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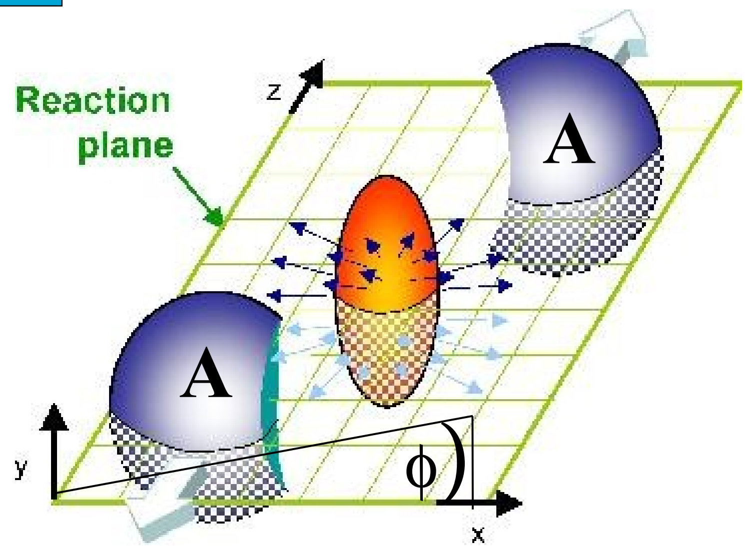
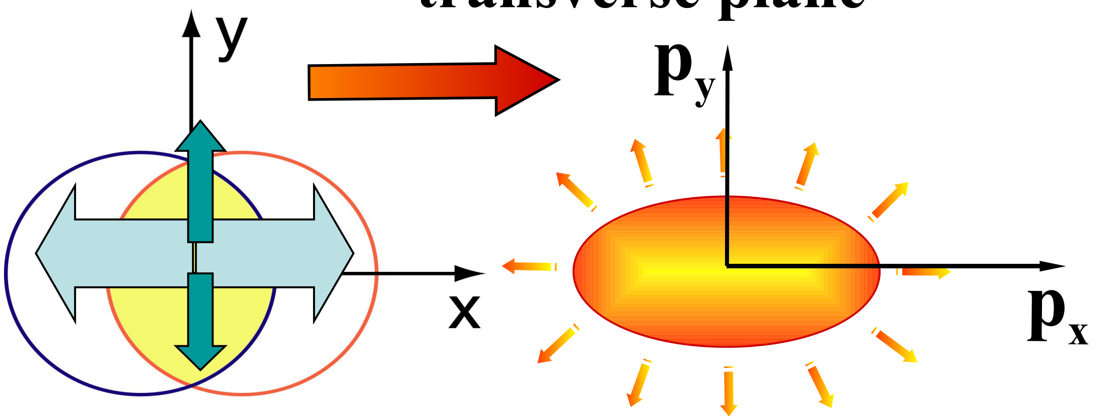
(for CMS Collaboration)

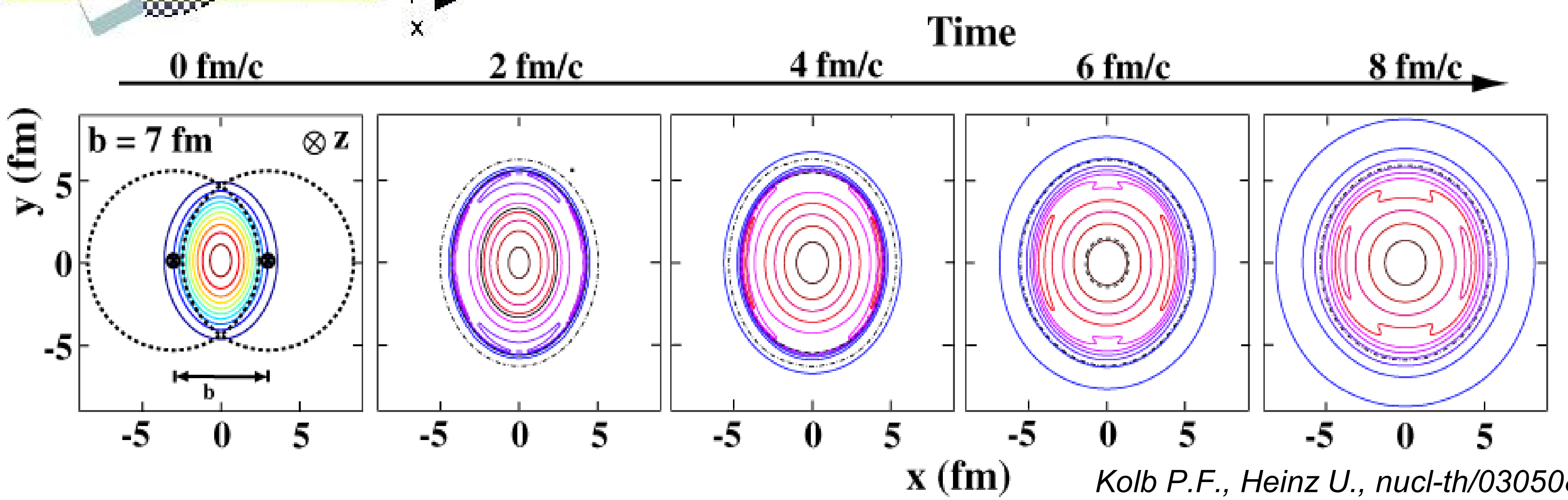
Elliptic flow studies in heavy-ion collisions using the CMS detector

