Monte Carlo Tools in ALICE

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CER/EP

Workshop on Monte Carlo Tools at the LHC
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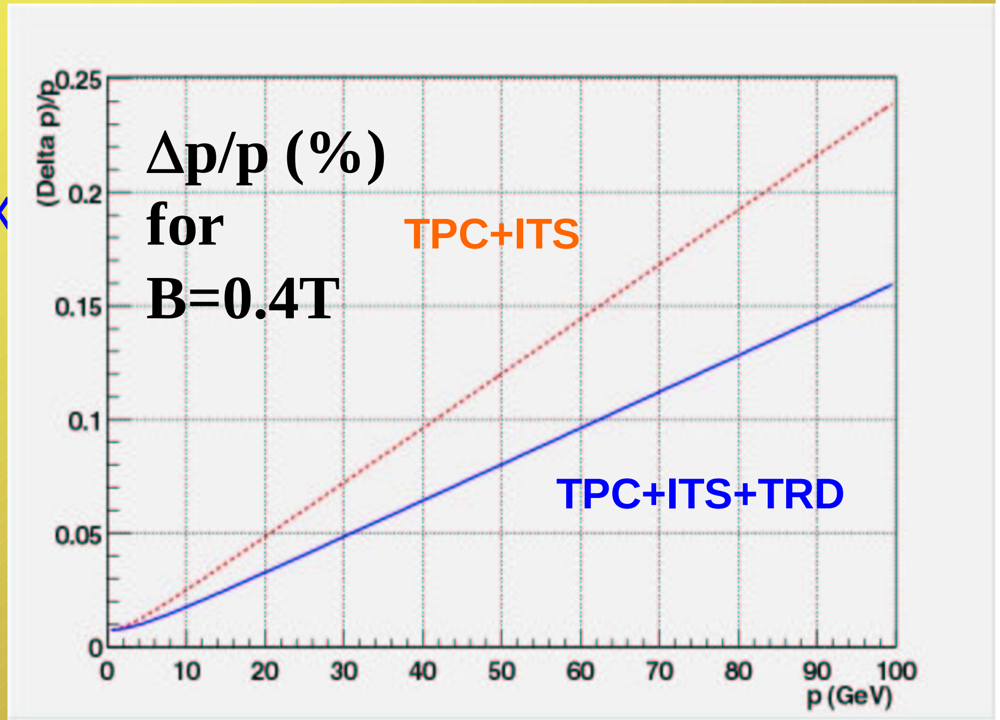
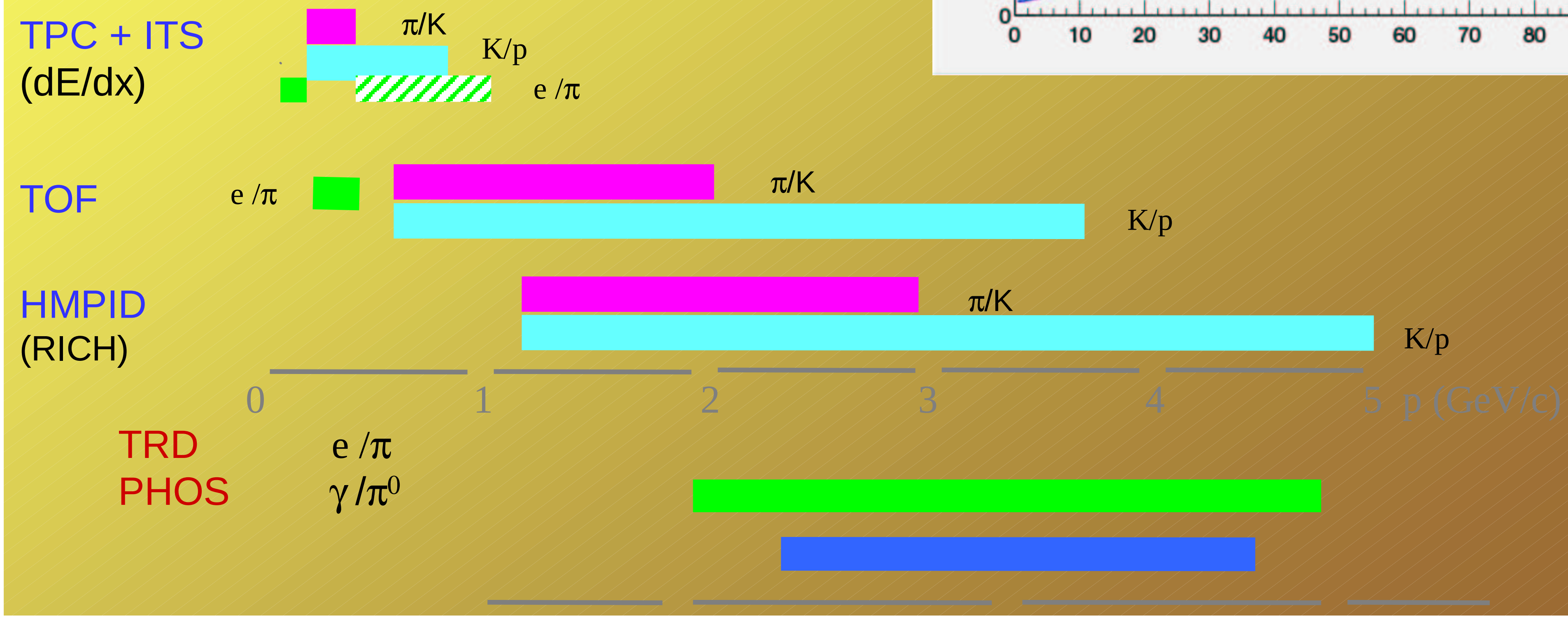
Topics

- Alice in short
- ALICE Simulation Strategy
- Simulation and Observables
  - Event Geometry
  - Particle Multiplicities
  - Particle Spectra
  - Particle Correlation
  - Heavy-Quarks
  - Quarkonia
  - Jets

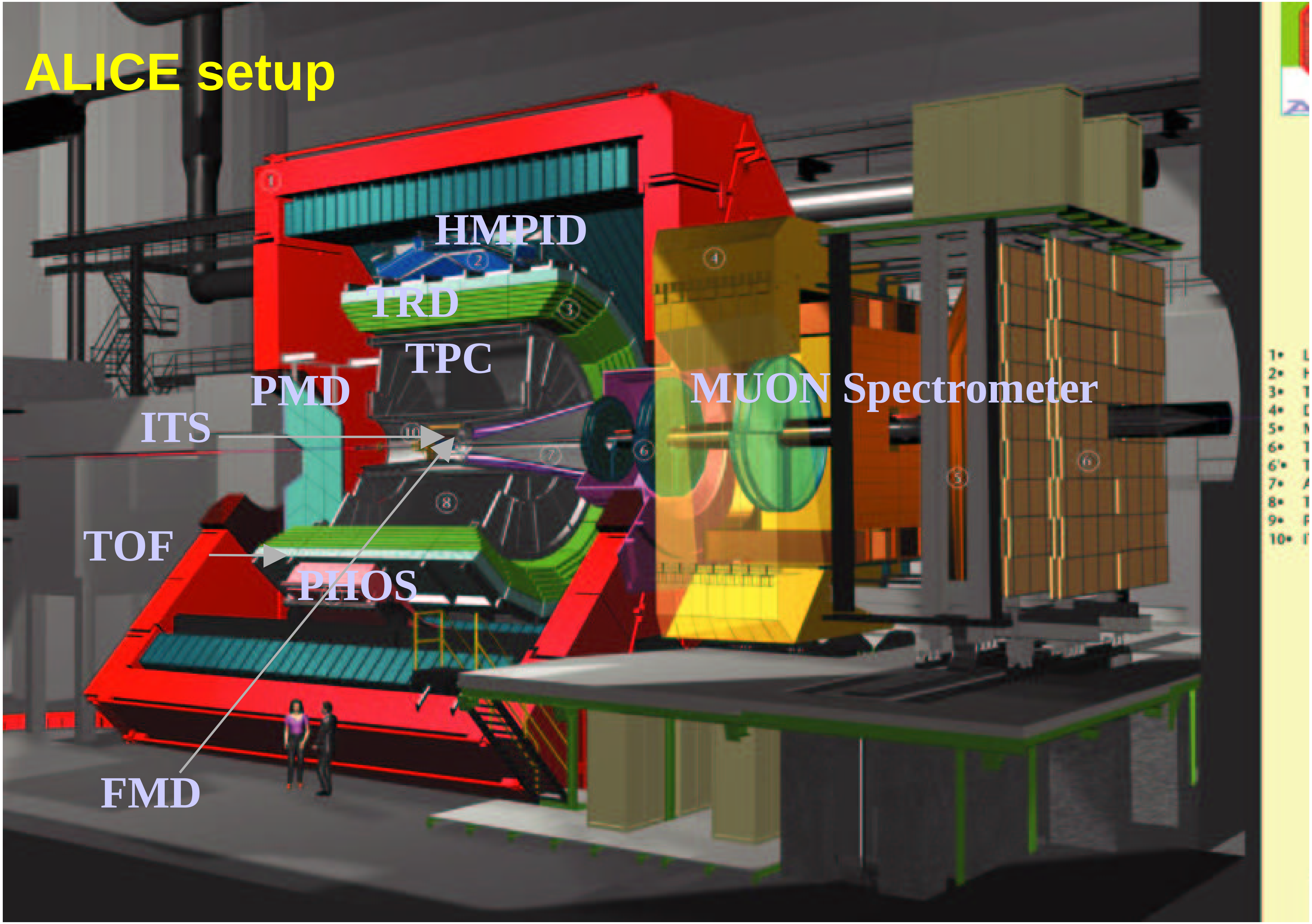
ALICE in short

- A multipurpose experiment, with excellent tracking and secondary vertex capability, electron and muon detection and high resolution γ spectrometer. Unique Particle Identification complex.





