Flow at the LHC: Heavy Ion Collisions using CMS pixel detectors

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Topics

- HI Physics needs at CMS drive technology, software and hardware

  Physics - 'Flow' = A collective nuclear motion
  Nuclear reaction plane in CMS?
  Azimuthal distribution of charged particles

- Heavy quarks, charm and beauty elliptic flow:
  information on "deconfined matter; e.g. **quark gluon plasma**

- CMS "Soft physics" drives:
  need a way to follow the produced particles
  need "low p_T" momentum particles measurement
  need data analysis techniques

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Heavy Quark Elliptic 'Flow'

up(u), down(d), strange(s) - "light"
charm(c), beauty(b), truth(t) - "heavy"

- Elliptic flow produced in the early stage of AA collisions
  - ($t \leq 0.1$ fm/c) best signal in semi-central collisions
- Sensitive to properties of dense matter (a quark gluon plasma?)
  - equation-of-state
  - $\sigma_{SCATTERING}$ of "partons" (u, d, s, c, b, t, gluons,??) produced in the collisions
- b-quarks, B mesons produced at LHC via PbPb
  - for CMS $B^{\pm} \rightarrow e^{\pm} X$, $B \rightarrow \mu^{+} \mu^{-} Y$
  - these particles require location of secondary vertex

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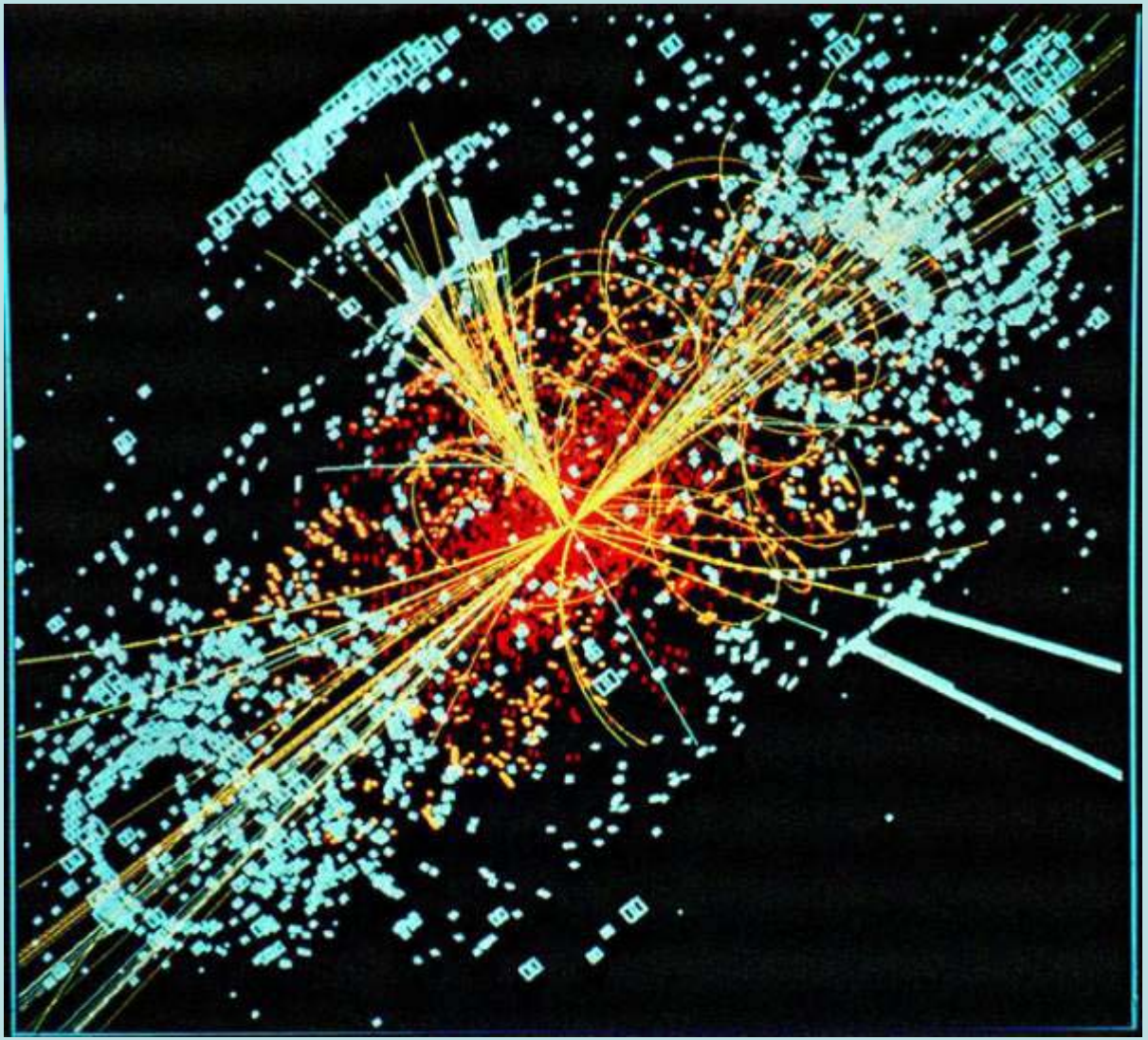
CERN p-p - tens of tracks