14th Lomonosov Conference
on Elementary Particle Physics
19-25 August 2009

Elliptic flow in non-central heavy-ion events







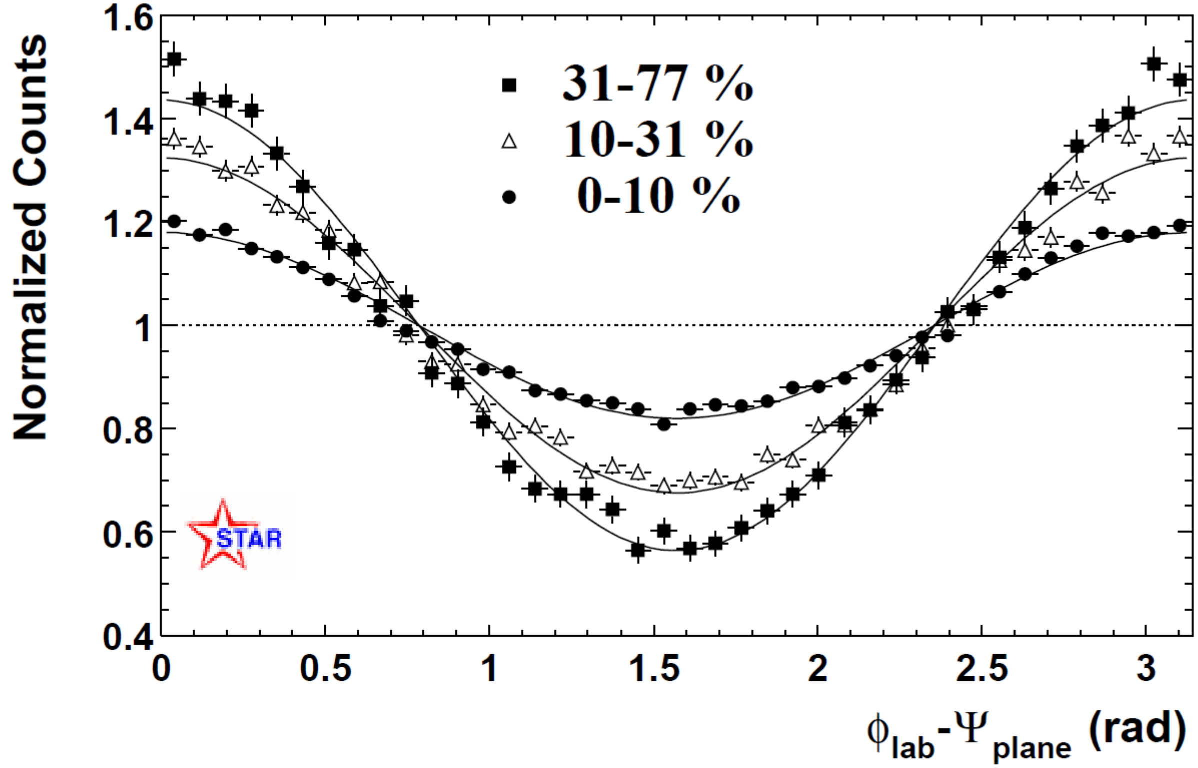
Kolb P.F., Heinz U., nucl-th/0305084

Initial spatial anisotropy results in elliptic flow of finite particles.
Azimuthal anisotropy of particles is a signature of termalizasion.

Azimuthal distribution on RHIC

Ψ_R – azimuthal angle of the reaction plane

STAR Collaboration, Phys.Rev.Lett.90:032301,2003.