ALICE setup



Simulation in ALICE

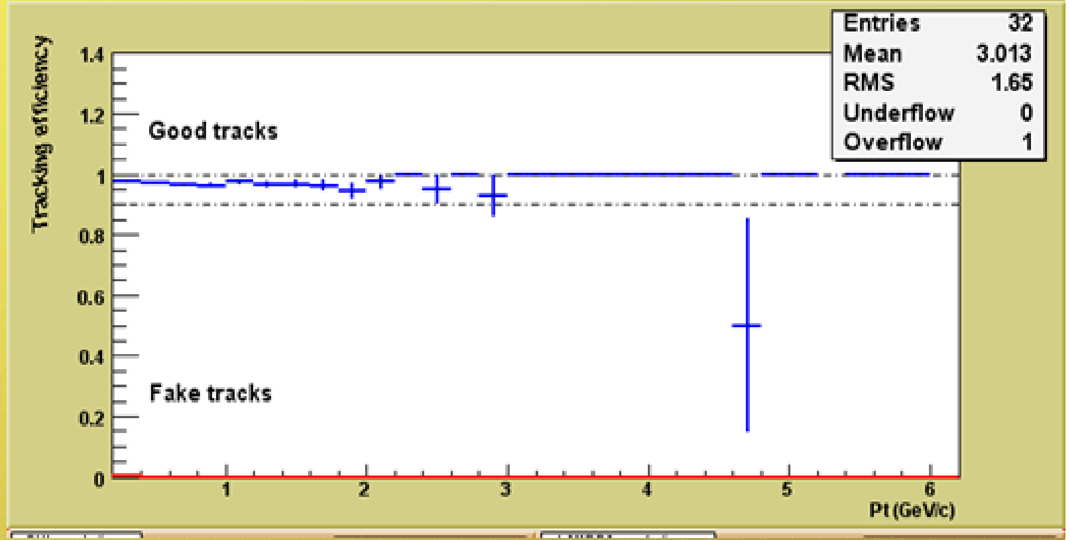
- Coherent simulation framework for detector and physics performance studies in the object oriented AliRoot Framework based on ROOT comprising
  - Physics simulation
  - Detailed detector response simulation
  - Fast simulation

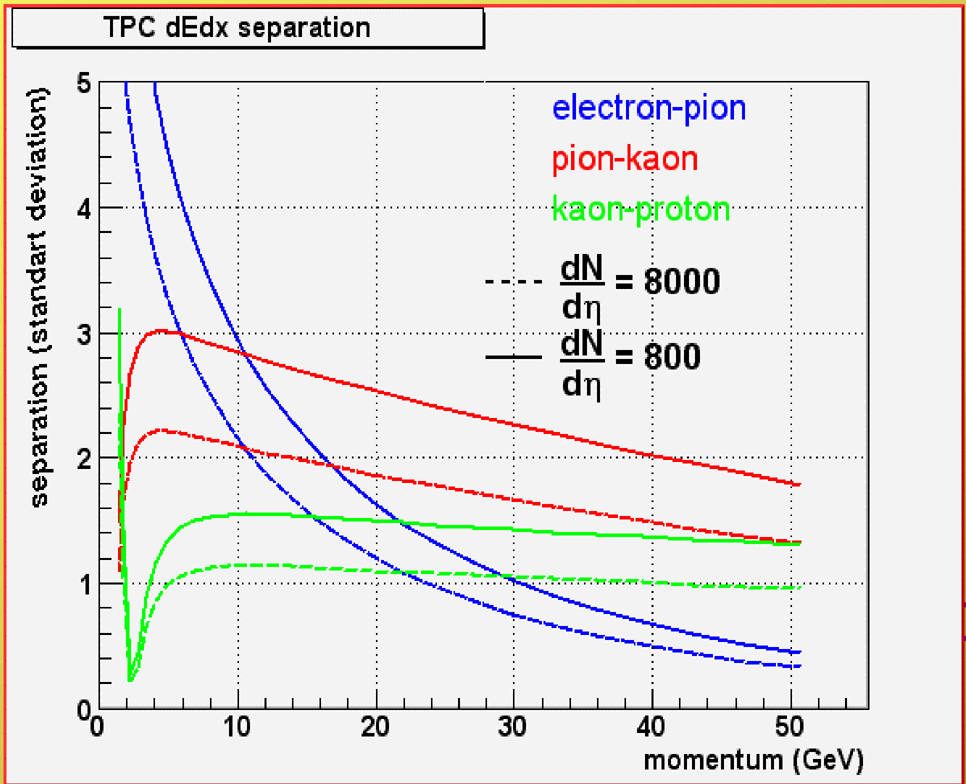
Event simulation strategy

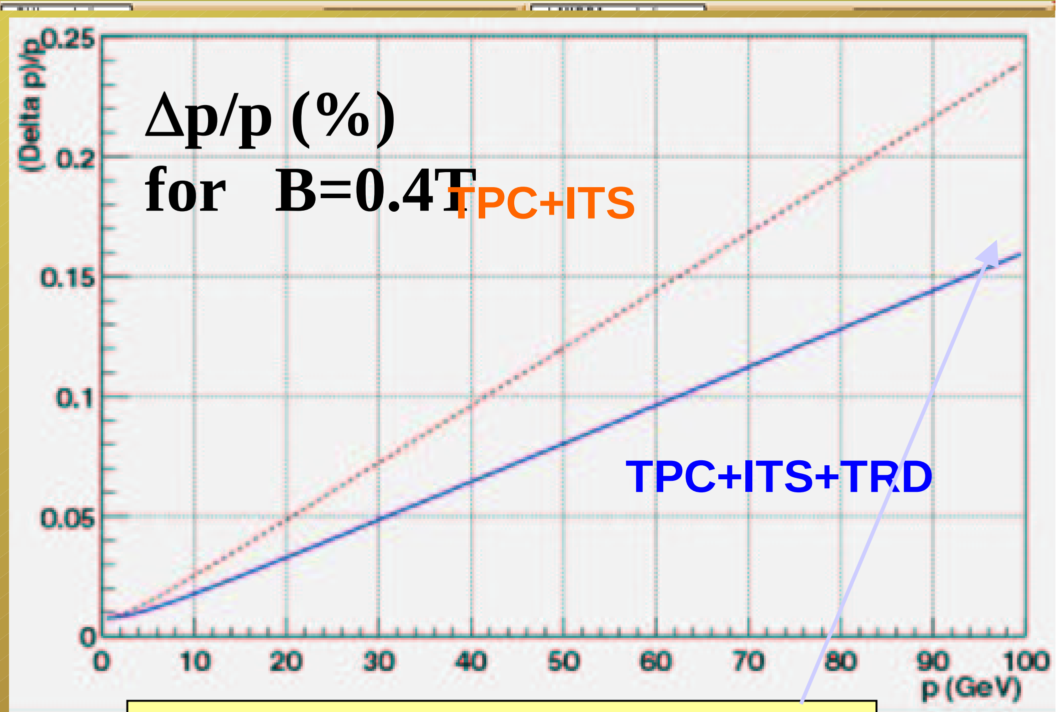
- ***The simulation framework provides an interface to external generators, like HIJING and DPMJET.***
- ***A parameterised "signal free" underlying event with multiplicity as a parameter is provided.***
- ***Rare signals can be generated using***
  - ***External generators like PYTHIA***
  - ***Libraries of parameterized p_t and rapidity distributions***
- ***The framework provides a tool to assemble events from different signal generators***
  - ***On the primary particle level (cocktail)***
  - ***On the digit level (merging)***
- ***After-Burners are used to introduce particle correlations.***

Examples: Performance

- Detector Performance
  - ‘parallel’ Kalman filter tracking







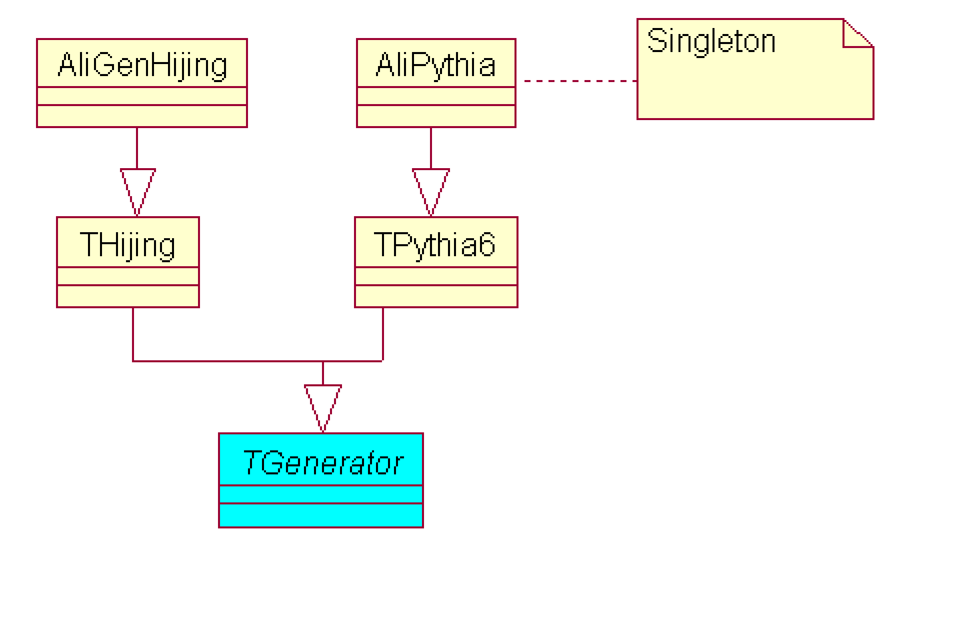
Δp/p ~ 16% at 100 GeV

(~ 11% at dN/dη =

Tracking/PID Performance

- Proof performance up to dN/dy = 8000
- Study as a function of multiplicity
- Use parameterized events (pt, eta) with multiplicity as a parameter

Event Generator Interfaces: External Generators



- Interface to external generators using the TGenerator class from ROOT
- Interfaced generators can be used interactively from the ROOT command-line

External Generators: HIJING

- HIJING
  - HIJING (Heavy Ion Jet INteraction Generator) combines a QCD-inspired model of jet production with the Lund model for jet fragmentation. The HIJING model has been developed with special emphasis on the role of mini jets in pp, pA and A A reactions at collider energies.