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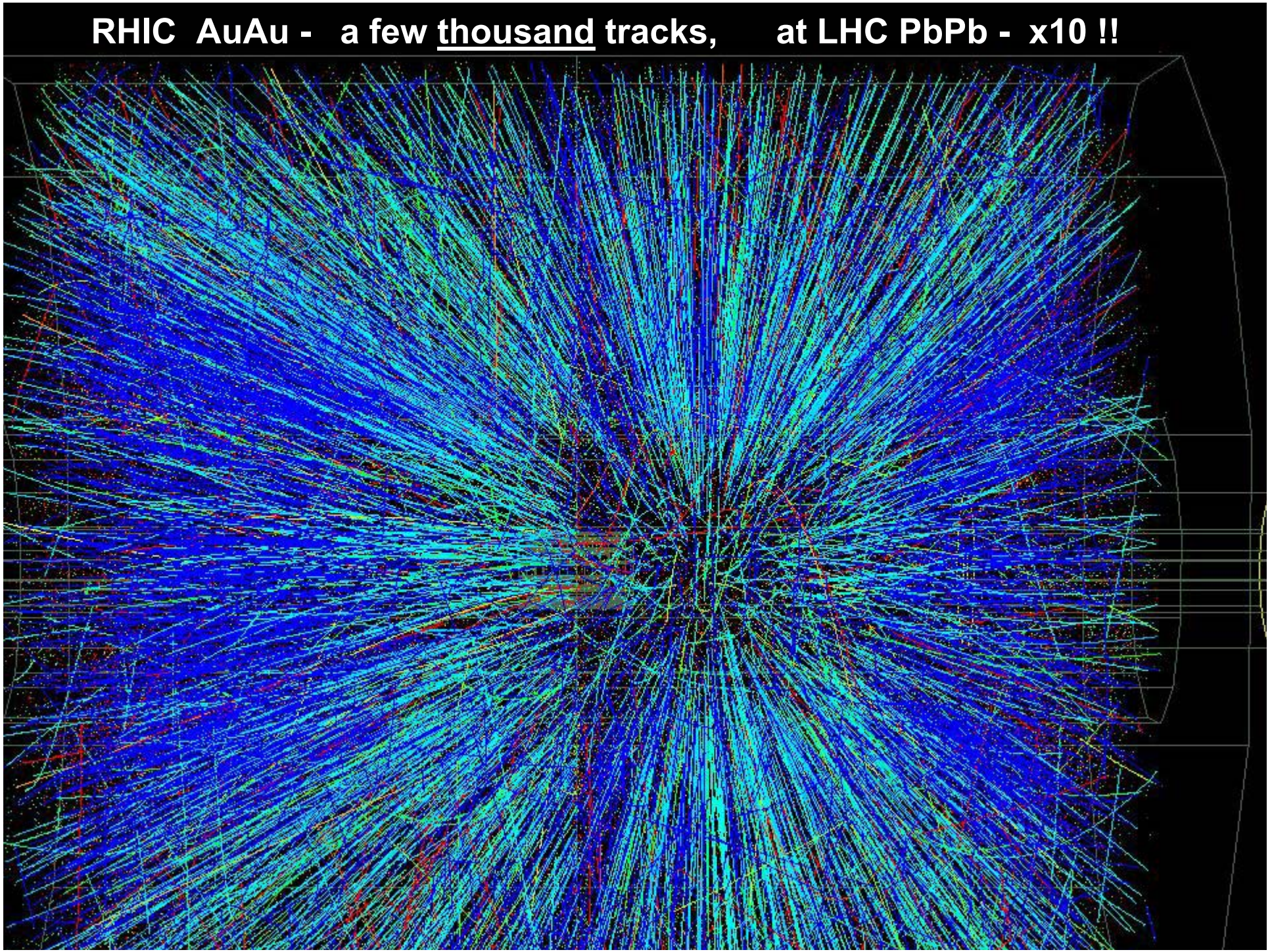
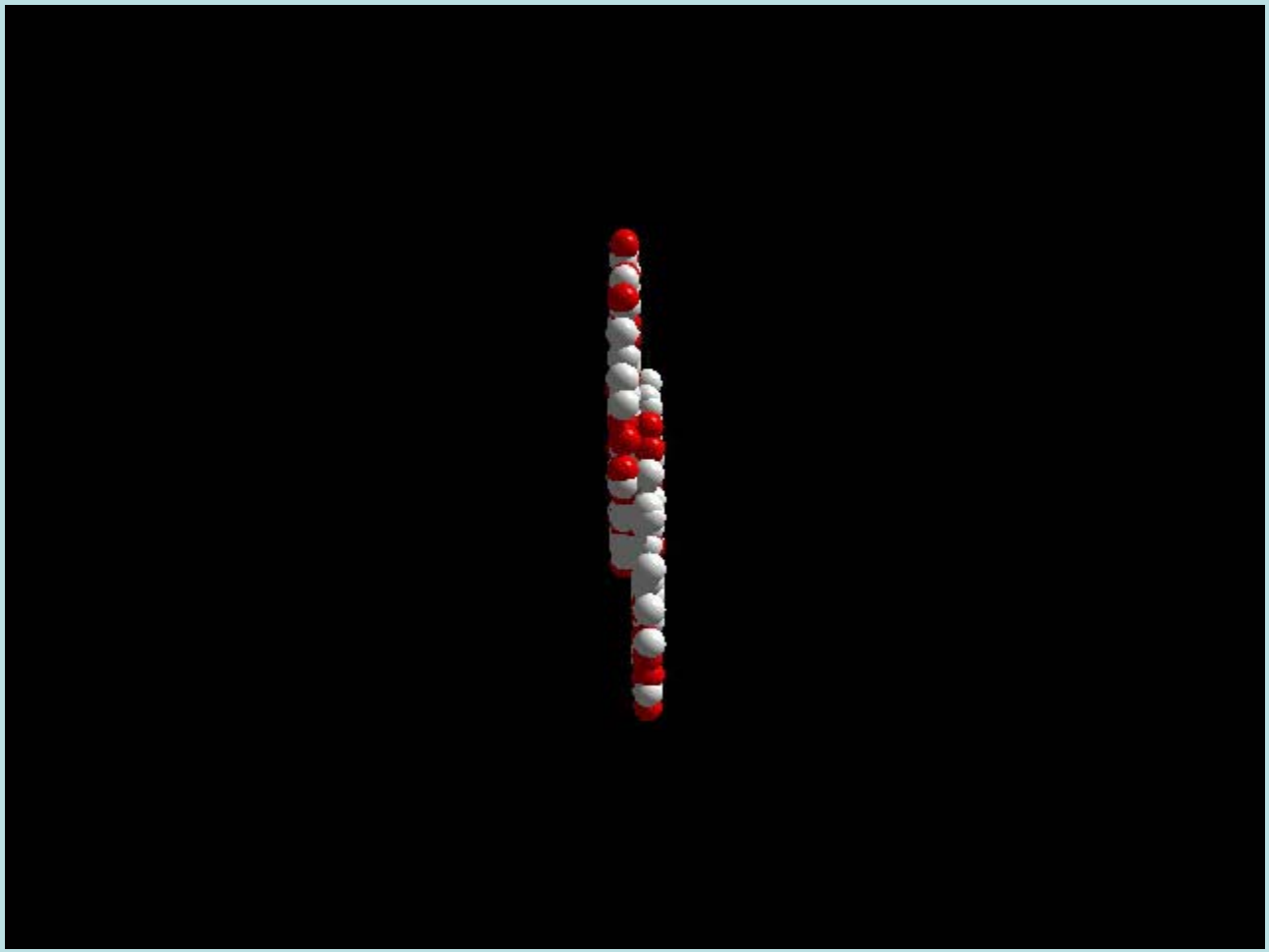
RHIC AuAu - a few thousand tracks, at LHC PbPb - x10 !!