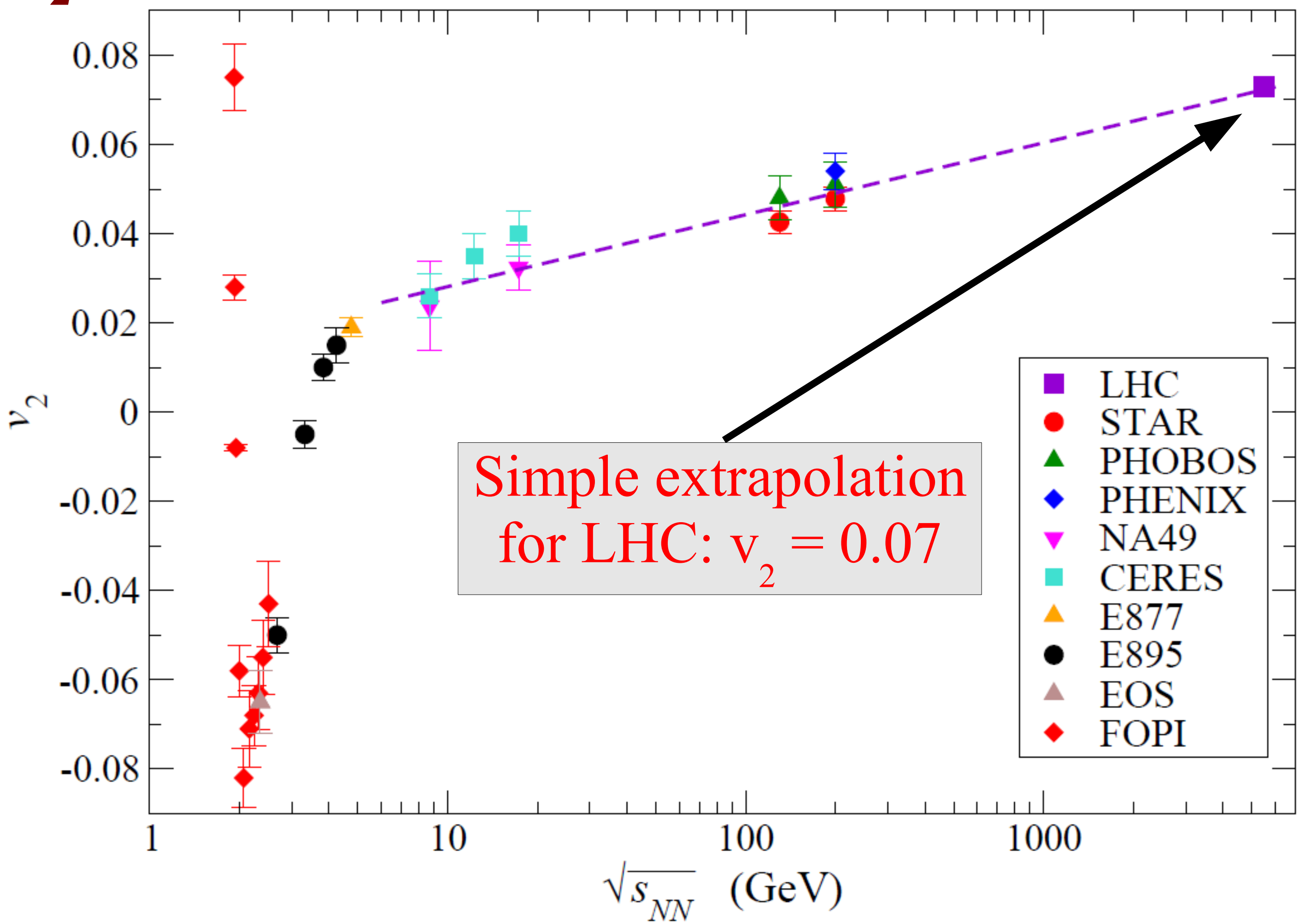


$$\frac{dN}{d\varphi}(\varphi_p) = N_0(1 + 2v_1\cos(\varphi_p - \Psi_R) + 2v_2\cos 2(\varphi_p - \Psi_R) + \ldots)$$

Elliptic flow $v_2 = \langle \cos 2(\varphi - \Psi_R) \rangle$

$\varphi = \tan^{-1}(p_y/p_x)$

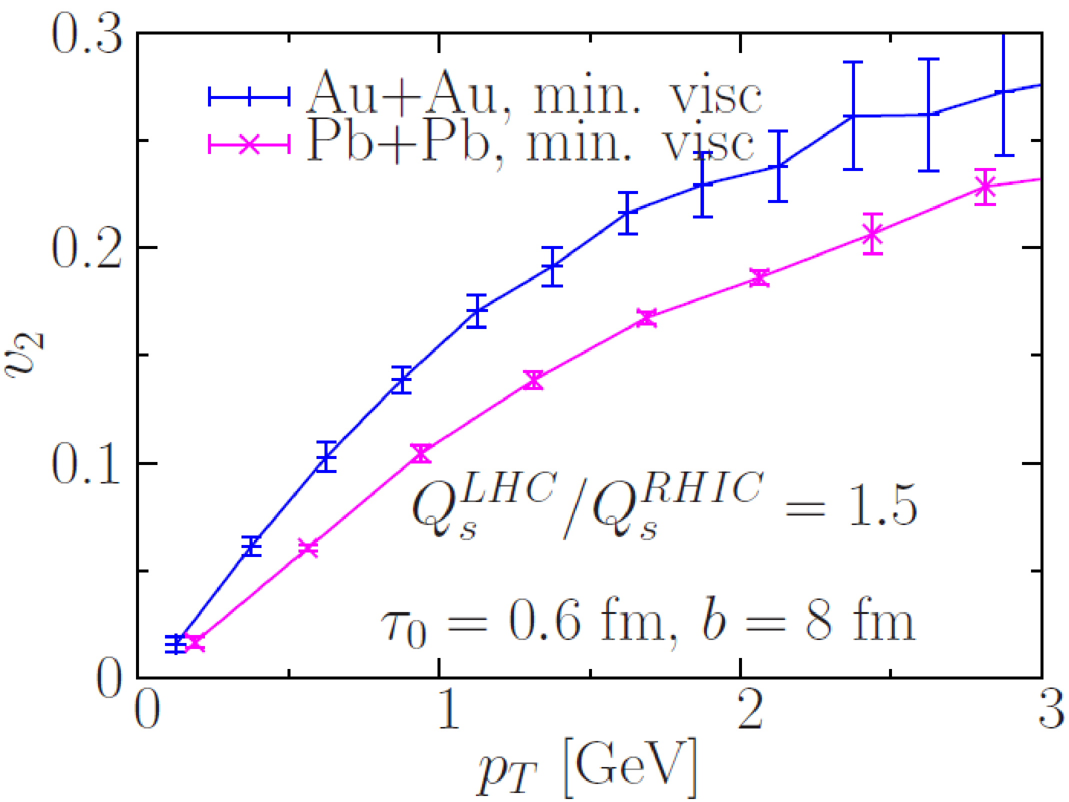
v_2 – current data and prediction for LHC



Alessandro B et al., 2006 J. Phys. G: Nucl. Part. Phys. 32 1295

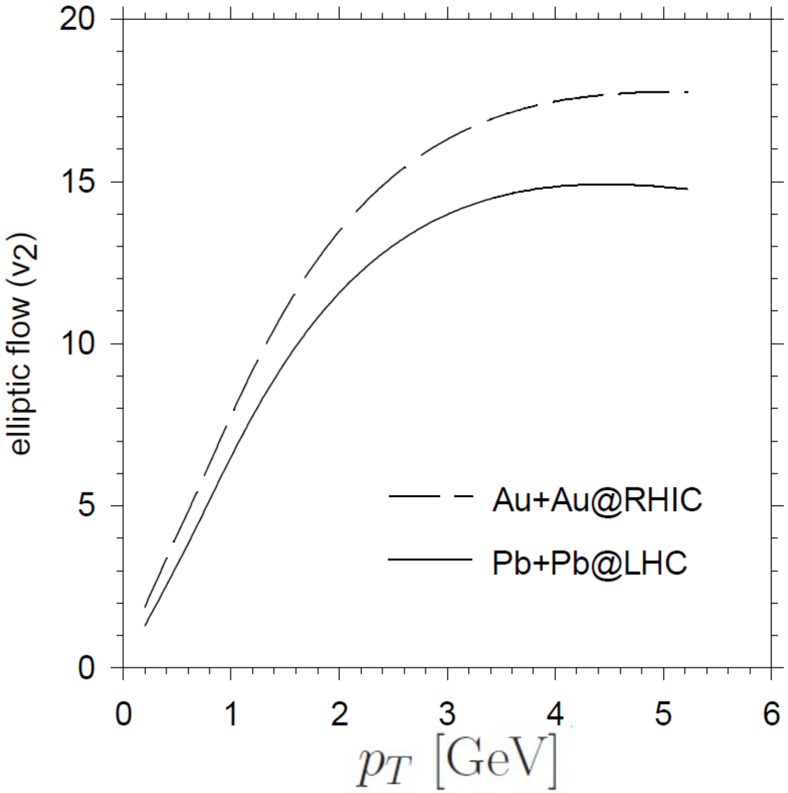
Simple extrapolation gives slight increasing of v_2 for LHC energy
(but a number of models predicts slight decreasing of v_2)

v_2 vs. p_T – RHIC and LHC



N. Armesto et al., J. Phys. G 35 (2008) 054001.

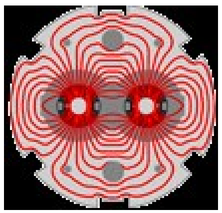
MPC parton cascade of Molnar for RHIC and LHC, b = 8 fm.