HIJING

- So far the only generators used in production
- Hijing used in ALICE for
  - Underlying event simulation
    - Realistic fluctuations (N,E) from jets
    - Pessimistic multiplicity (dN/dy ~ 6000)
  - Particle Correlation studies
    - Inclusive
    - Reconstructed jets
  - Nuclear effects
    - Shadowing
    - Quenching (parton energy loss)

External Generators: DPMJET

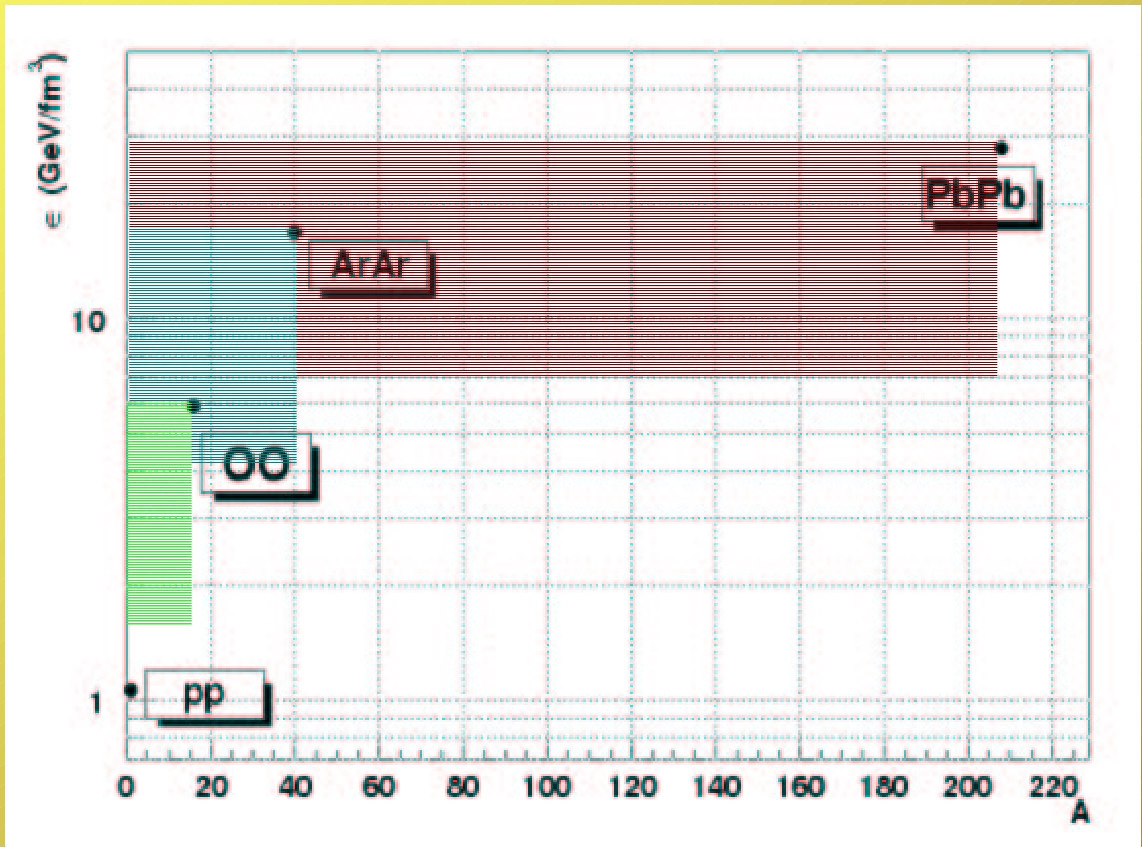
- DPMJET
  - DPMJET is an implementation of the two-component Dual Parton Model for the description of interactions involving nuclei based on the Glauber-Gribov approach. DPMJET treats soft and hard scattering processes in an unified way. The fragmentation of parton configurations is treated by the Lund model PYTHIA. (see talk by J. Ranft during HI session)

External Generators: SFM

- SFM (String Fusion Model)
  - The soft interactions are described by the Gribov-Regge theory of multipomeron exchange. The hard part of the interaction is simulated by PYTHIA and the strings formed by gluon splitting are fragmented with JETSET. Fusion of soft strings is included. Fragmentation is through the Artru-Mennessier string decay algorithm.

Heavy Ion Runs at the LHC

- Highest energy density in PbPb collisions
- Modify energy density using lower A ions
- Need for pA collisions to understand initial and final state modifications in hadronic medium

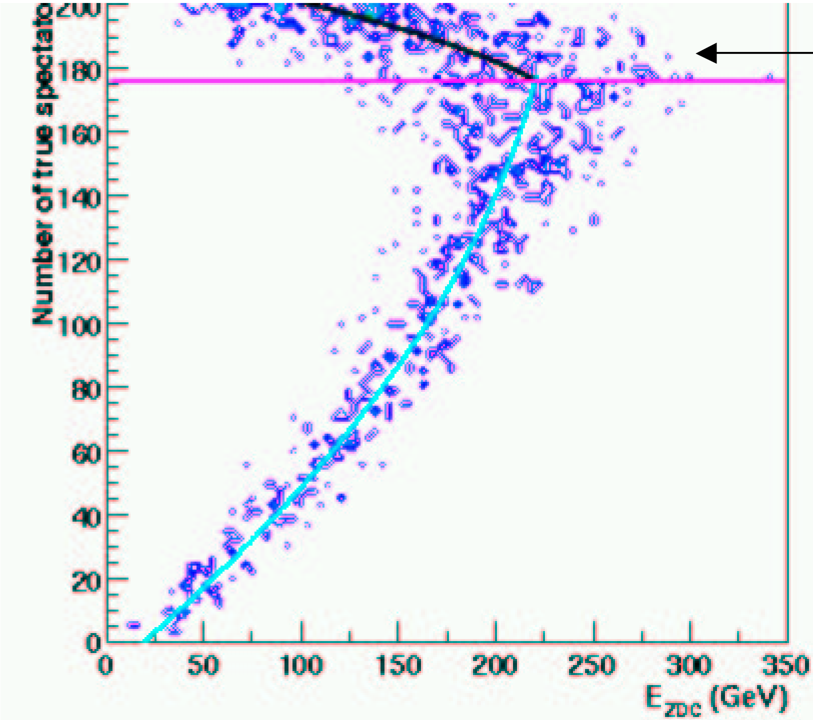


Priorities in first 5 years of running
- PbPb
- pPb
- ArAr

Need for MC Programs for
- pp, pA, AA
- Initial and final state nuclear modifications (shadowing, quenching) as function of impact parameter