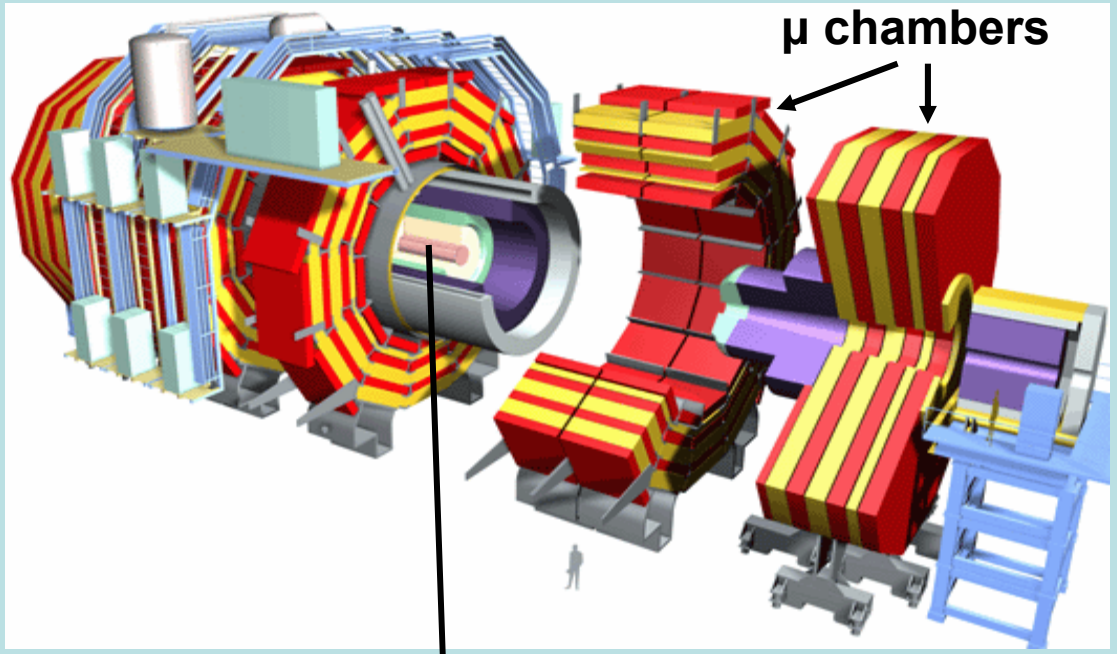
Au + Au at √S = 5 ATeV

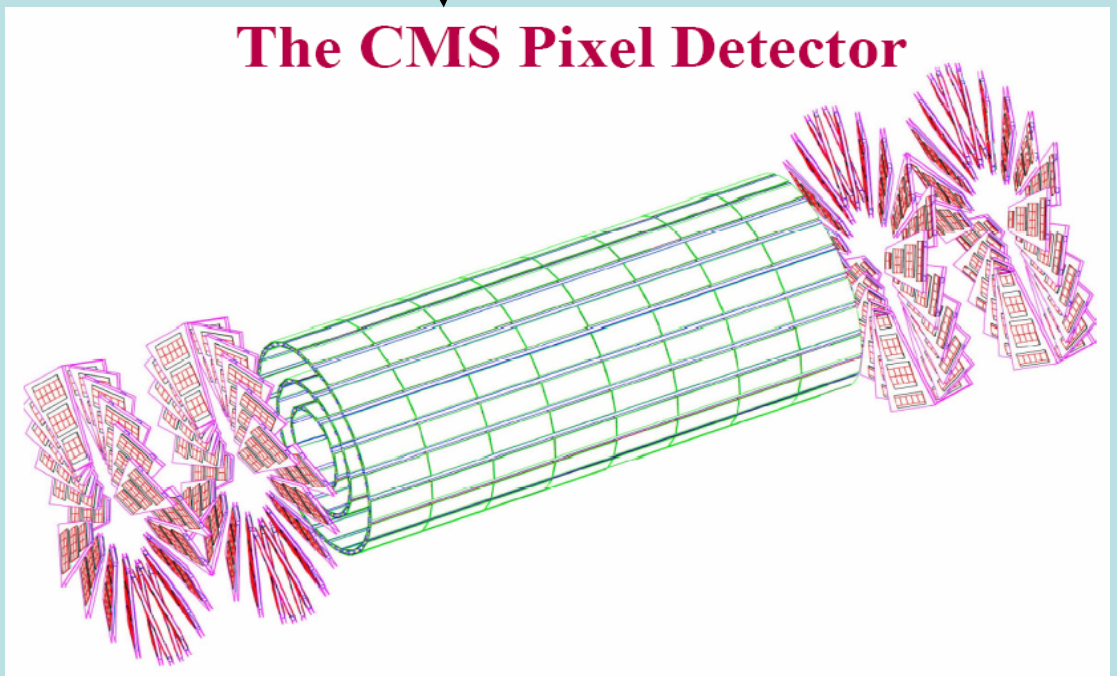


URQMD - courtesy of Columbia University, USA

CMS Detector

- 3 pixel barrel layers and 2 endcap disks
- 720 barrel modules, 672 endcap modules ~66 million pixels!!
- Pixel size 100x150 μm





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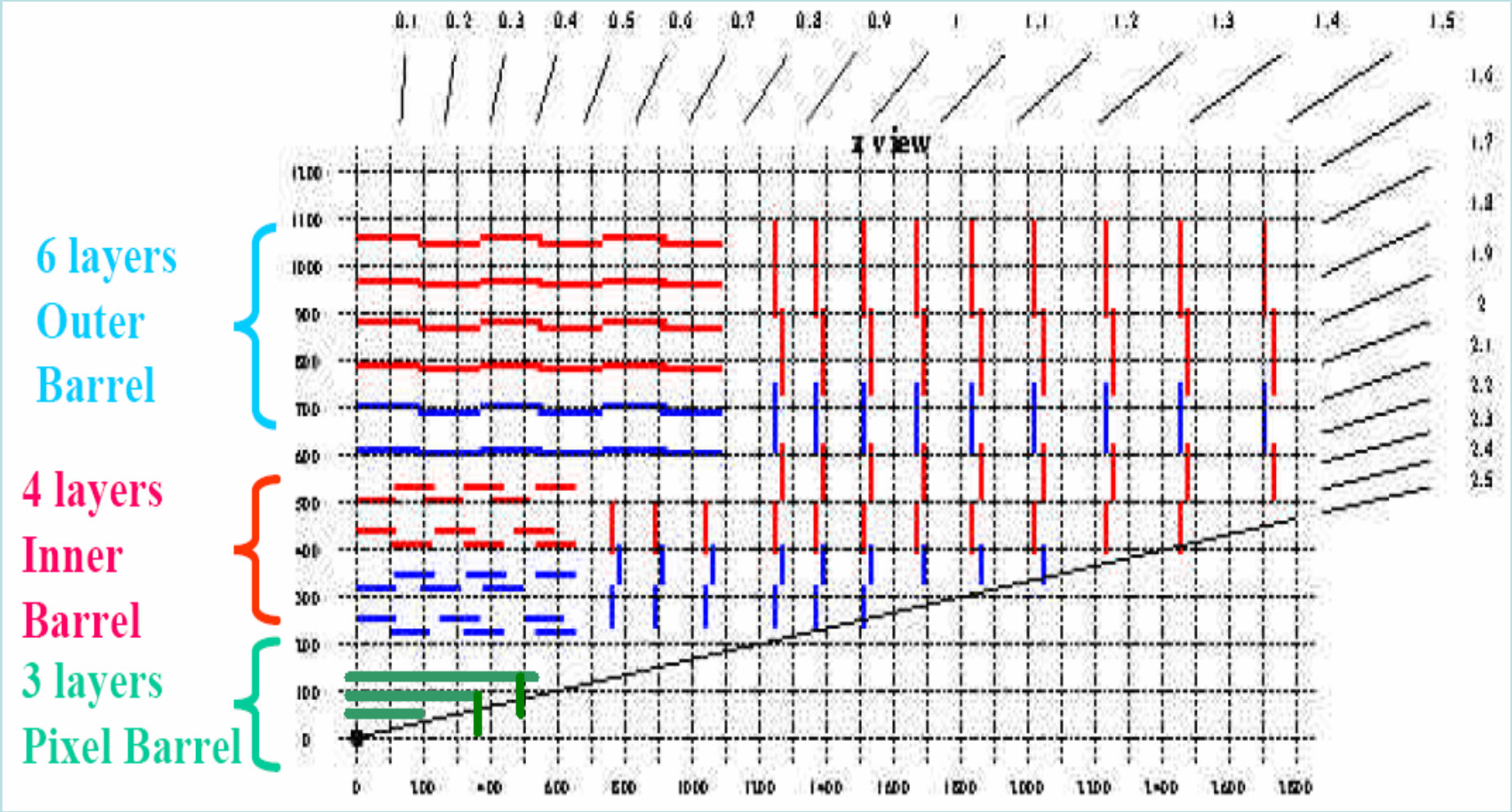
Tracker Layout



