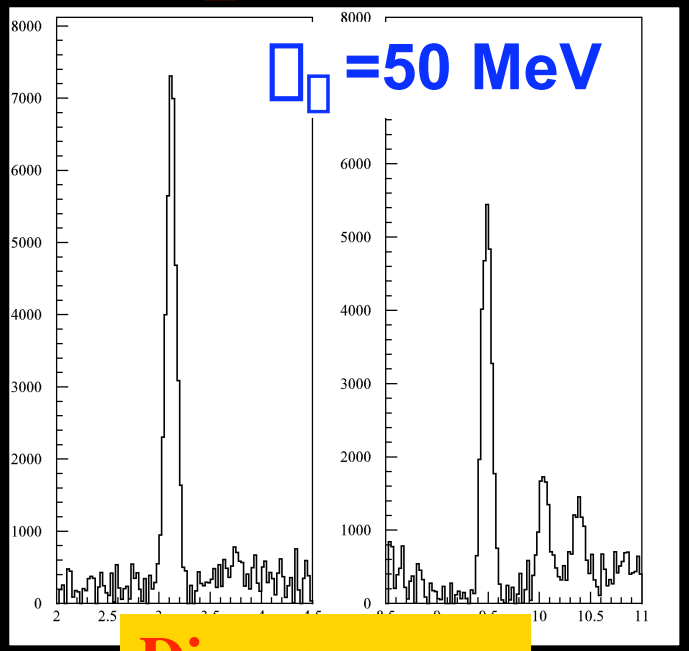


-□- □-

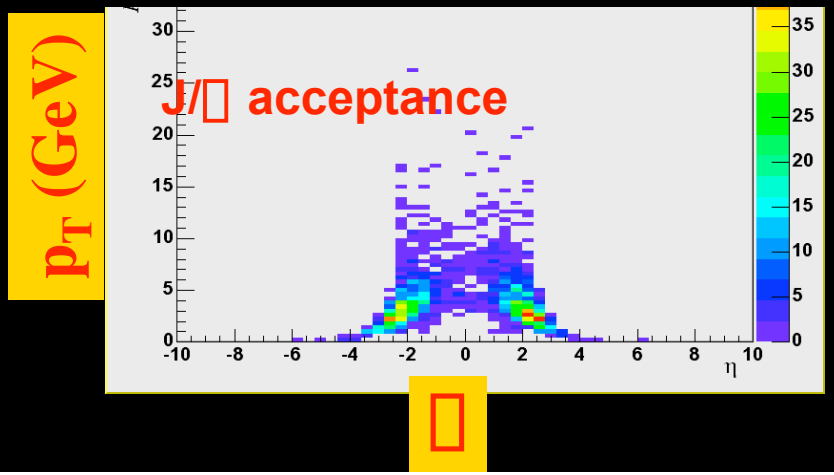
-□+ □+

Dimuon mass

J/□ family



Dimuon mass



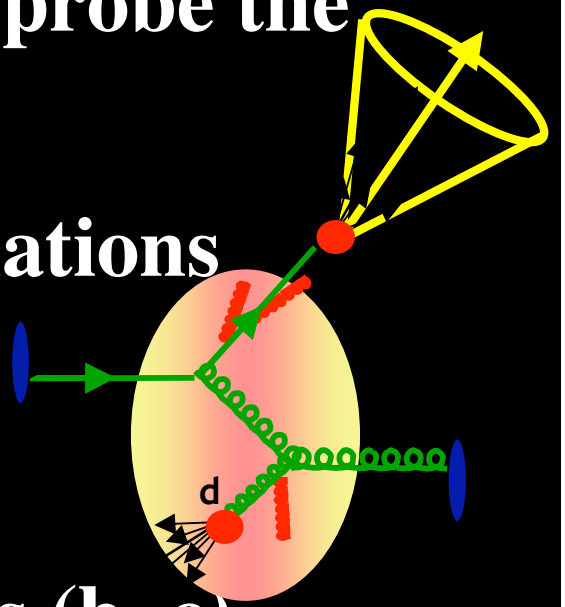
Expect ~24k J/□ and
~ 18/5/3 k , ', "
for one month with
L=10²⁷cm⁻²s⁻¹ and 50%
efficiency

Coverage in central rapidity region

Jets in Heavy Ion Collisions

Hard partons and their energy loss probe the medium.