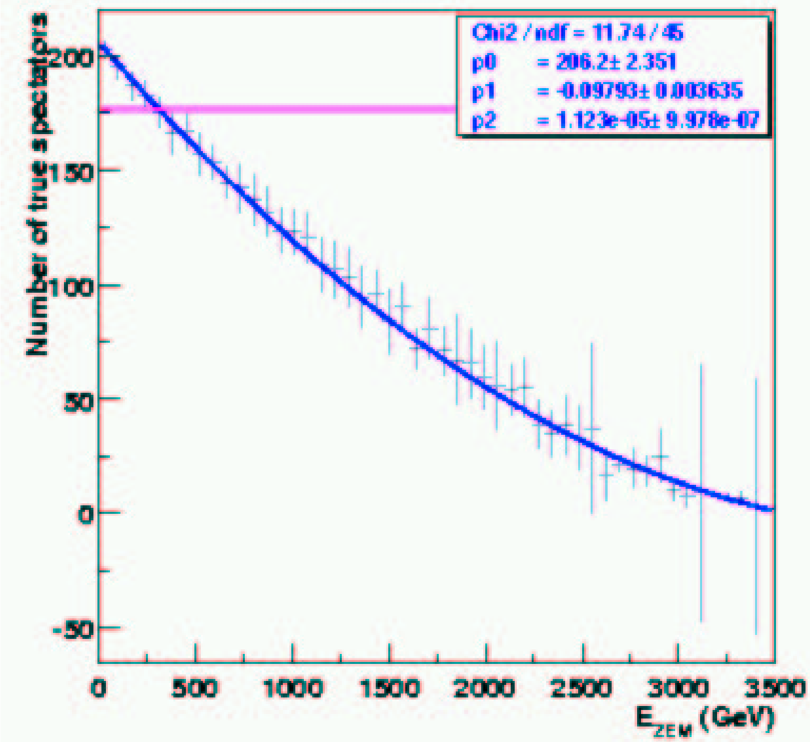
Event Geometry

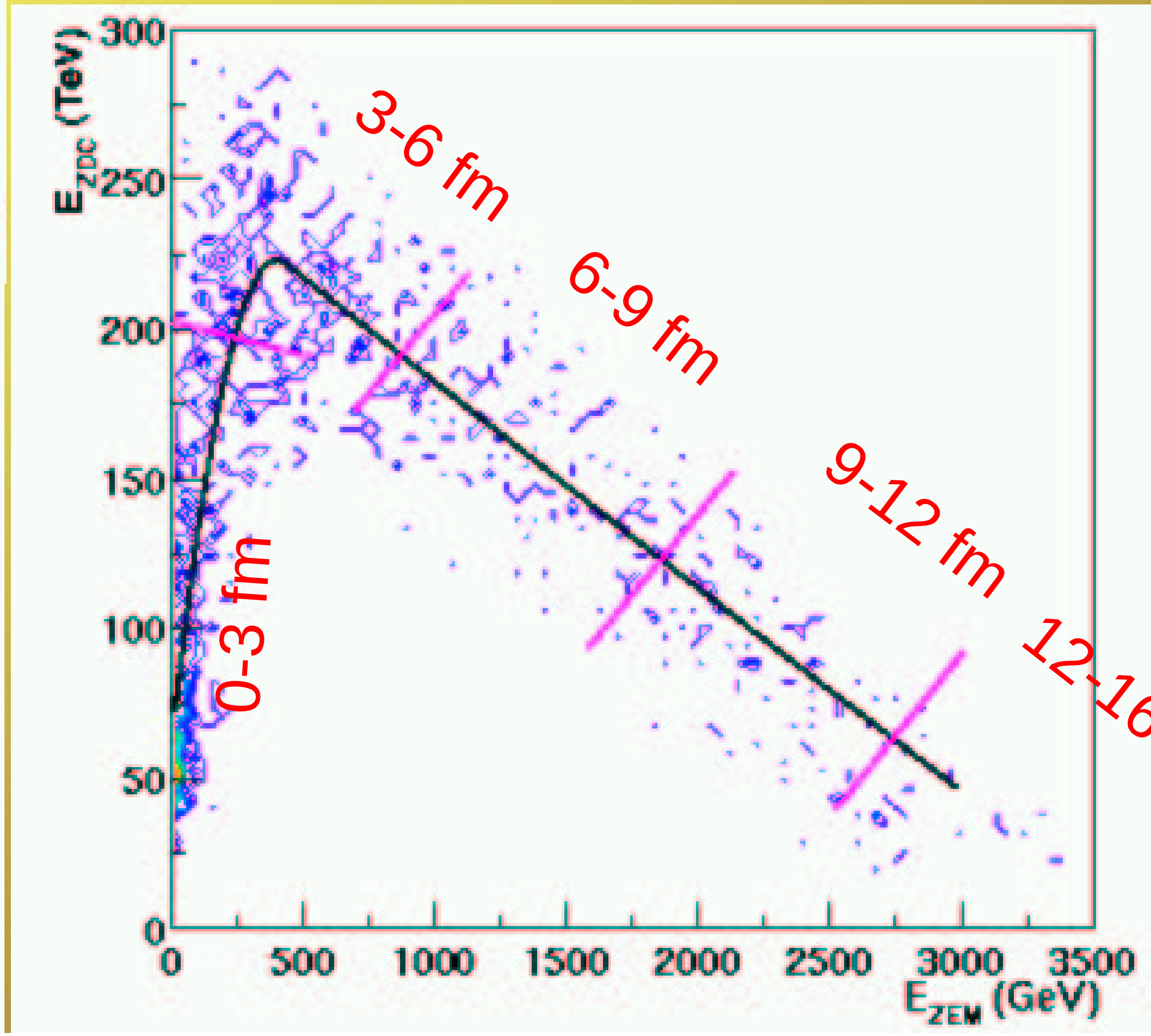
- Maximum energy density reached in central collisions
- Determine centrality of collision
  - Impact parameter b
  - Number of participants N_{part}
- Study observables as a function of impact parameter to see the onset of anomalous phenomena



Importance of correct simulations of fragments.

Remove spectator nucleons from HIJING and replace by fragments from phen. model



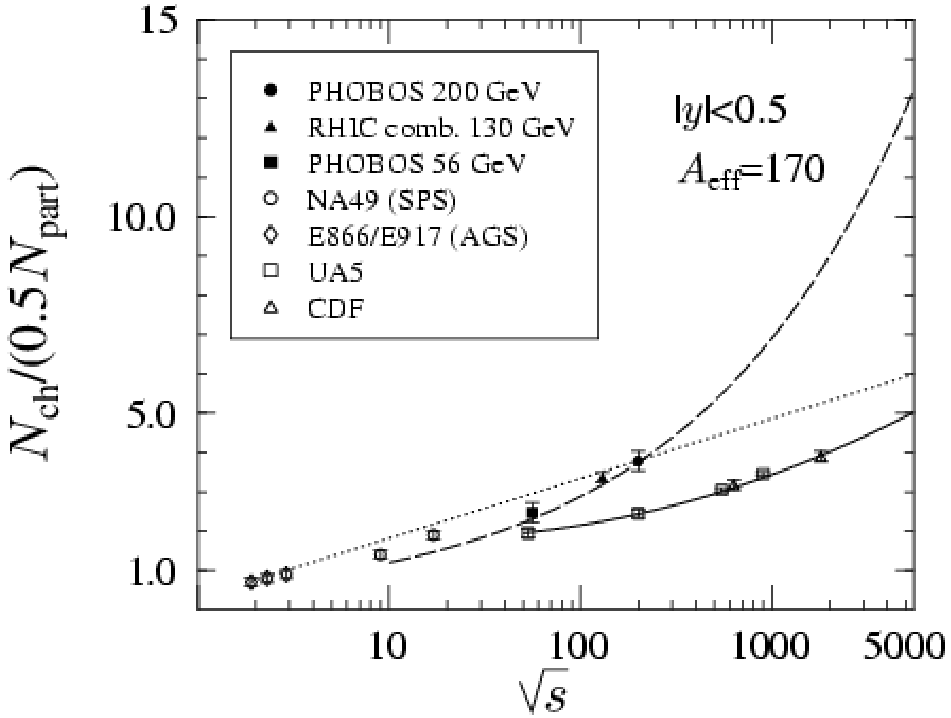


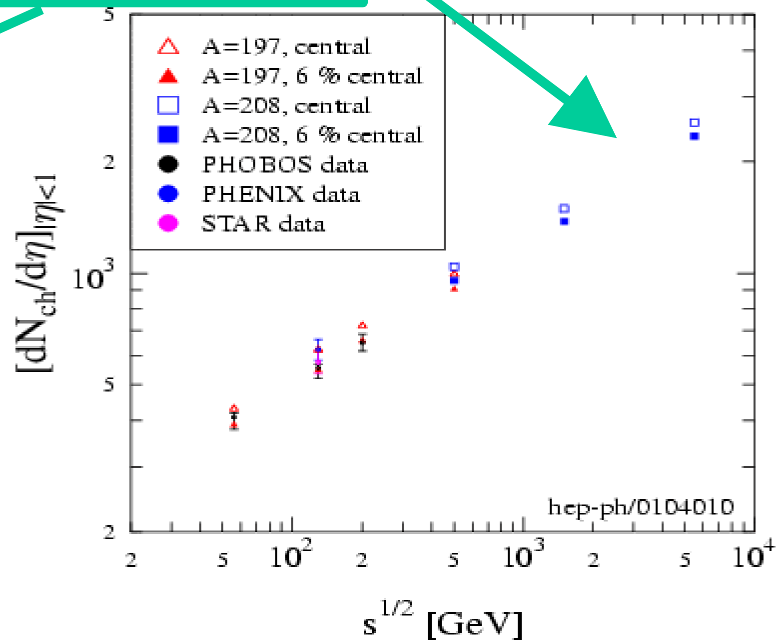
Particle Multiplicities

- The average charged particle multiplicity per rapidity unit (rapidity density dN_{ch}/dy) is the most fundamental day-one observable.
- It is related to the attained energy density.
- Can not be calculated from first principles.
- Large uncertainties for the LHC

Particle Multiplicity

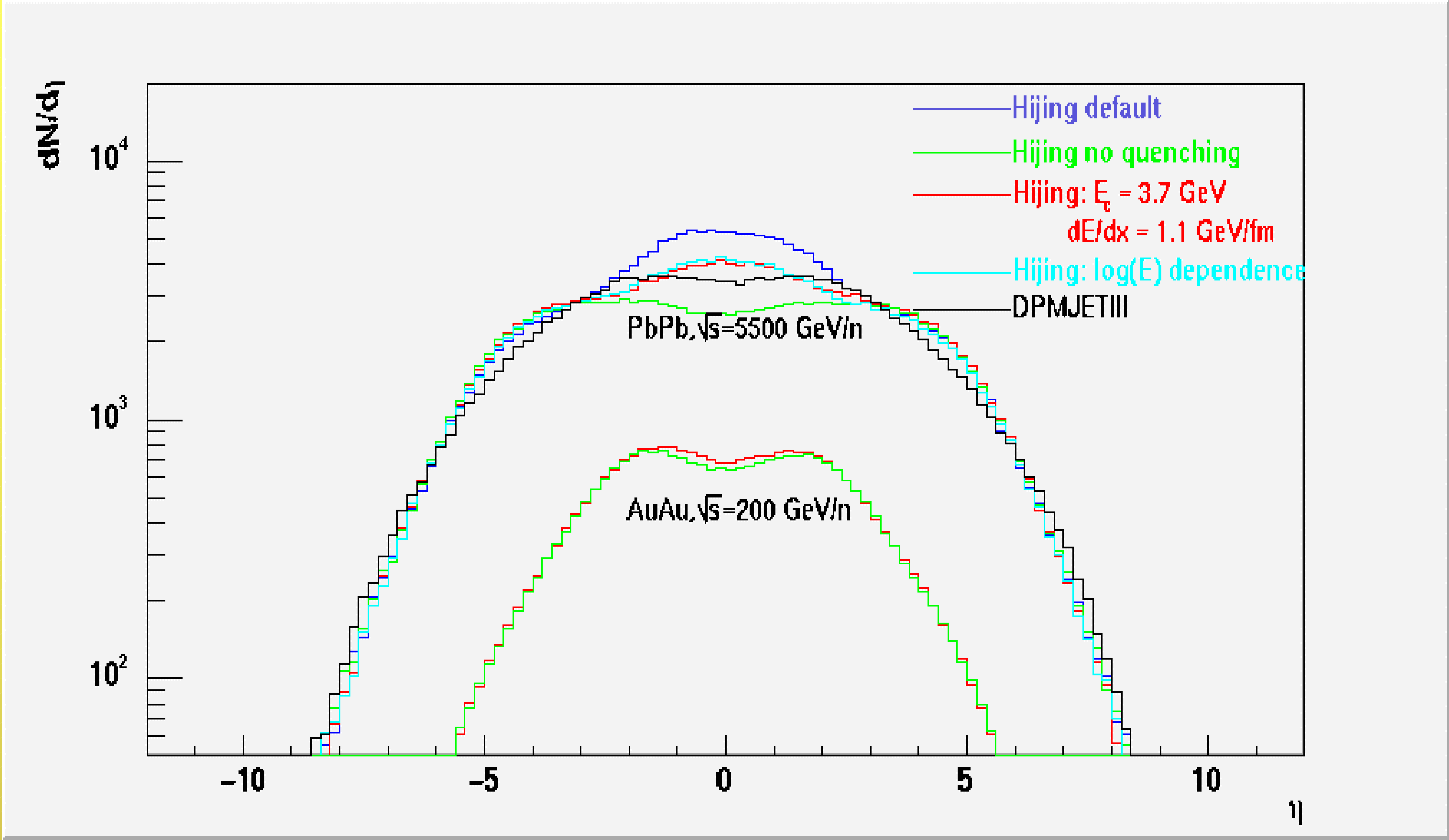
$dN_{ch}/d\eta \sim 2500$





(from K.Kajantie, K.Eskola)