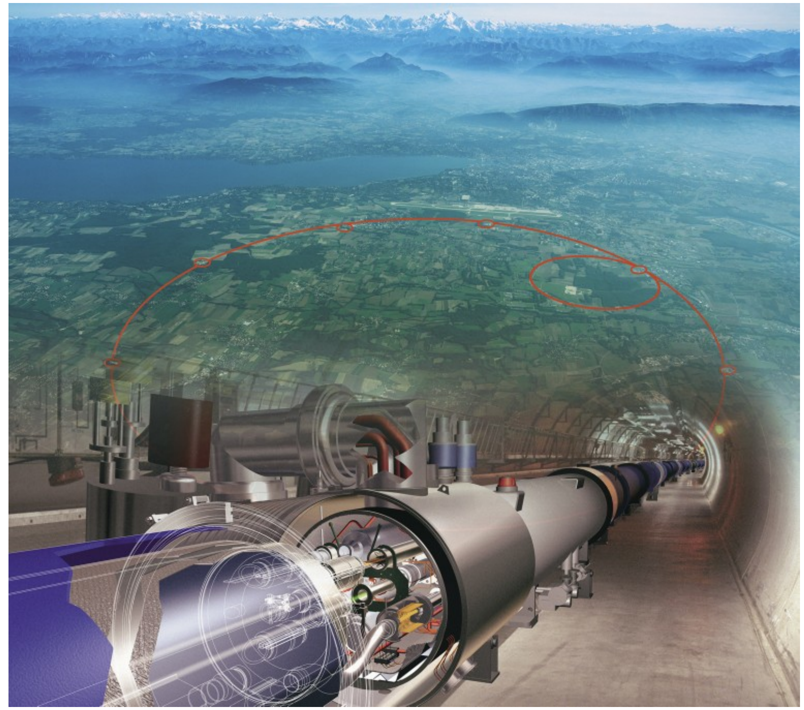


A. K. Chaudhuri, Phys. Lett. B 672 (2009) 126

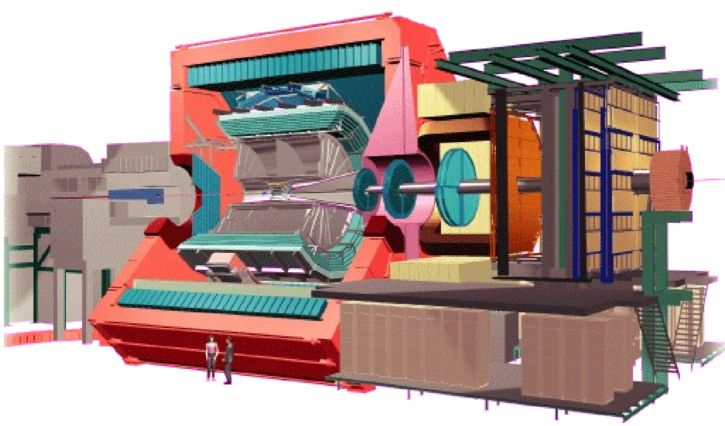
Viscous hydrodynamical calculations for RHIC and LHC, minimum bias collisions.