- **High p_T particles & particle correlations**
- **Jet rates: single jets, multi-jets**
- **Jet fragmentation and shape**
- **Jets originating from heavy quarks (b, c)**

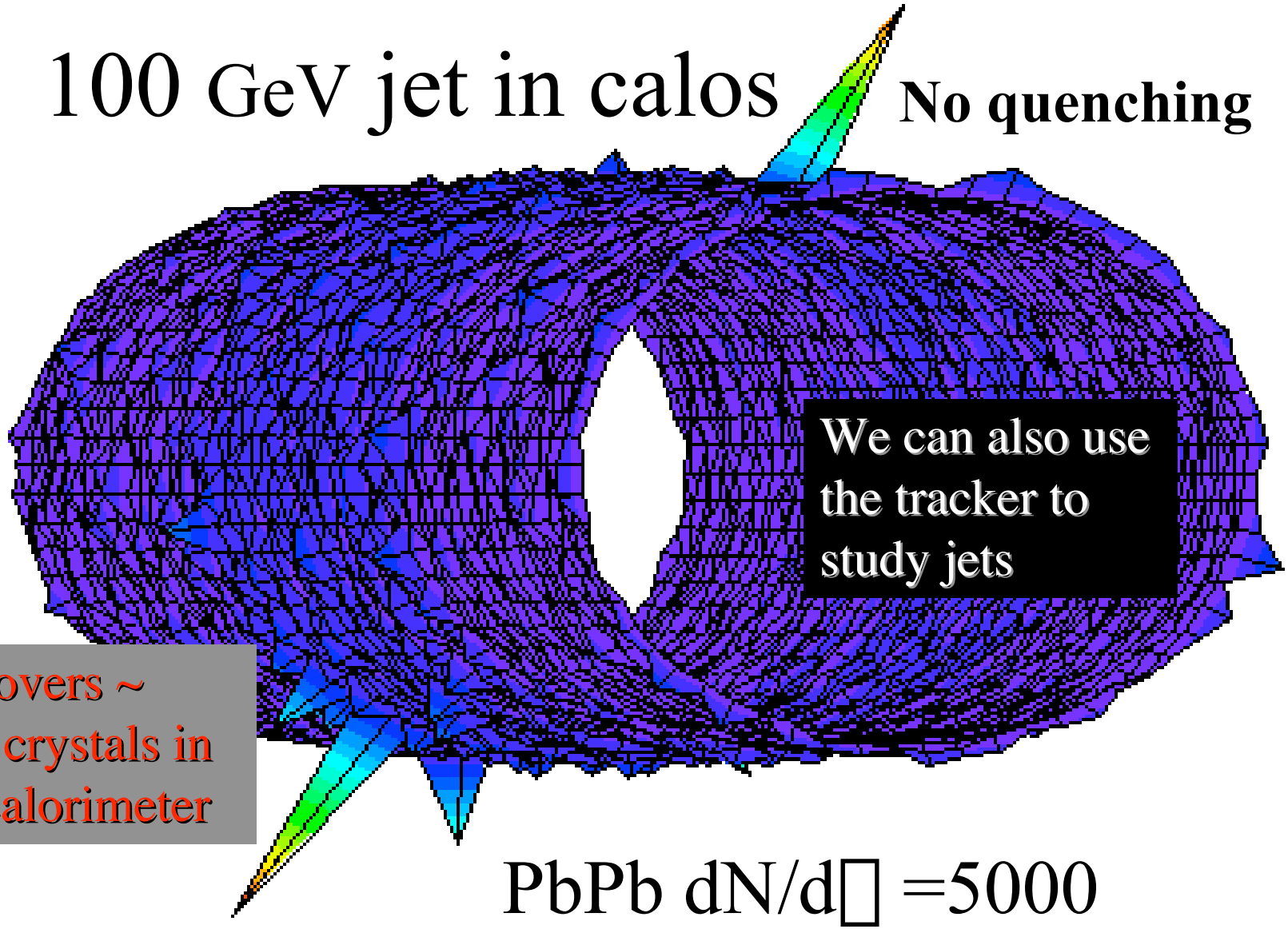