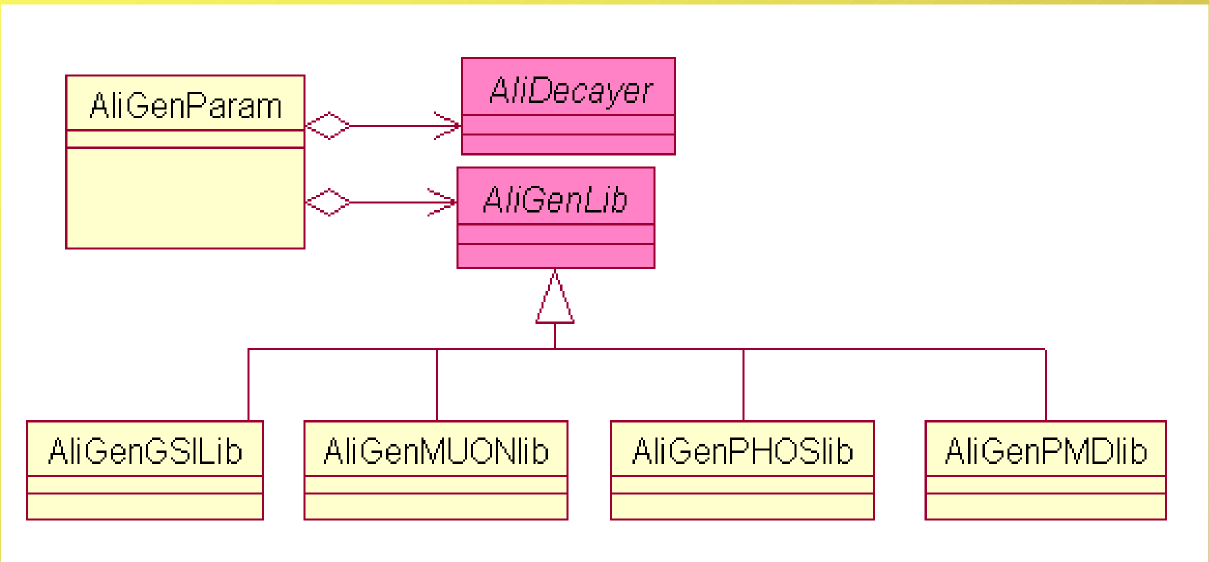
Multiplicity:
HIJING and DPMJET



Particle Spectra (soft)

- Measure particle production in region $0 < m_t < 2$ GeV
  - Constraints for the dynamical evolution
  - Indirect information about early stages of the collision
- Shape
  - Related to temperature and collective (transverse) flow
  - Kinetic freeze-out
- Hadron yields (absolute and relative)
  - Extrapolation to p_T=0 needed
  - Chemical freeze-out
- Elliptic flow and early pressure
  - Initial anisotropy of collision zone gets transferred to momentum space (early pressure)

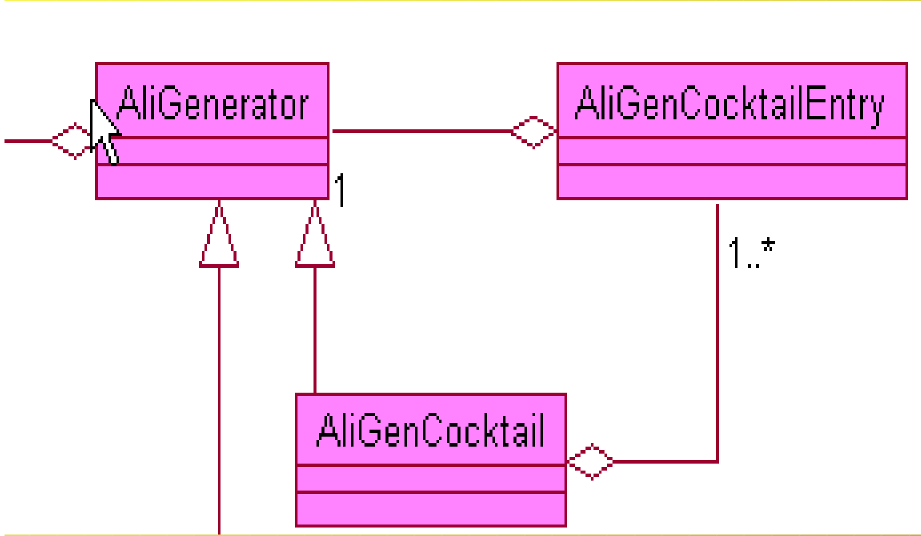
Event Generator Interfaces: Parameterisations



- Interface to parameterisations and decayer.