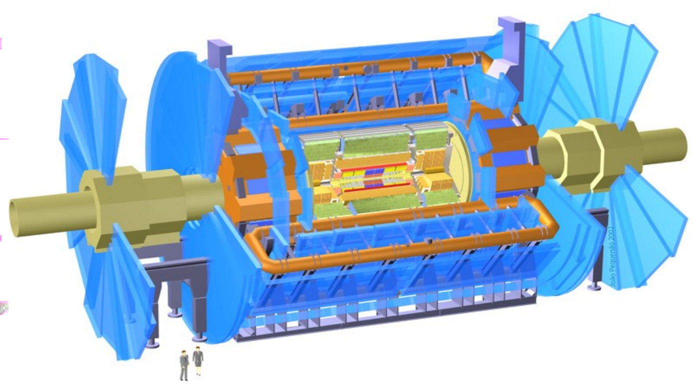
Elliptic flow on LHC: experiments

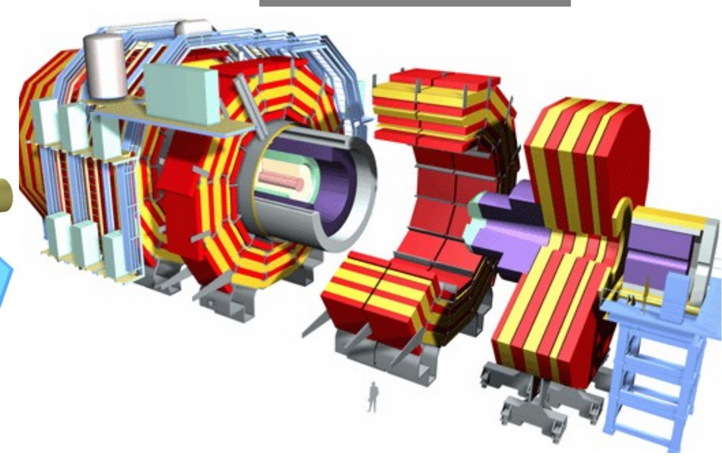




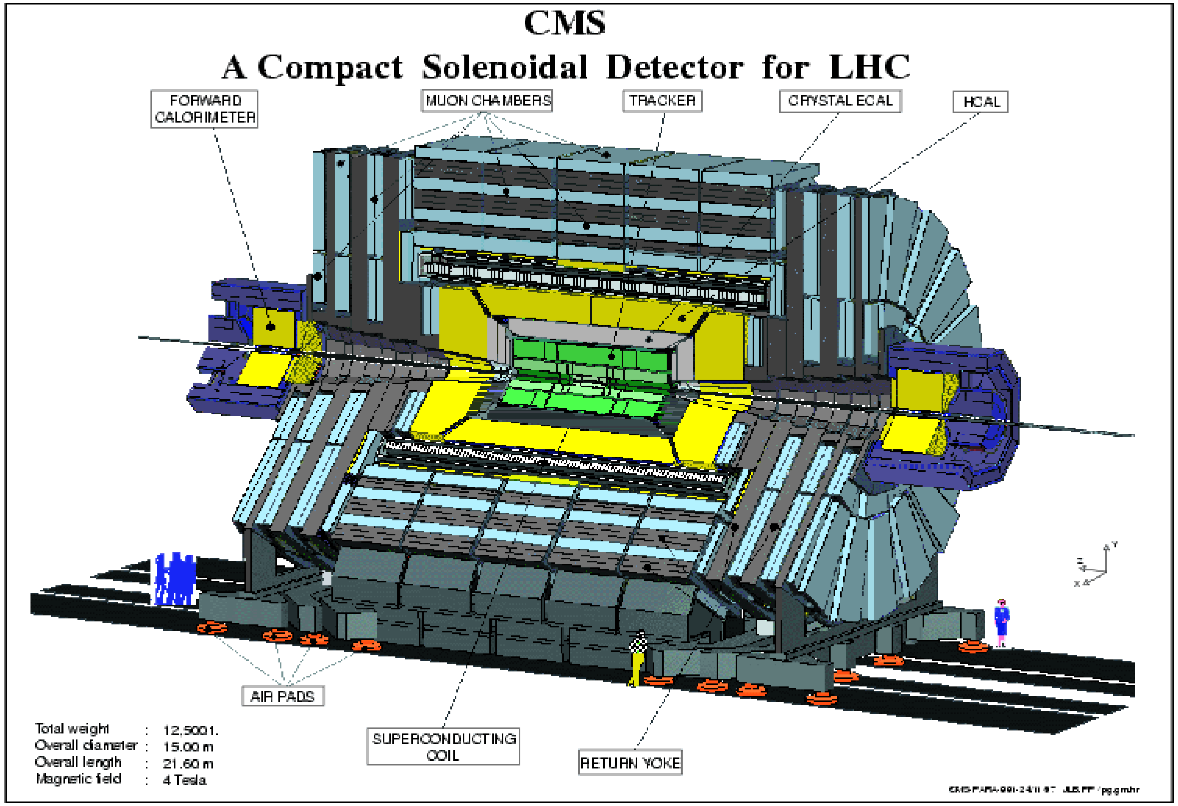
ALICE **ATLAS** **CMS**







CMS experiment on the LHC



- **Silicon Tracker**
  $|\eta| < 2.4$
- **Electromagnetic Calorimeter**
  $|\eta| < 3.0$
- **Hadron Calorimeter**
  barrel and endcap
  $|\eta| < 3.0$
  with HF-calorimeter up to
  $|\eta| < 5.2$
- **Muon Chambers**
  $|\eta| < 2.4$

+ CASTOR detector
$5.3 < |\eta| < 6.4$
+ Zero-degree calorimeter
+ TOTEM

Magnetic field: 3.8 Tesla

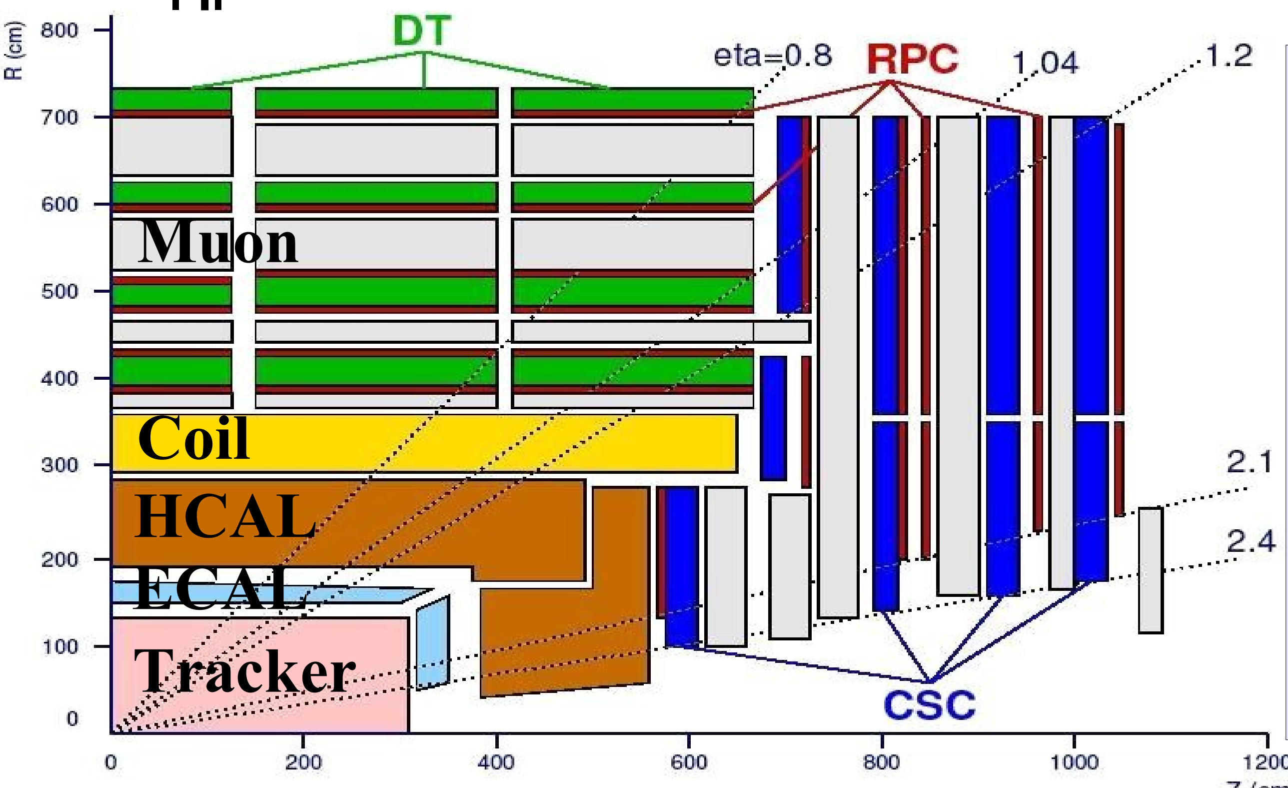
CMS experiment on the LHC

Tracker system:

- Silicon pixel layers (3 in barrel $|\eta| < 1.5$, 2 in endcap $1.5 < |\eta| < 2.4$)
- Silicon strips layers (10 in barrel $|\eta| < 1.5$, 12 in endcap $1.5 < |\eta| < 2.4$)

Calorimeter system:

- ECAL – electromagnetic (crystals of lead tungstate $PbWO_4$) $|\eta| < 3.0$
- HCAL – hadron (active plastic scintillator tiles interspersed between stainless steel and brass absorber plates) $|\eta| < 3.0$
- HF – hadron forward (steel absorbers and embedded radiation hard quartz fibers) $3.0 < |\eta| < 5.2$



- **Excellent coverage:**
  Tracker
  ~ **5 units** of rapidity and 2π
  Calorimeter
  > **10 units** of rapidity and 2π

- **Momentum resolution:**
  ~ 2% of momentum resolution for tracks with $p_T < 100$ GeV/*c*

From RHIC to LHC: time and statistics for first heavy-ion run

Physics proton-proton run on LHC will start in mid-November 2009

Two weeks heavy-ion run will be expected in the end of 2010

Expected LHC one week of 1-st year run for PbPb collisions at **~ 4 TeV**

L=10 μb $^{-1}$ ~ 70M events

STAR (similar acceptance as CMS)

2000 year, first publications on Elliptic flow on RHIC:

~ 25M events

Statistical reach at CMS will be better or comparable with the RHIC results

Elliptic flow – one of the priorities of the CMS heavy-ion group for the first heavy-ion run on the LHC

Reconstruction of the reaction plane in CMS

CMS Tracker
Reconstructed Tracks

$$tan(2\varphi_{rec}) = \frac{\sum_i \omega_i \sin 2\varphi_i}{\sum_i \omega_i \cos 2\varphi_i}$$

$$\omega_i = 1, p_T^i, (p_T^i)^2$$

The reaction plane at the CMS can be determined independently by different detector subsystems and in different pseudorapidity windows.

CMS Calorimeters
ECAL and HCAL

$$tan(2\varphi_{rec}) = \frac{\sum_{towers} \omega_{tower} \sin 2\varphi_{tower}}{\sum_{towers} \omega_{tower} \cos 2\varphi_{tower}}$$

$$\omega_{tower} = E^{tower}, E_T^{tower}$$

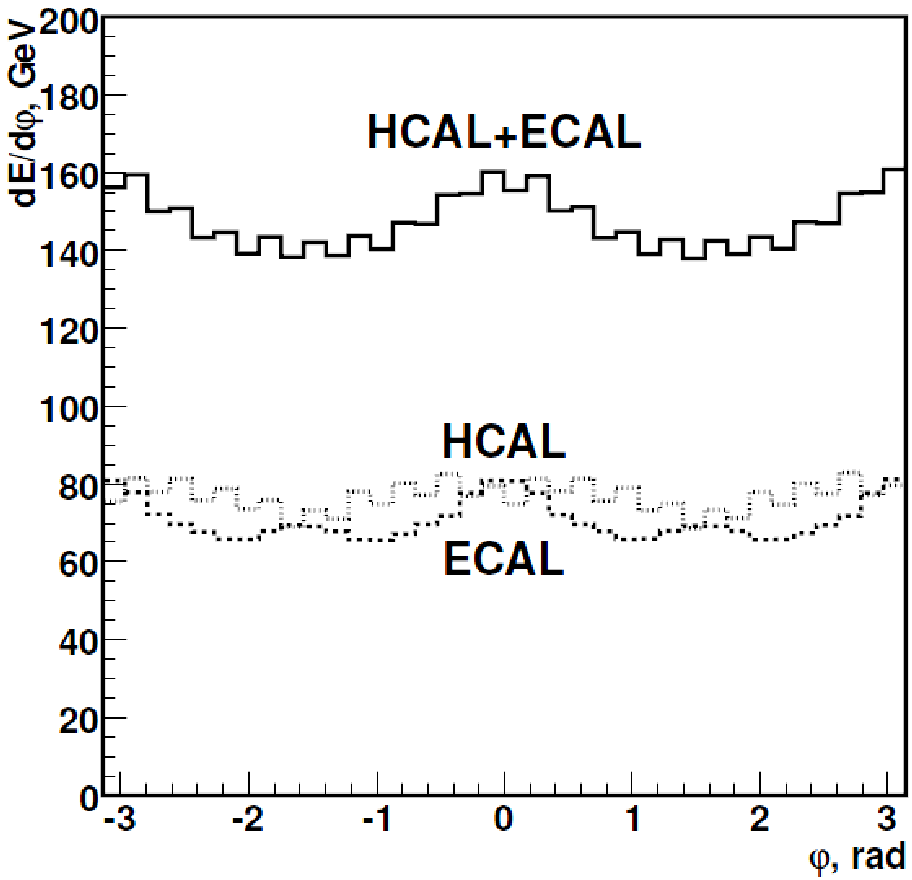
HYDJET generator was used to simulate PbPb events at the LHC.