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The "Standard" Picture

Bhalero, Borghini, Ollitraut, Phys. Lett. B580 157-162 (2004)

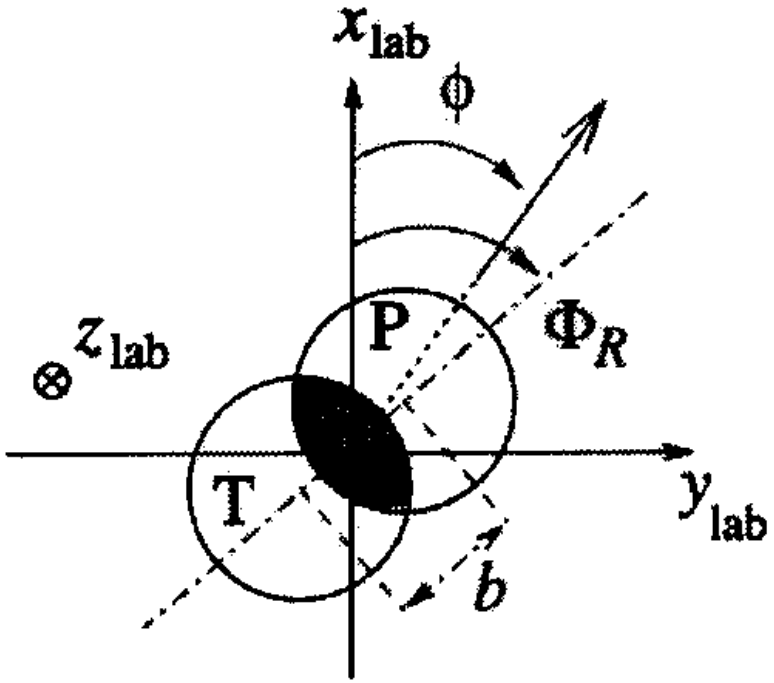

Fig. 1. Schematic picture of a nucleus–nucleus collision viewed in the plane transverse to the collision axis z. b is the impact parameter, Φ_R its azimuthal angle. ϕ is the azimuthal angle of an outgoing particle.

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Reaction Plane From CMS Hcal + Ecal Endcaps

"Lokhtin, Petrushanko, Sarycheva, Snigirev"
Hydrodynamics + HIJING
CMSIM_125 + ORCA 6.2.0

CMS NOTE 2003/019

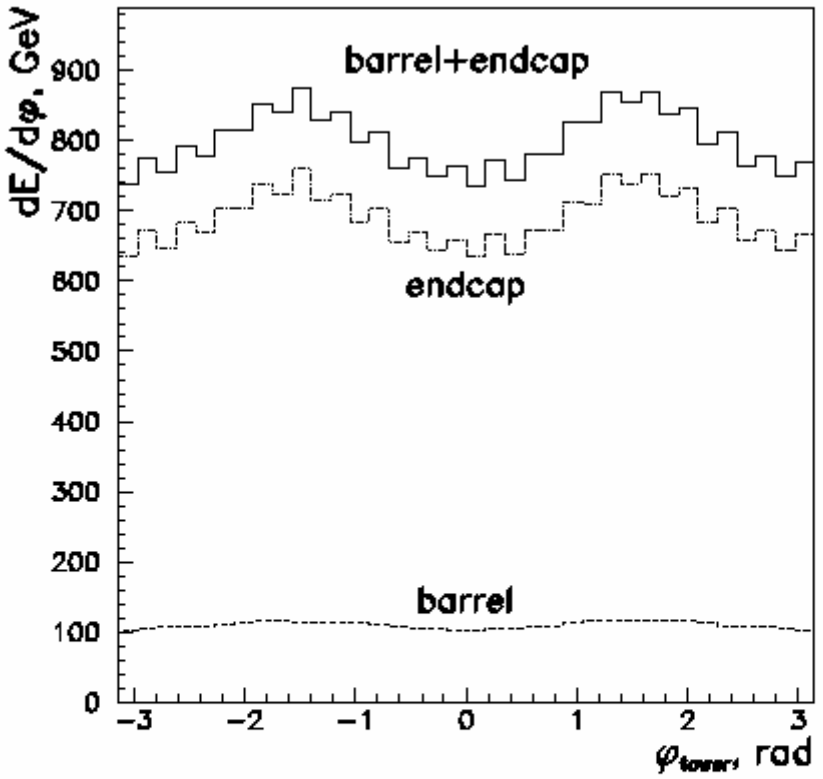

Figure 7: Energy deposition in the CMS HCAL and CMS ECAL: barrel (dashed histogram), endcap (dotted histogram), total deposition (solid histogram); Pb−Pb collisions at $b = 6$ fm (hydrodynamics with CMSIM_125+ORCA_6.2.0).