- Plugin libraries for transverse momentum and rapidity distributions

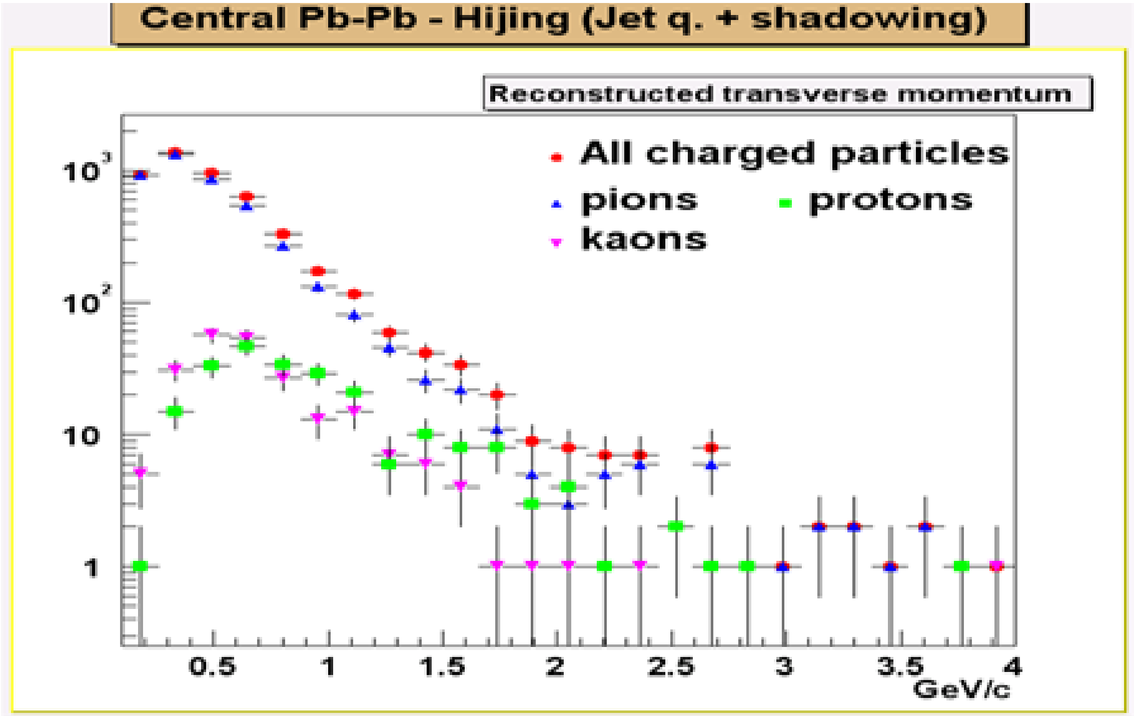
Event Generator Interfaces



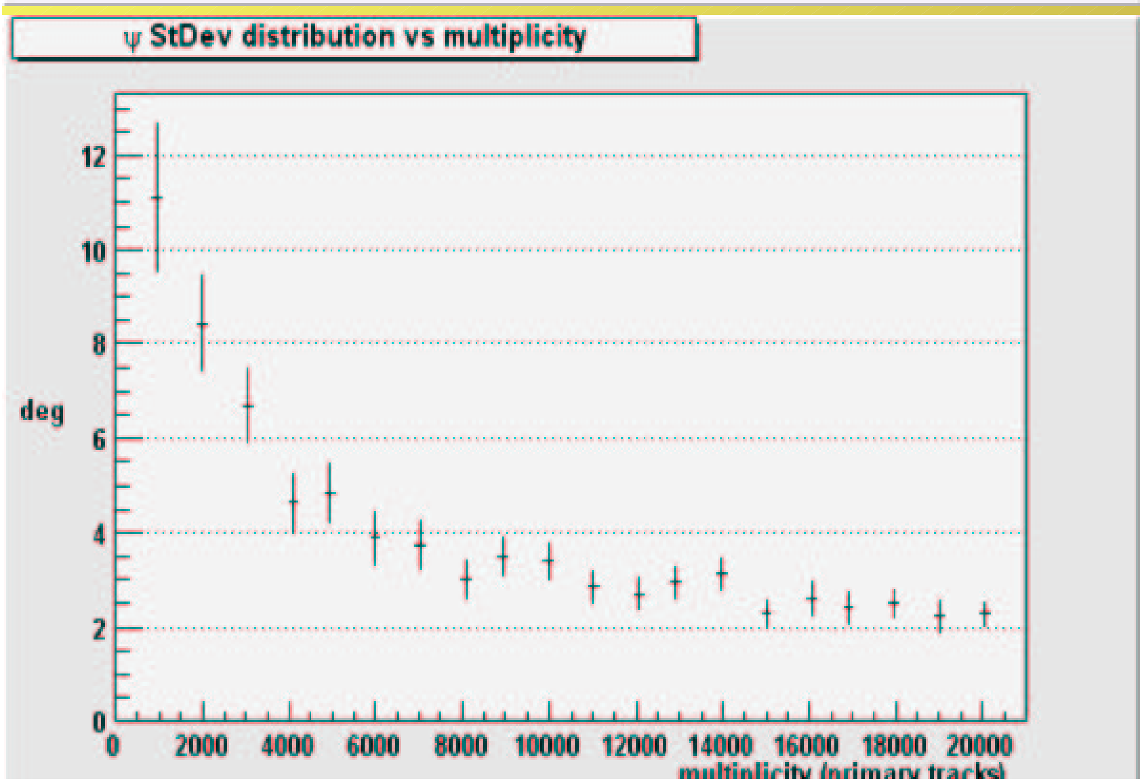
- Cocktail class to assemble events, for example:
  - Underlying event + hard process
  - Different muon sources
  - pA + slow nucleons

Afterburner Processors

- Introduction of correlations in otherwise uncorrelated events
  - 2 particle correlations
  - Flow
- Design of classes involved in event generation (*AliRun*, *AliStack*, *AliGenerator*) supports requirements for Afterburner
- (see talk be P. Skowronski during HI Session)



Single event transverse momentum spectra

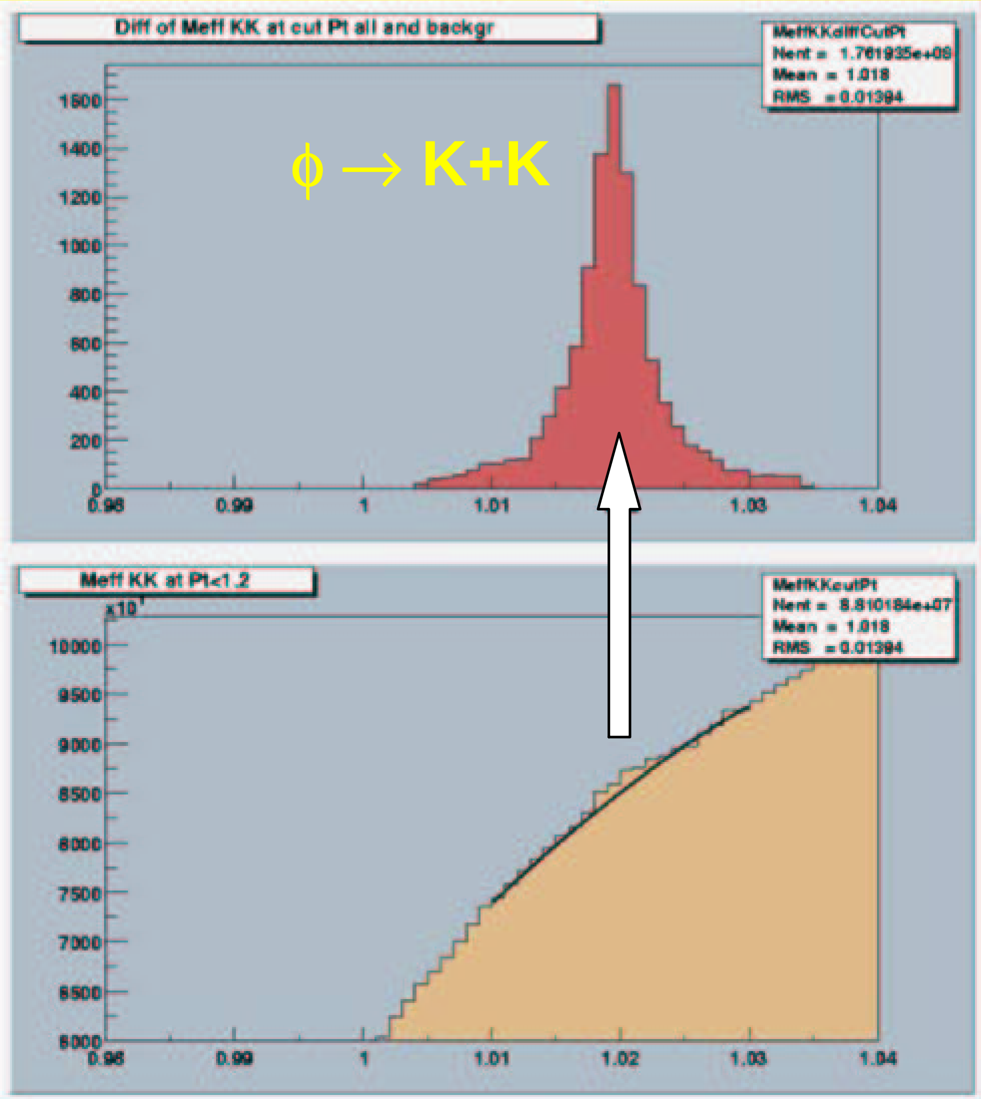


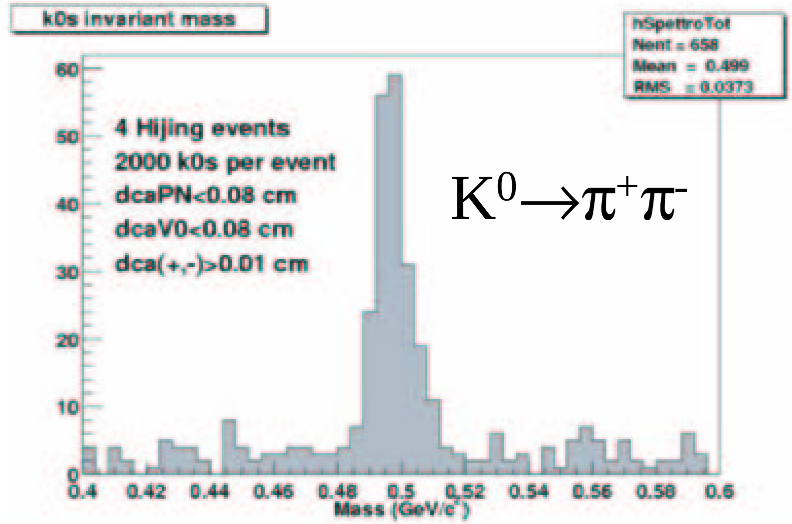
Event plane resolution

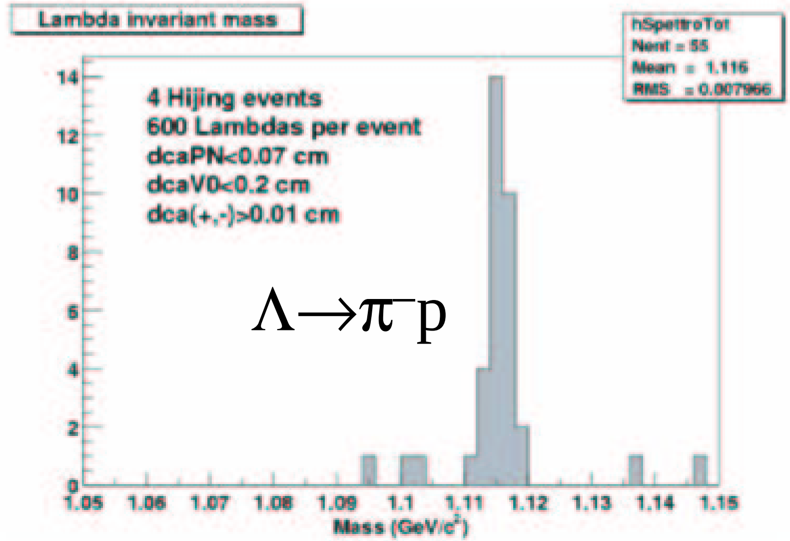
- Event plane can be determined event by event.

Hadronic Observables

π,η,ω,φ,p,K,K*, Λ, Ξ, Ω, D, d, T, α, ..