Comparison to pp and pA is essential

Jets for |□|<5

100 GeV jet in calos

No quenching

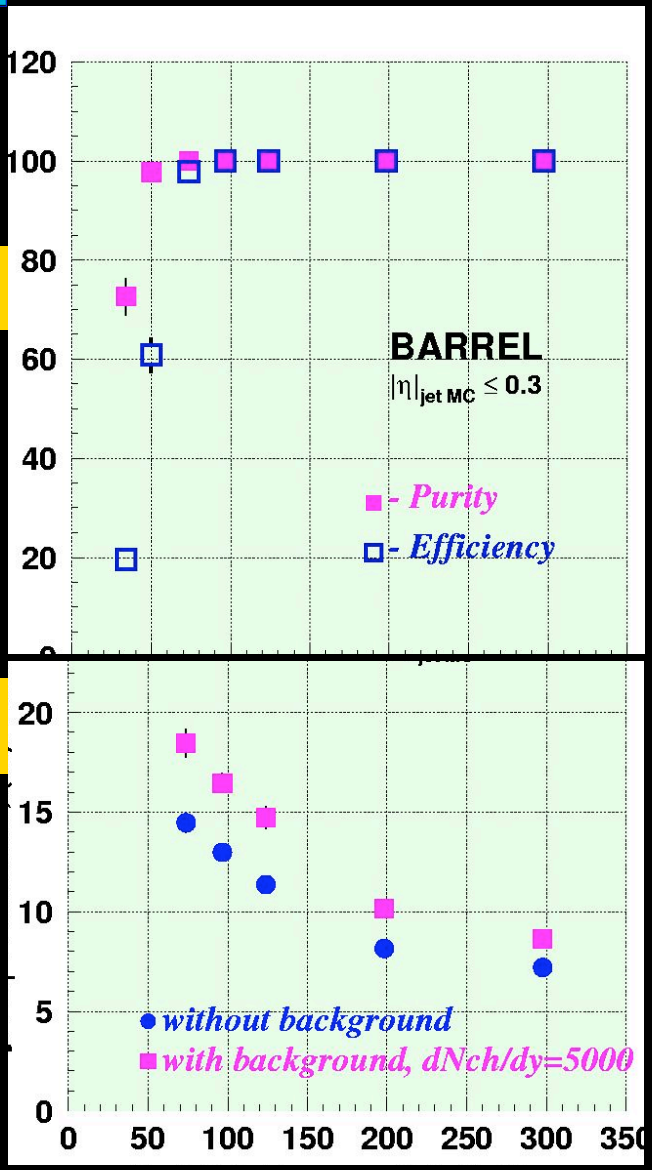


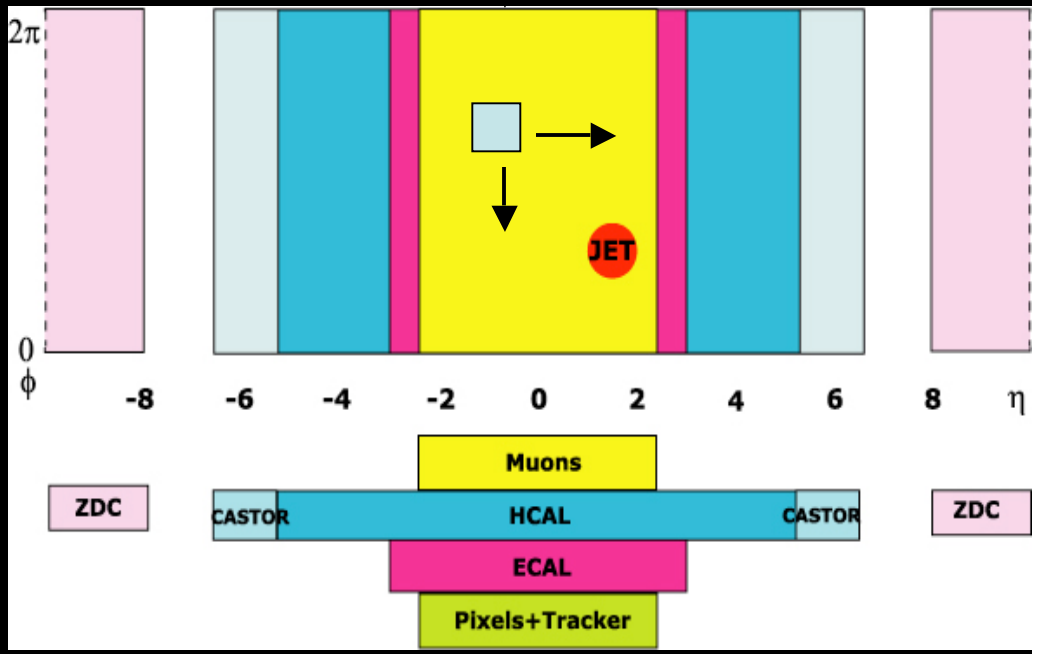
We can also use the tracker to study jets