I.P. Lokhtin and A.M. Snigirev, Eur. Phys. J. C 46 (2006) 211, http://lokhtin.web.cern.ch/lokhtin/hydro/hydjet.html

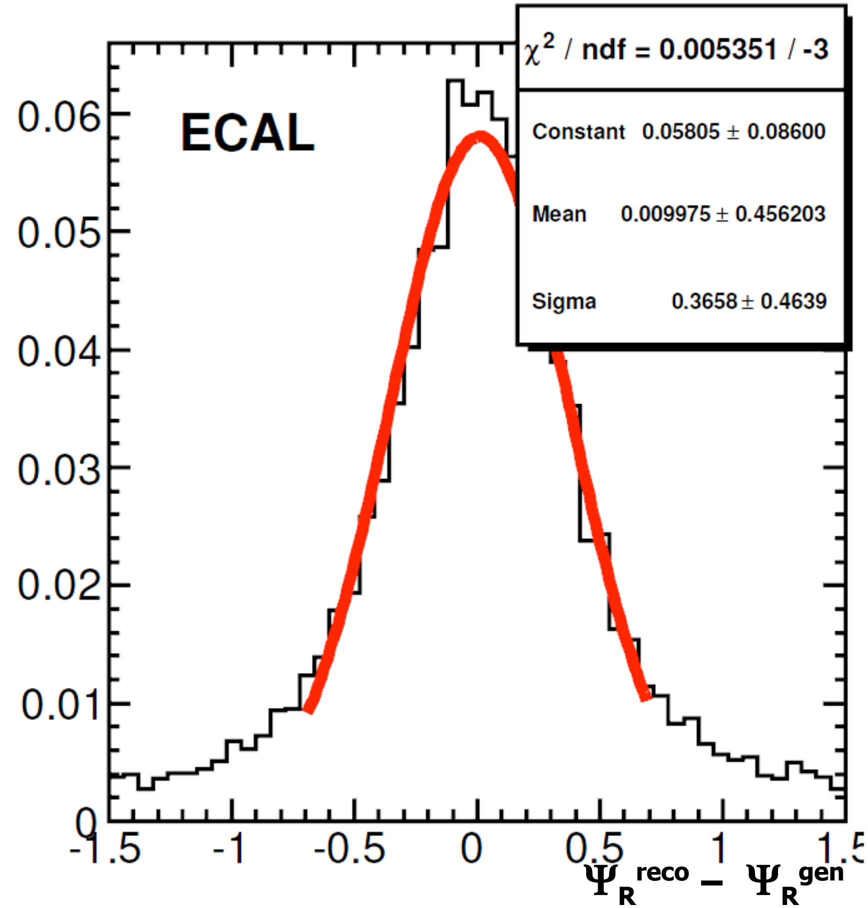
GEANT-based software was used to simulate CMS responses.