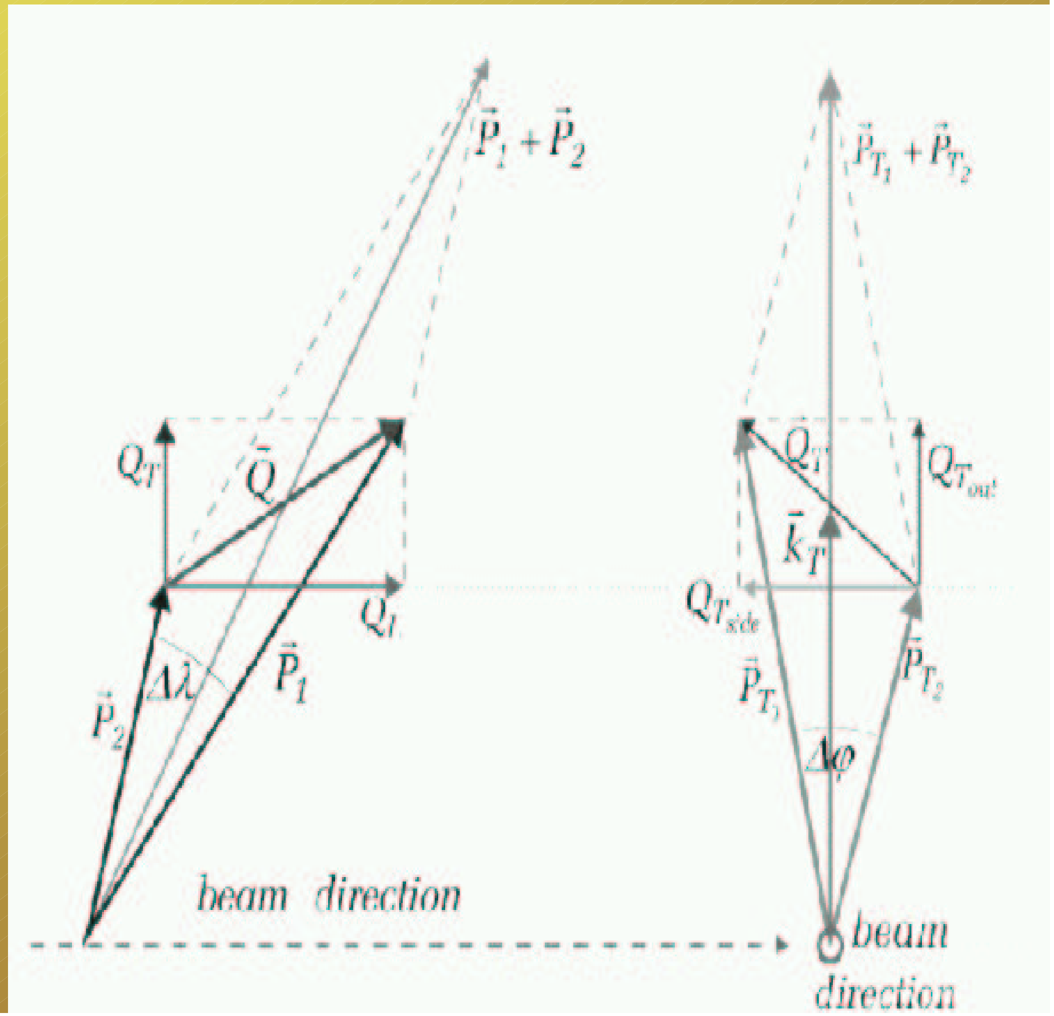


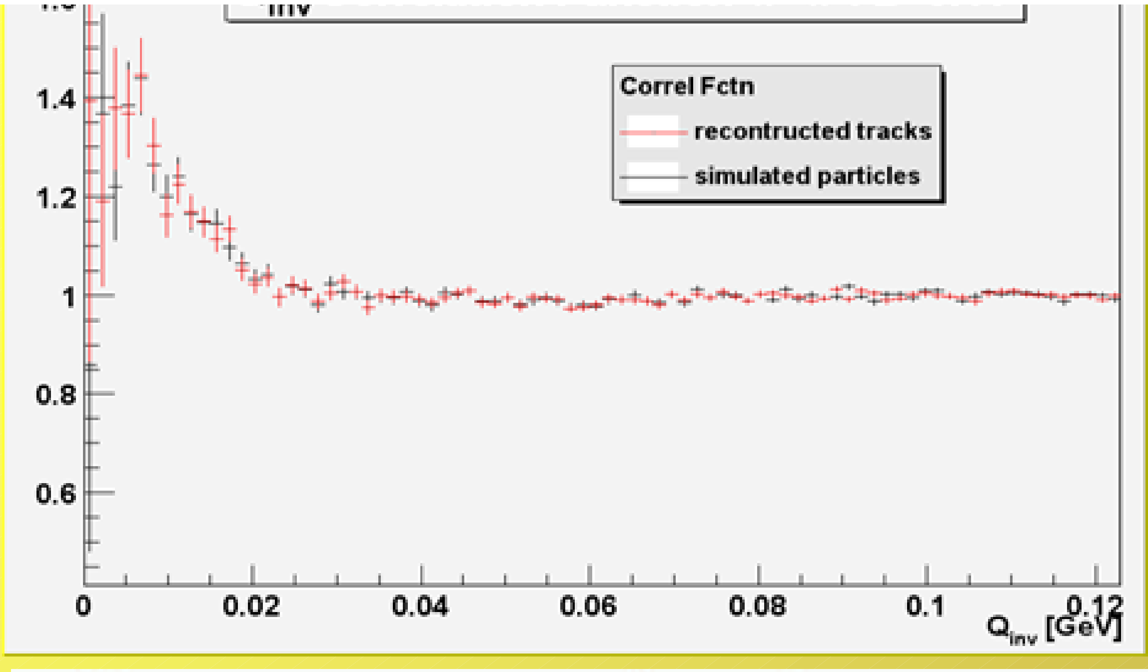
Reconstruct (dN/dy ~6k):

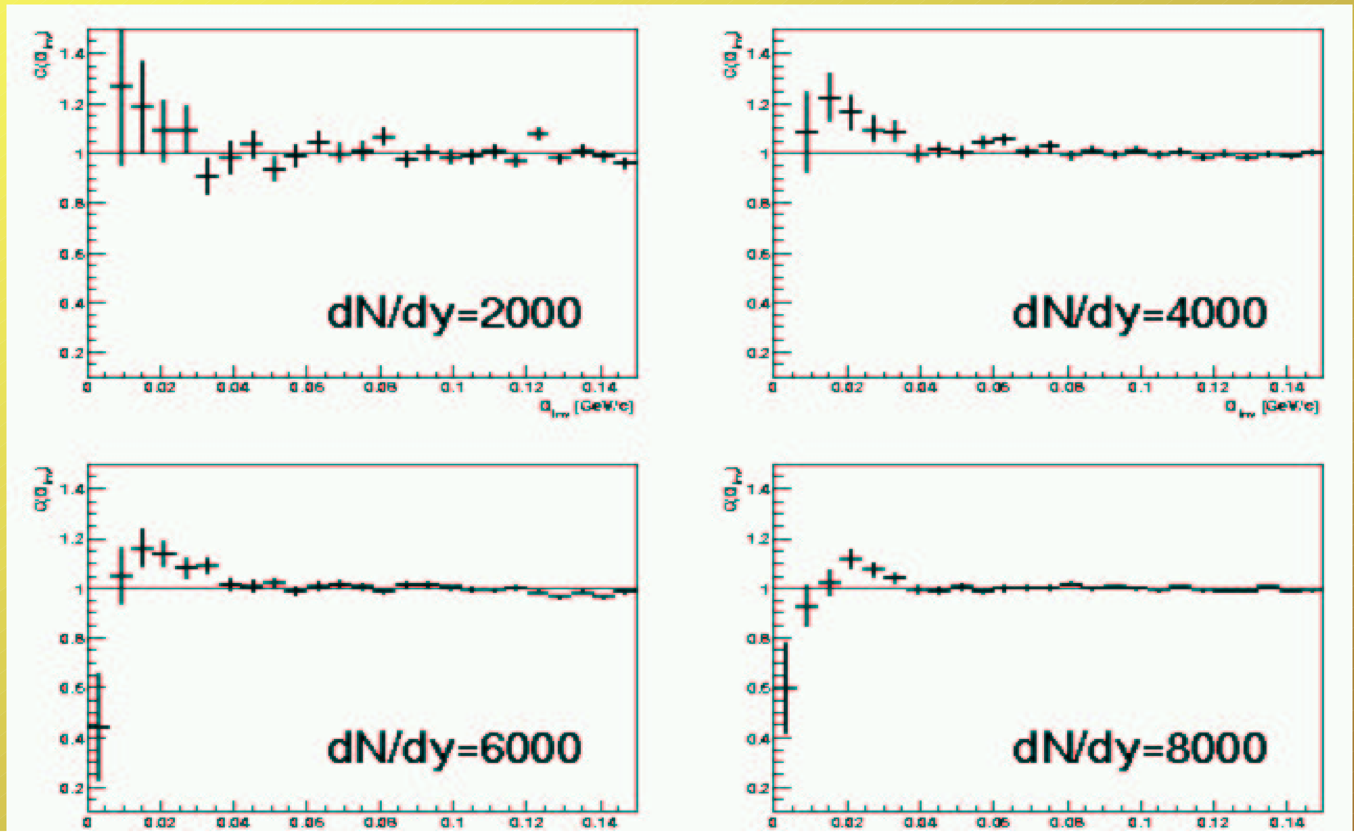
~ 30 K^0/central event, ~ 3 Λ/central event

Particle Correlations

- Space time evolution of hot and expanding system created in HI collisions is studied using momentum correlation of particles emitted with close velocities.
  - Particle interferometry (HBT)
- Particle correlations due to
  - Quantum statistics
  - Final state interactions
- Dependence on space-time distance of emission points







Single event correlation function

Particle Spectra (hard)