Jet Covers ~ 4000 crystals in EM calorimeter

PbPb dN/d□ =5000

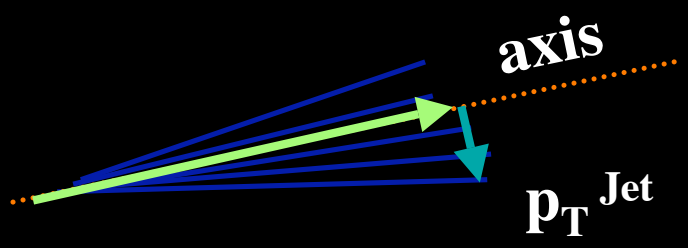
Jet reconstruction



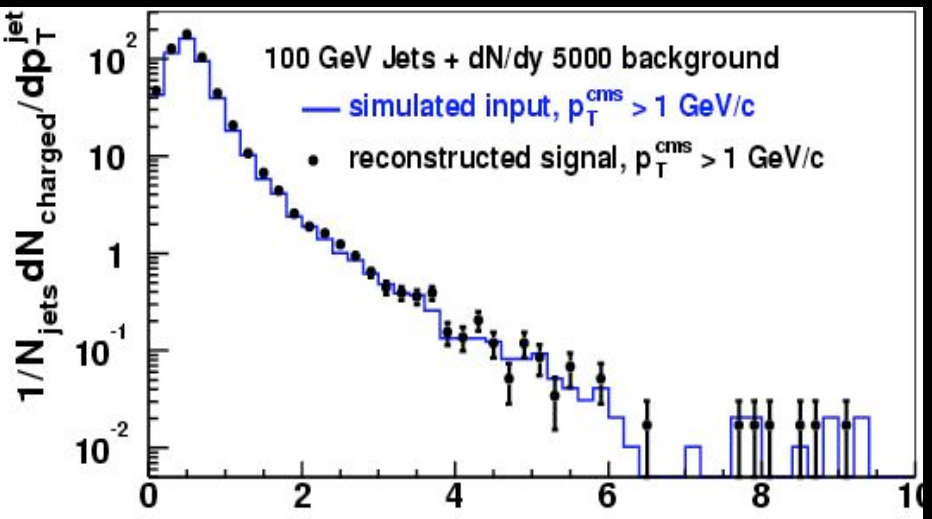


1. Subtract average pileup
2. Find jets with sliding window
3. Build a cone around maximum E_T
4. Recalculate pileup outside cone
5. Recalculate jet energy