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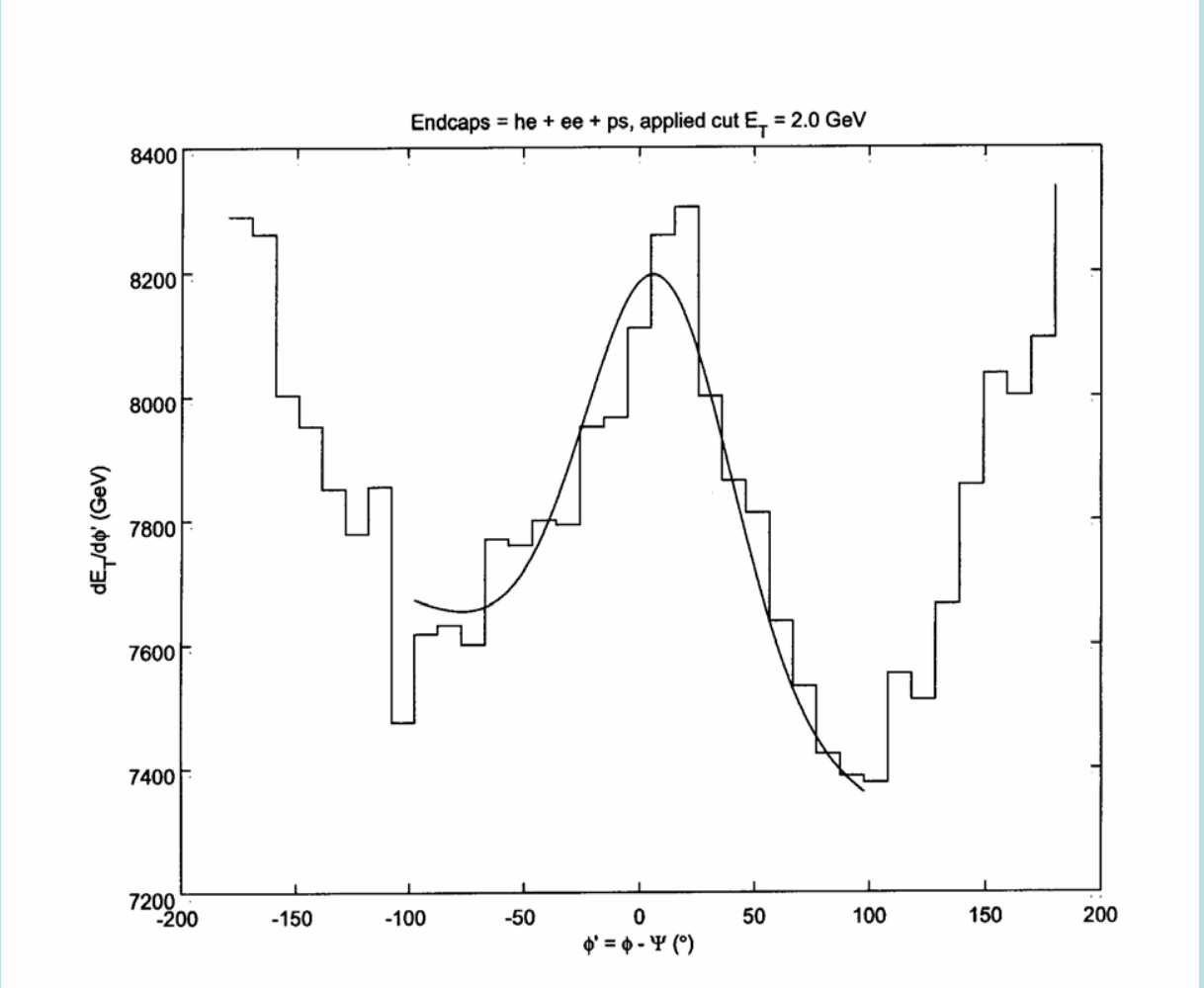
Reaction Plane From CMS Hcal + Ecal Endcaps

- HIJING $B\overline{B}$

  $\sqrt{S} = 5.5$ ATeV

  100 events $b = 5 - 8$ fm

CMSIM_125 + ORCA 6.2.3



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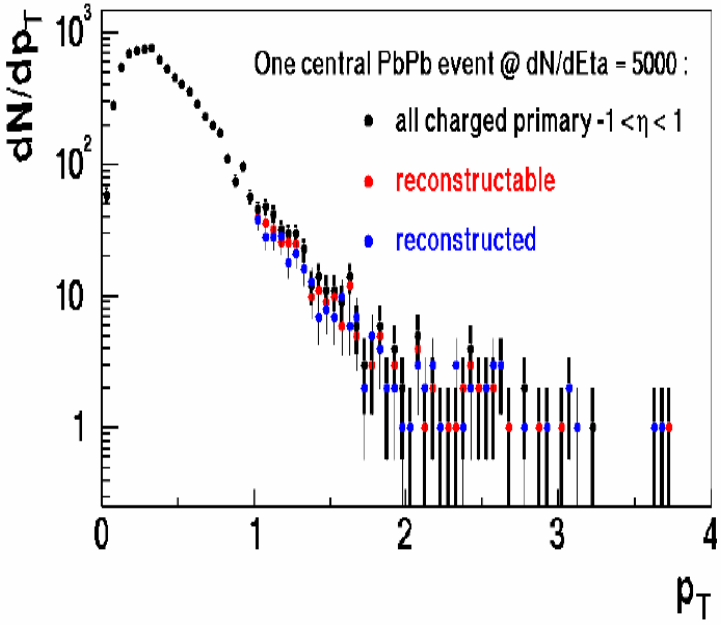
I.J. Kil MSc Thesis Auckland 2002
(unpublished)

- **Need to see**
RHIC high p_T ↔ LHC low p_T

- **Reconstruction of "soft" charged particles**

Christof Roland, May 2003, DoE

A full event reconstructed @ dN/dy ~5000



- Charged particle spectra can be reconstructed for p_T>1GeV
- Lower cutoff possible with reduced field

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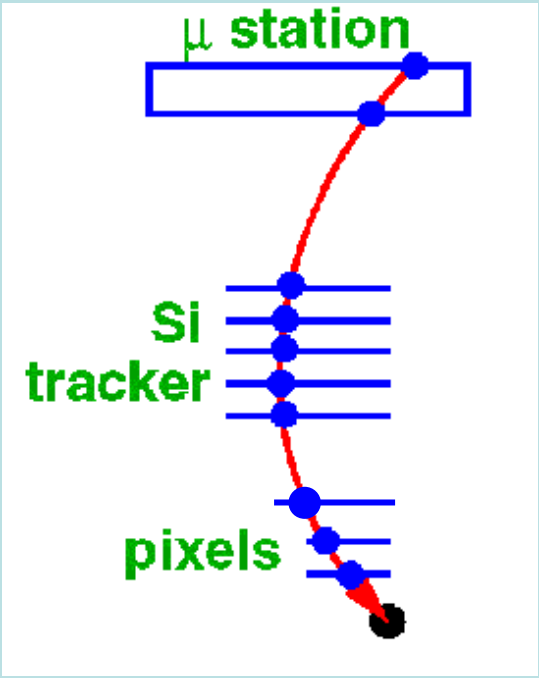
Track reconstruction using pixel detectors