Reaction plane in CMS with calorimeter

PbPb, b=9 fm

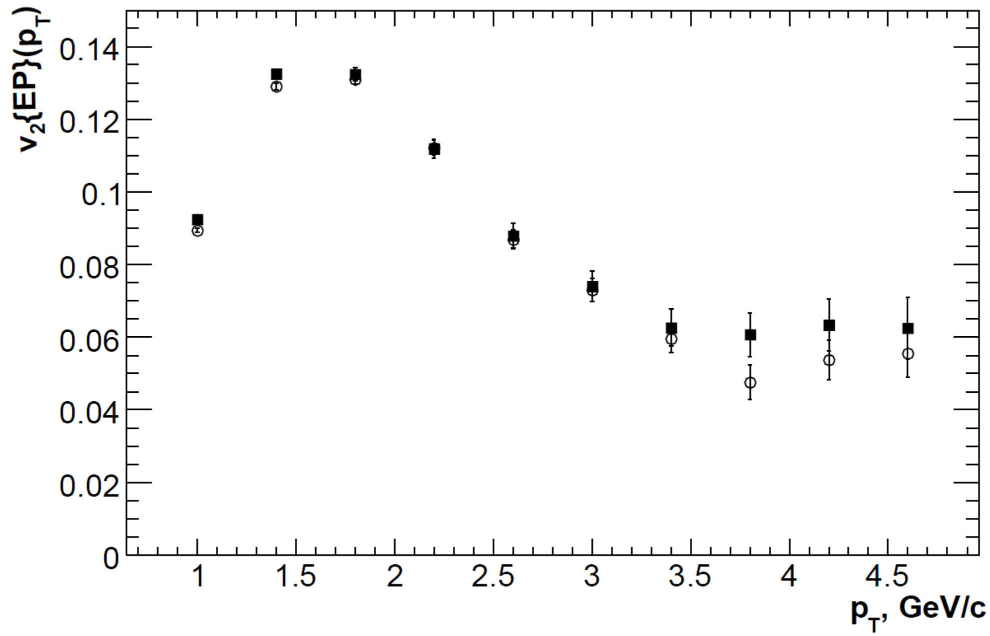


Azimuthal distribution of the reconstructed energy



Event plane resolution with ECAL: 0.37 radian

v_2 vs. p_T – CMS tracker, PbPb b=9 fm



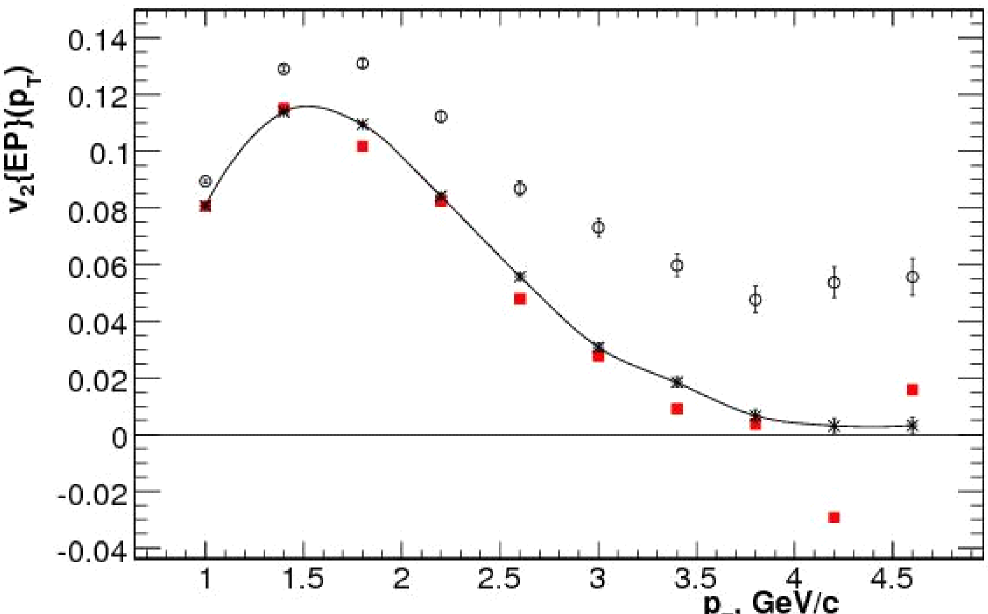
Tracks with p_T >0.9 GeV/*c*

○ - generated

■ - reconstructed

(by Event Plane method)

The uncertainties of the CMS Tracker detector is not higher than 3%



Methods of v_2 extraction

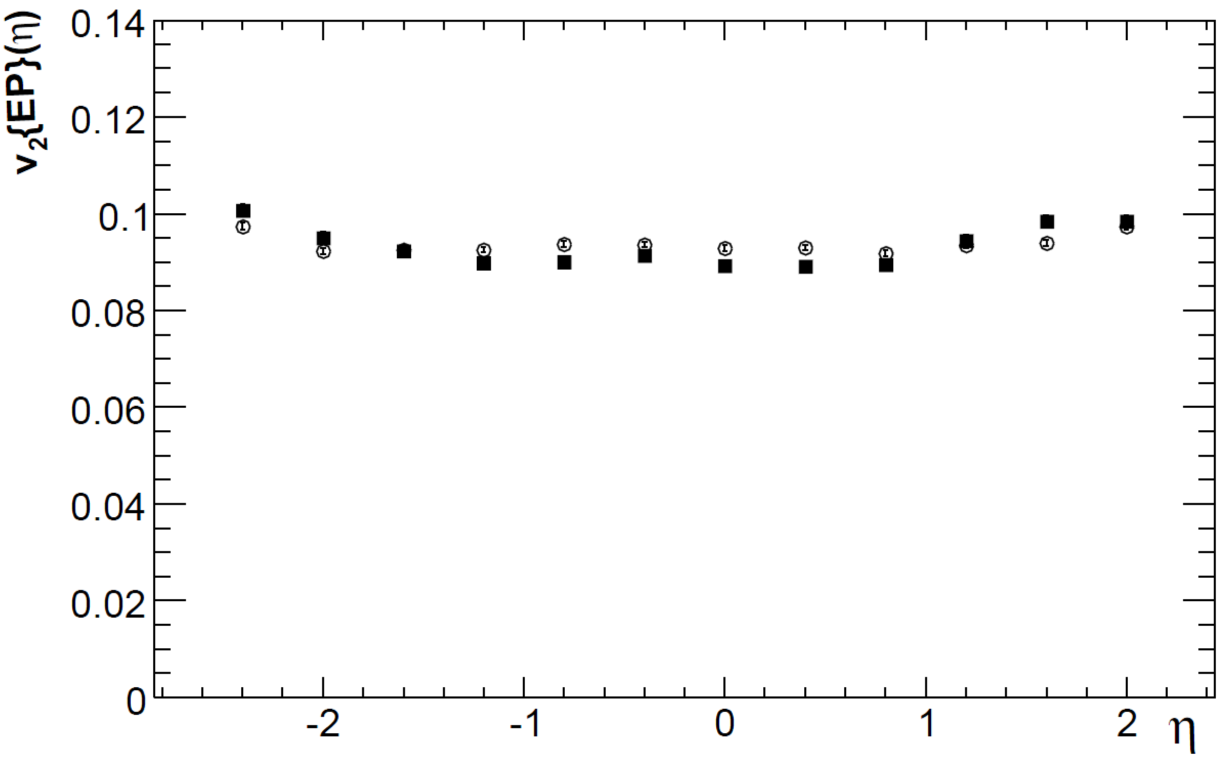
○ - $v_2\{EP\}$ in generated events

■ - original events

■ - Lee-Yang zeros method

Non-flow corrections

v_2 vs. η – CMS tracker
PbPb, b=9 fm



Tracks with p_T >0.9 GeV/*c*

○ - generated

■ - reconstructed

(by Event Plane method)

Summary

- ✓ v_2 study at LHC energy can give important information about quark matter.
- ✓ Heavy-ion collisions are expected at the LHC in the end of 2010.
- ✓ CMS detector at the LHC is ready to study elliptic flow by different detector subsystems, in different pseudorapidity windows and by different methods.

BACK UP

Materials about elliptic flow at the CMS

G.Kh.Eyyubova, V.L. Korotkikh, I.P. Lokhtin, S.V. Petrushanko, L.I. Sarycheva, A.M. Snigirev (SINP MSU, Russia) & David Krofcheck (Auckland, NZ)

- **CMS NOTE-2003/019, "Azimuthal Anisotropy and Jet Quenching in Heavy Ion Collisions with CMS Calorimetry"**
  http://cms-secr.web.cern.ch/cms-secr/documents/03/note03_019.pdf
- **Chapter 4 "Elliptic Flow" in PTDR Addendum "High Density QCD with Heavy Ions"**
  http://cdsweb.cern.ch/record/1019832/files/lhcc-2007-009.pdf
- **CMS AN-2007/004 "Azimuthal Anisotropy in Heavy Ions Collisions with CMS Tracker"**
  http://cms.cern.ch/iCMS/jsp/openfile.jsp?tp=draft&files=AN2007_004_v4.pdf
- **Quark Matter 2008 Proceeding**
  http://cms.cern.ch/iCMS/jsp/openfile.jsp?type=CR&year=2008&files=CR2008_022.pdf