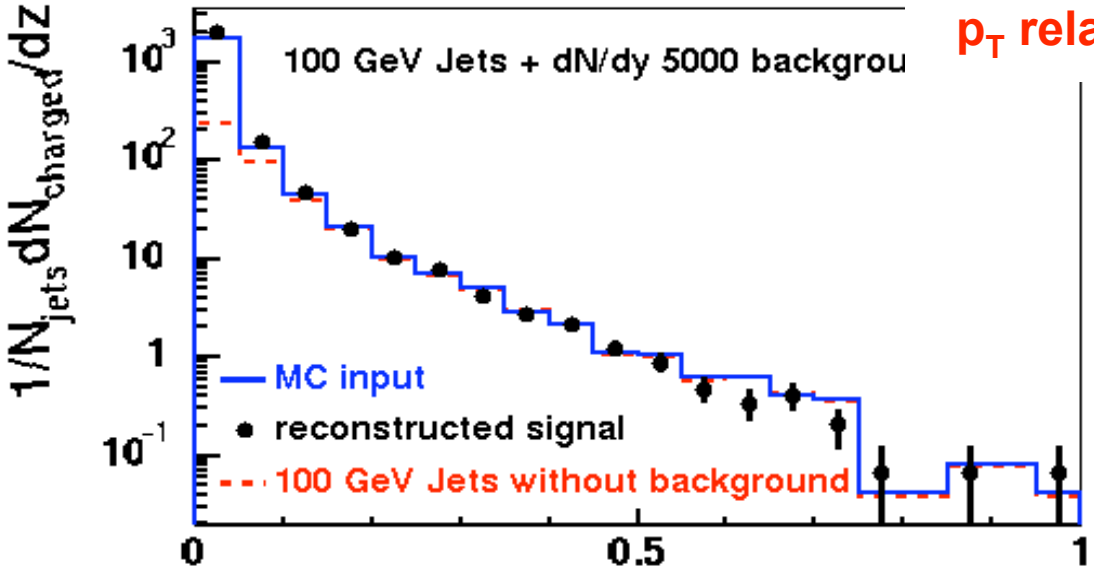
Fragmentation of 100GeV jets



dN/dy ~5000



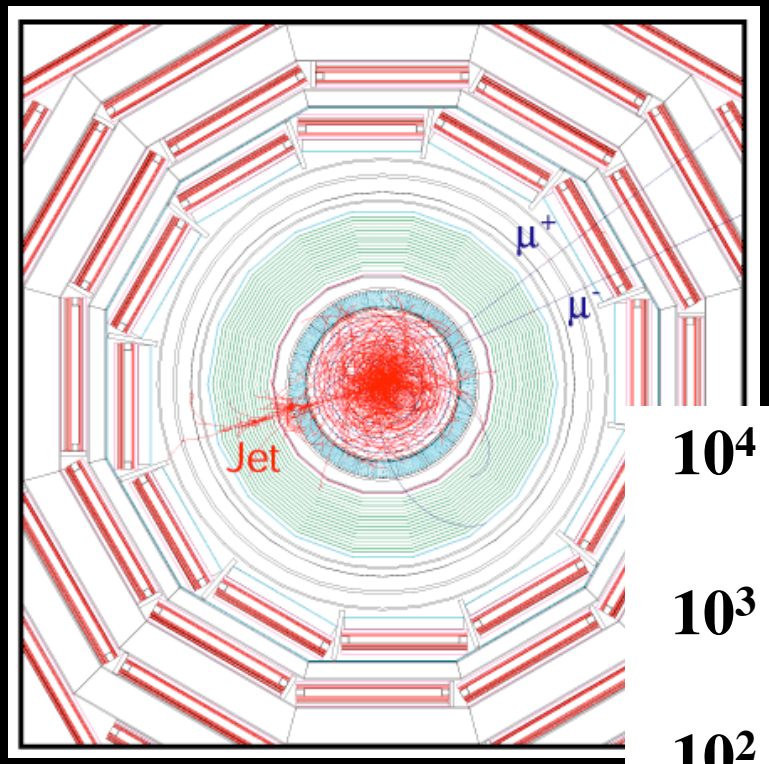
p_T relative to thrust axis:



Momentum fraction z along thrust axis $z = p_{||}/|p_{jet}|$

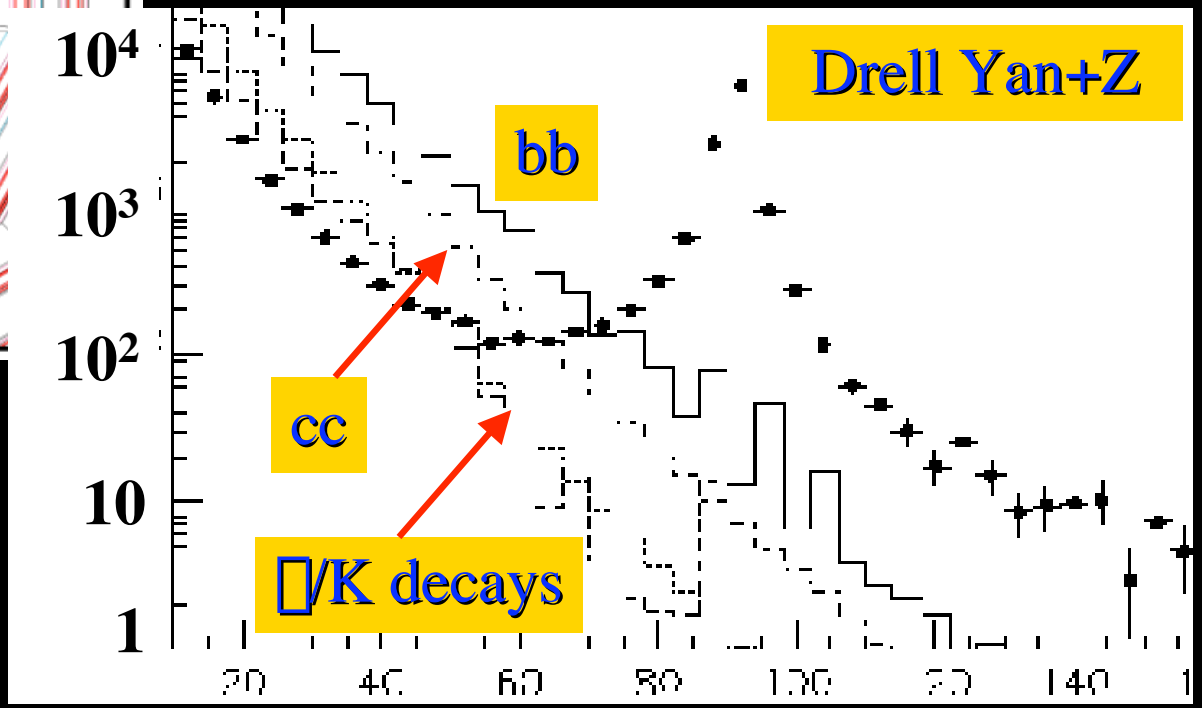
Precision tracking out to high momenta will give detailed information on modification of the jet by the medium