- **Need:**

1) <u>Primary Vertex</u> location
(dr ~ 100 μm dz ~ 350 μm window)
initial 2 pixel extrapolation
~15 μm resolution

2) <u>Reconstruction</u>
CMS pixels for "triplet seeds"



3) Require the track to cross more than 8 detector layers (~12 hits) and hits in three pixel layers

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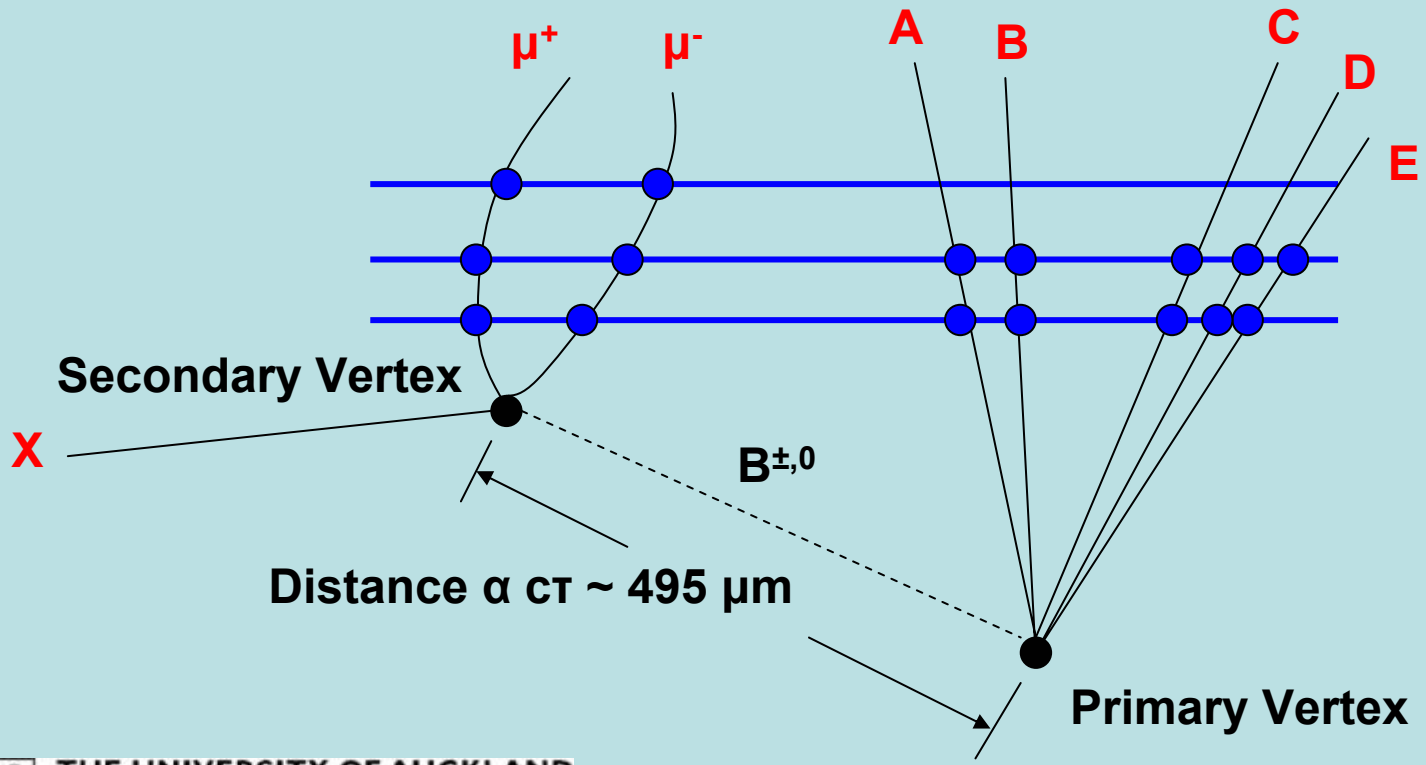
4) CMS pixels for Secondary Vertex - heavy quark mesons

$B^{\pm,0}$ signature ($c\tau \sim 495\ \mu m$)

$D^{\pm}$ signature ($c\tau \sim 315\ \mu m$)



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Analysis: elliptic flow from cumulants

$$\frac{dN}{d\varphi} \propto 1 + 2\, v_2 \cos\{2(\varphi - \psi_R)\}$$

$$v_2 = \langle \cos\{2(\varphi - \psi_R)\} \rangle$$

$$\text{2 – particles correlated} = \left\langle e^{i2(\varphi_1 - \varphi_2)} \right\rangle = \left\langle e^{i2(\varphi_1)} \right\rangle \left\langle e^{i2(\varphi_2)} \right\rangle + \left\langle \left\langle e^{i2(\varphi_1 - \varphi_2)} \right\rangle \right\rangle$$

$$\text{4 – particles correlated} = \left\langle e^{i2(\varphi_1 + \varphi_2 - \varphi_3 - \varphi_4)} \right\rangle = \left\langle e^{i2(\varphi_1 - \varphi_3)} \right\rangle \left\langle e^{i2(\varphi_2 - \varphi_4)} \right\rangle + \left\langle e^{i2(\varphi_1 - \varphi_4)} \right\rangle \left\langle e^{i2(\varphi_2 - \varphi_3)} \right\rangle + \left\langle \left\langle e^{i2(\varphi_1 + \varphi_2 - \varphi_3 - \varphi_4)} \right\rangle \right\rangle$$