Reconstructing Zs opposite Jets



Study jets with calibrated energy

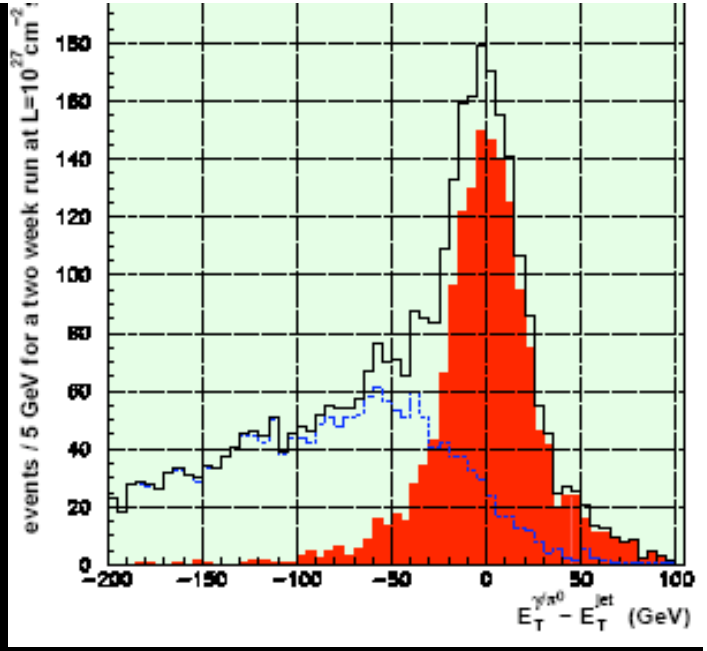
E_{Tjet}, □> 120GeV in Barrel

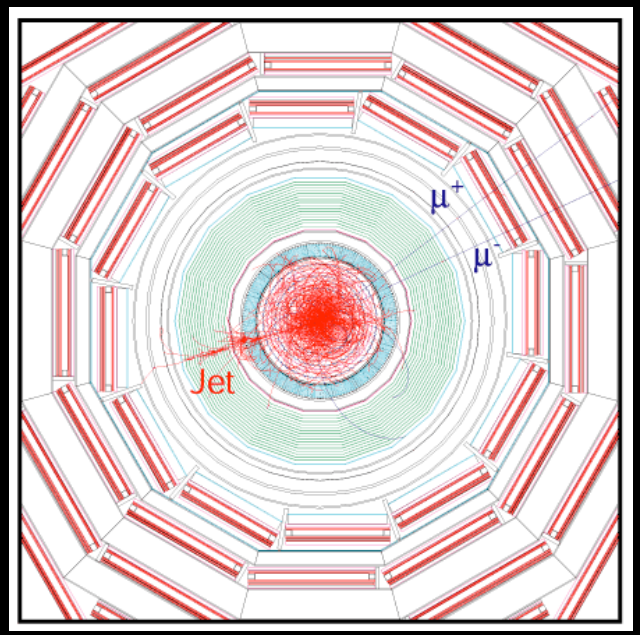


Balancing jets with □ or Z_0

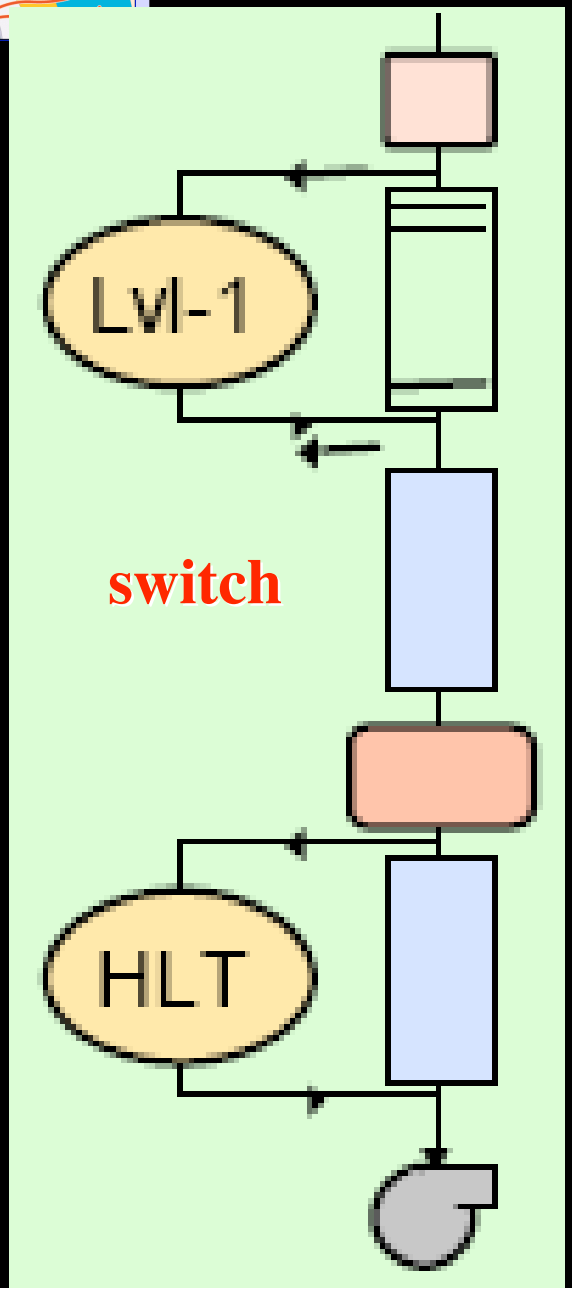
Events for 1 month at 10^{27} cm^{-2} s^{-1}

Jet E_T	Probe	Events
100GeV	Jet > 100GeV	8,700,000
100GeV	□ > 100GeV	6,000
100GeV	Z→□$^+$□$^-$ >100GeV	90
50GeV	Z→□$^+$□$^-$ >50GeV	600