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- HIJINGBB PbPb

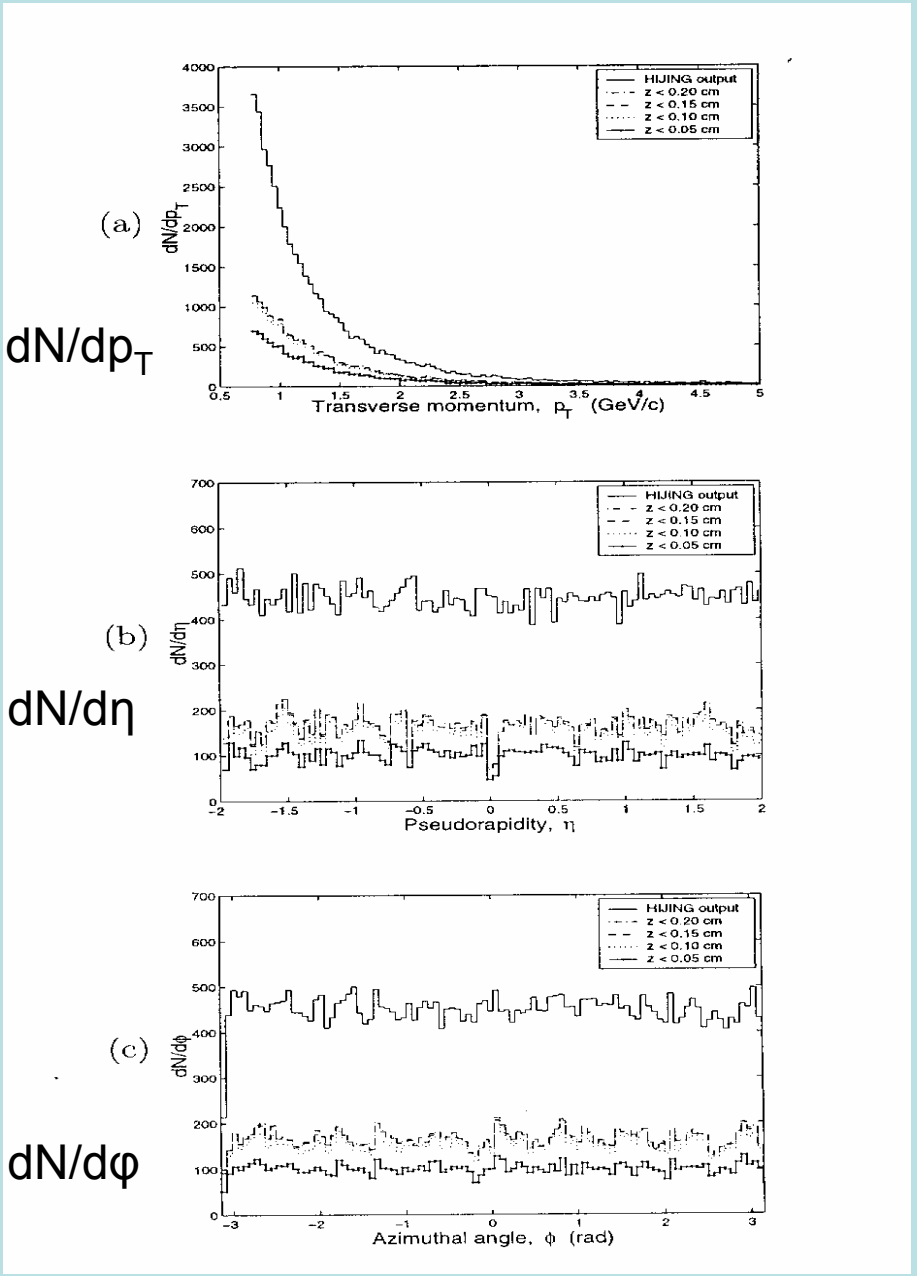
  100 events, √S =5.5 ATeV

  b=5-8 fm

- p_T > 1GeV/c, $|\eta| < 2$

CMSIM_125 + ORCA 6.2.3

Try cumulant analysis on this set of reconstructed events



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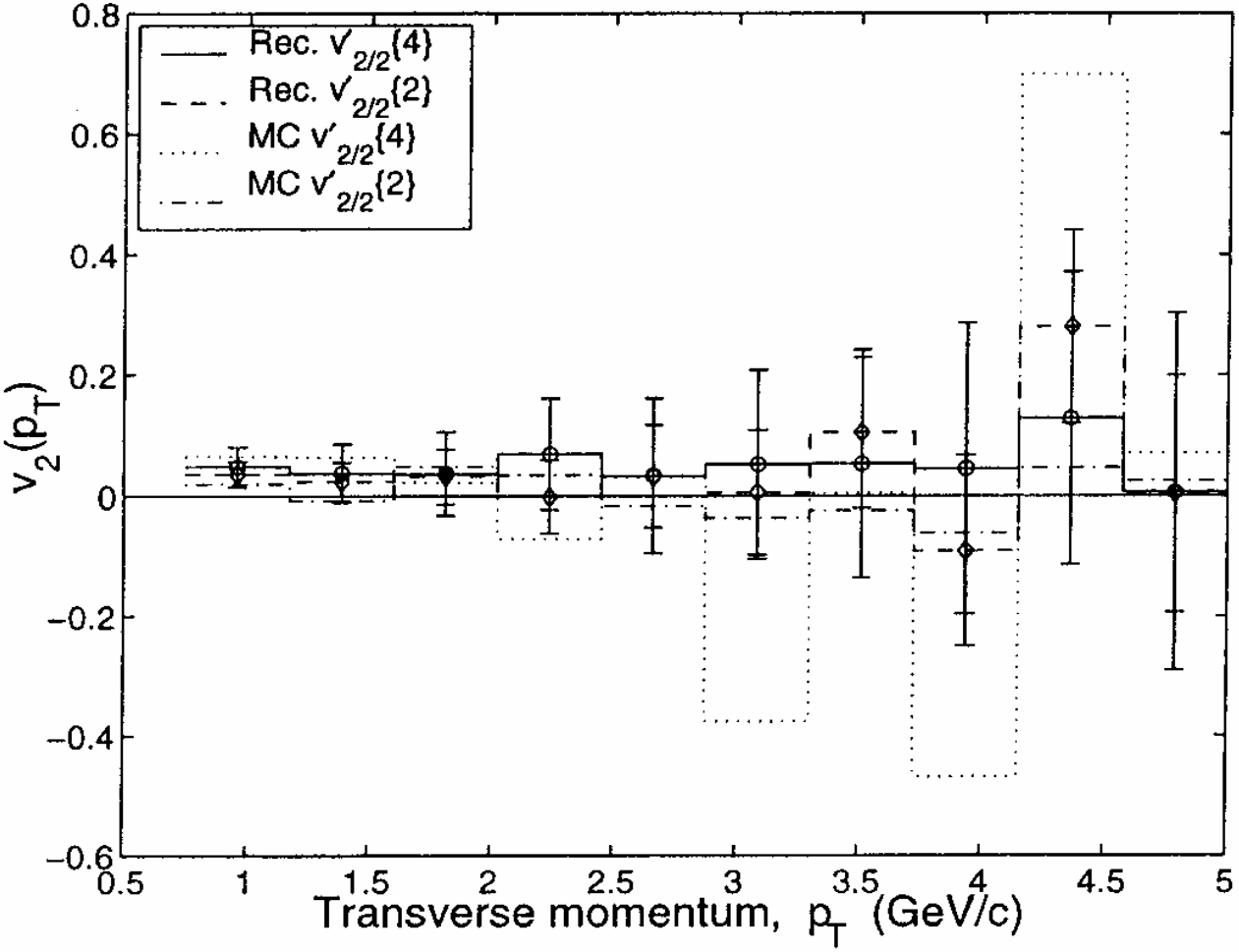
Elliptic Flow From Cumulants



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HIJING/BB CMSIM+ORCA 6.2.3

P. Allfrey MSc Thesis, Auckland (2002)
(unpublished)

Heavy Quark Elliptic Flow at RHIC

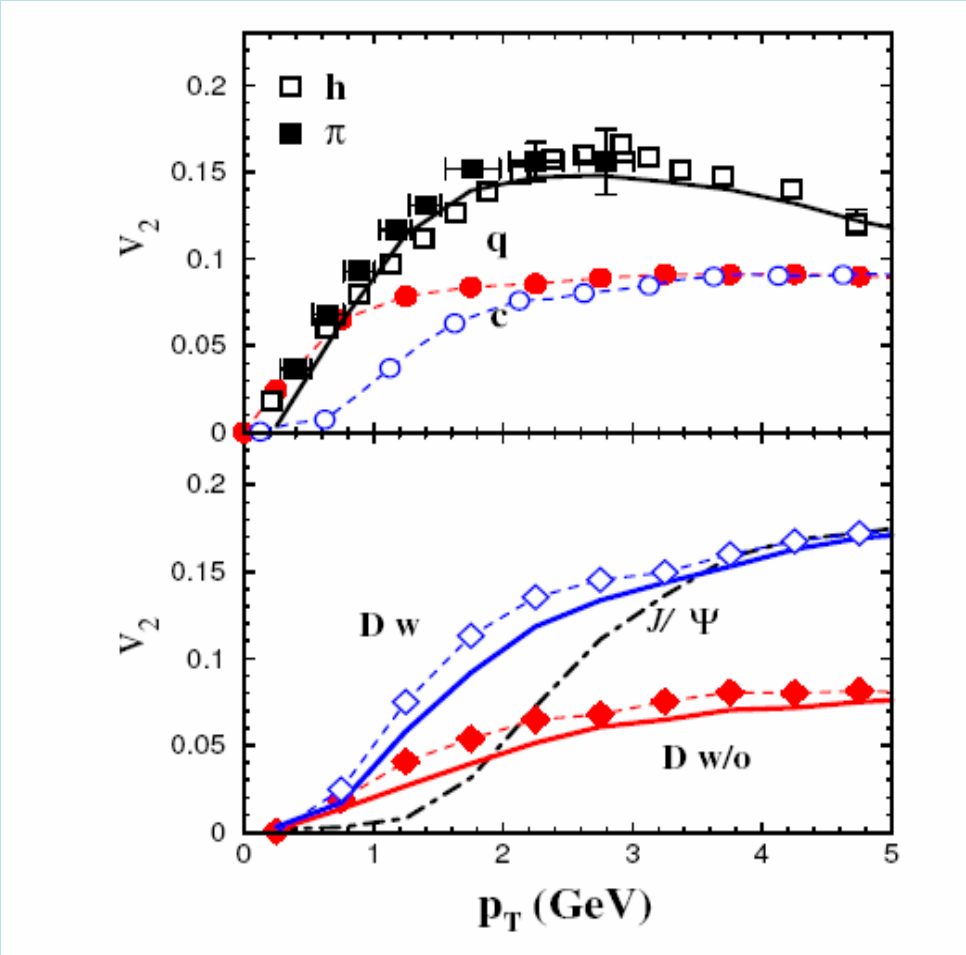
- $\sqrt{S} = 200$ AGeV
- **quark coalescence model calculations**

Greco, Ko, and Rapp Nucl-th/0312100

Assumed two Scenarios:

i) No rescattering
perturbative QCD → D w/o

ii) Complete thermalization
→ D w



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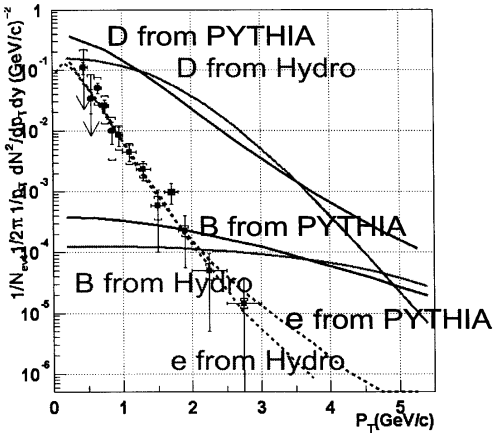
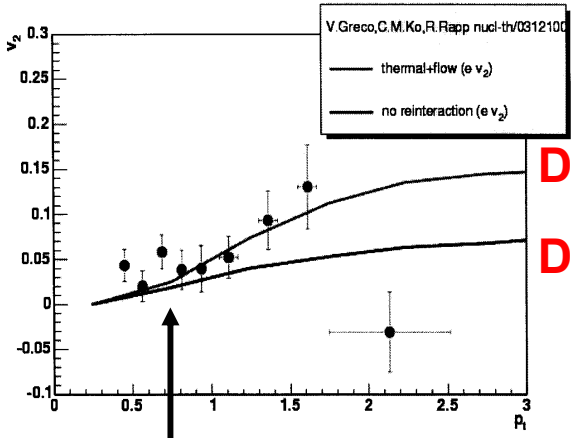
PHENIX: Esumi et al., NP A715 599 (2003), Adler et al., nucl-ex/0305013

Heavy Quark Flow at RHIC Energy

PHENIX: Charm Flow in AuAu?





*Batsouli, Kelly, Gyulassy, Nagle, Phys. Lett B 557, 26-32

Why might we care?

- Does charm agree with binary scaling because little interaction with the medium or does charm flow result in no net change in p_T spectrum (within our measurement)?

How do we attempt to measure it?

- Calculate flow of single electrons (remember cocktail: photon conversion, … and charm)
- Calculate flow of photonic sources and compare to model with and without charm flow

Los Alamos NATIONAL LABORATORY

Quark Matter 2004 Oakland – January 11-17

Melynda Brooks

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e- data, Averback et al. NP A715 695-698 (2003)

Conclusions

- Low p_T particles can be reconstructed in CMS via pixels
- Heavy quark mesons detected via Secondary Vertex using pixels
- Cumulant analysis technique for V_2 test with HYDRO + flow code
  I.Lokhtin, A.Snigirev hep-ph/0312204
- Coalescence model calculations B meson V_2 , Ko et al. coming
- D and B elliptic flow via $B,D \rightarrow e^{\pm} X$, $B \rightarrow \mu+ \mu- Y$
  CMS can follow hydro vs pQCD
- **Flow (V_2) may create anisotropic jet cone – high p_T connection**

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C. Salgado, "Jet Physics in heavy ion collisions at the LHC", CMS Week June 2004