Data Acquisition and Trigger



Level 1 hardware trigger

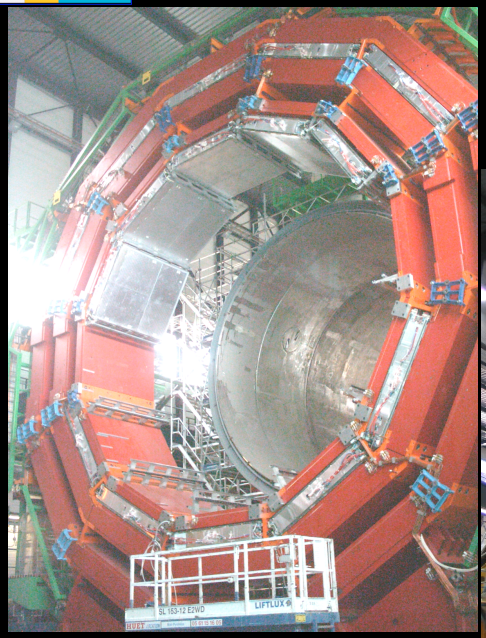
- Muon track segments
- Calorimetric towers
- No tracker data
- Output rate (Pb+Pb): ***1-2 kHz comparable to collision rate***

High level trigger

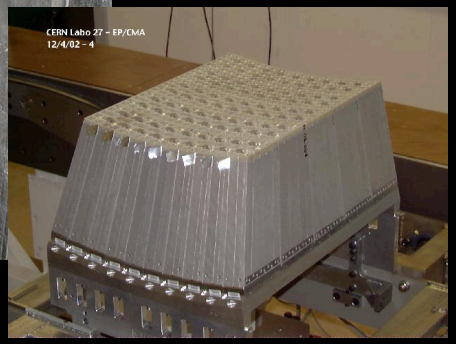
- Full event information available
- Every event accepted by L1 sent to an online farm of 2000 PCs
- Output rate (Pb+Pb): ***~ 40 Hz***
- ***Trigger algorithm same or similar to offline reconstruction***

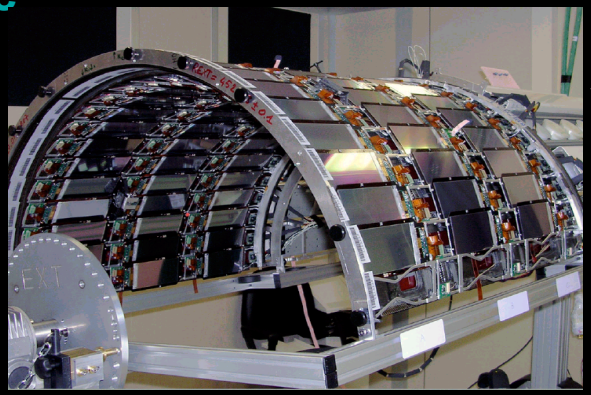
CMS under construction

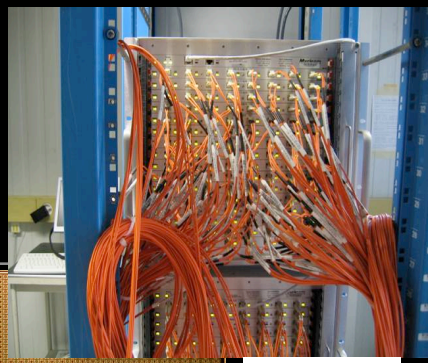
Magnet & Muon Absorber



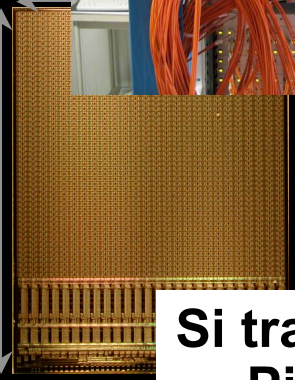
Electromagnetic Calorimeter







DAQ



Si tracker & Pixels

Conclusions

LHC will extend S, low x and p_T reach of HI physics.

CMS strengths:

- Excellent rapidity & azimuthal coverage including ZDC, CASTOR & TOTEM in forward region
- High resolution tracking, calorimetry, muon identification
- Quarkonia, photons and Z_0
- Jets
- Essentially no modification to the core detector hardware
- New High Level Trigger algorithms specific for A+A
- Heavy-Ion program is well integrated into the overall CMS Physics Program