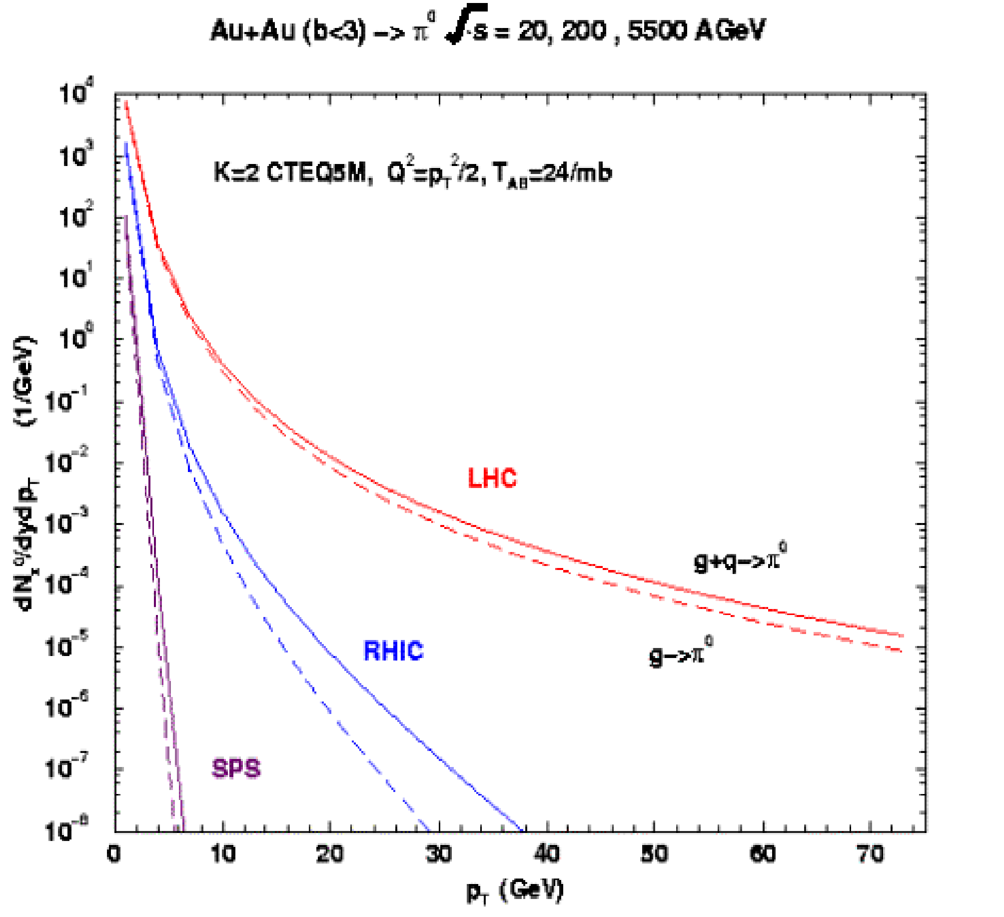
Dominant processes in particle production

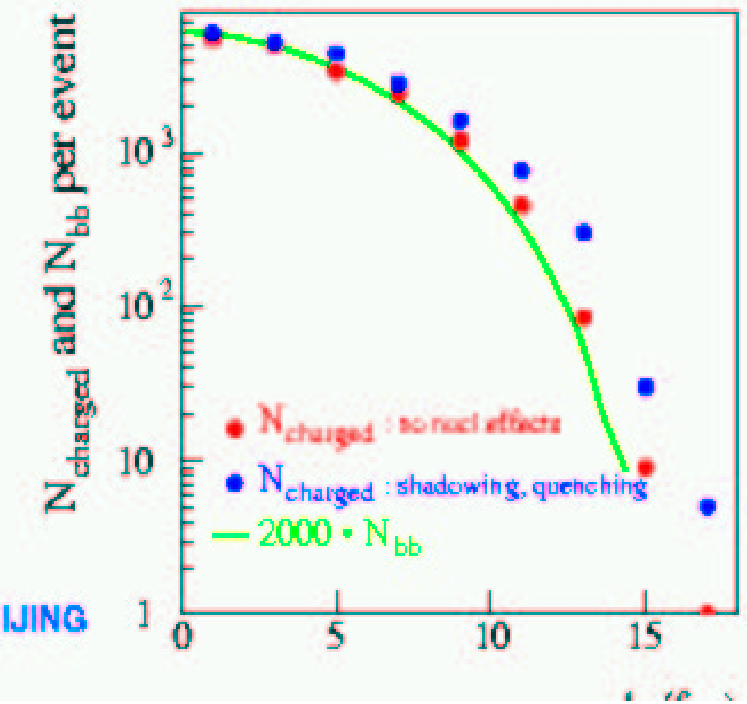
SPS: soft

RHIC: soft and semi-hard

LHC: semi-hard and hard

High p_t important in order to leave even tails of 'hydrodynamics'





$N_{charged}$ from HIJING

Hard Probes

- Sensitive to early stage of Heavy Ion Collision
- To be studied
  - Production cross-section of heavy quarks
  - Direct Photons
  - Attenuation of heavy quark resonances or even enhancement ?
  - Energy loss of partons in nuclear matter
- As a function of
  - Transverse momentum
  - Energy density (collision system)
  - Compare pp/pA/AA

Charm and Beauty

- Motivation: measurement of c and b total cross-section and spectra
  - Acceptance at low p_t
  - Possible 'charm enhancement' - centrality dependence
- Open charm detection in hadronic decays
  - $D^0 \rightarrow \pi K$ and $D^+ \rightarrow \pi\pi K$
- Charm and Beauty detection using inclusive semileptonic decays
  - electrons with large impact parameter
- Charm and Beauty detection via e-μ coincidence

ALICE's Heavy Quark Shopping List

probe	channel	acceptance
$J/\psi, \psi', \Upsilon, \Upsilon', \Upsilon''$	e^+e^-	$\lvert\eta\rvert < 0.9$
$J/\psi, \psi', \Upsilon, \Upsilon', \Upsilon''$	$\mu^+\mu^-$	$2.5 < \eta < 4$
$c\bar{c}$ & $b\bar{b}$	e^+e^-	$\lvert\eta\rvert < 0.9$
$c\bar{c}$ & $b\bar{b}$	$\mu^+\mu^-$	$2.5 < \eta < 4$
D mesons	π,K	$\lvert\eta\rvert < 0.9$
B mesons	$B \to J/\psi \to e^+e^-$	$\lvert\eta\rvert < 0.9$
D & B mesons	single $e^\pm$	$\lvert\eta\rvert < 0.9$
$c\bar{c}$ & $b\bar{b}$	$e^\pm\mu^\mp$	$1 < y < 3$

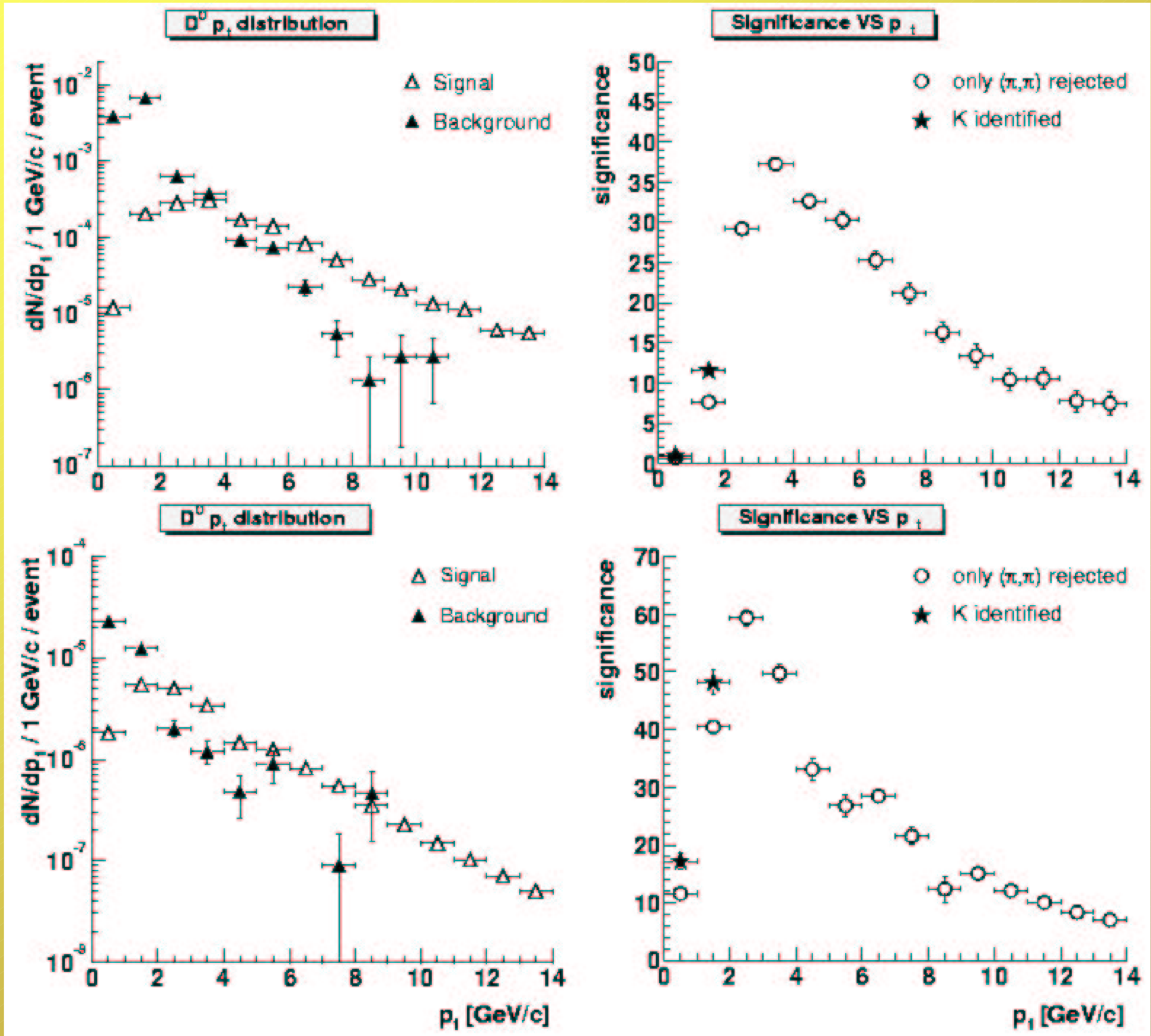
Simulation of Hard Probes

- Hard Probes (see talk by A. Dainese during HI session)
  - Pythia tuned to NLO (MNR)
  - NLO topology
  - Modification of nuclear structure functions via EKS in PDFlib (see talk by C. Salgado during HI session)

Hadrons: $D^0 \rightarrow K^- \pi^+$

Pb-Pb

pp



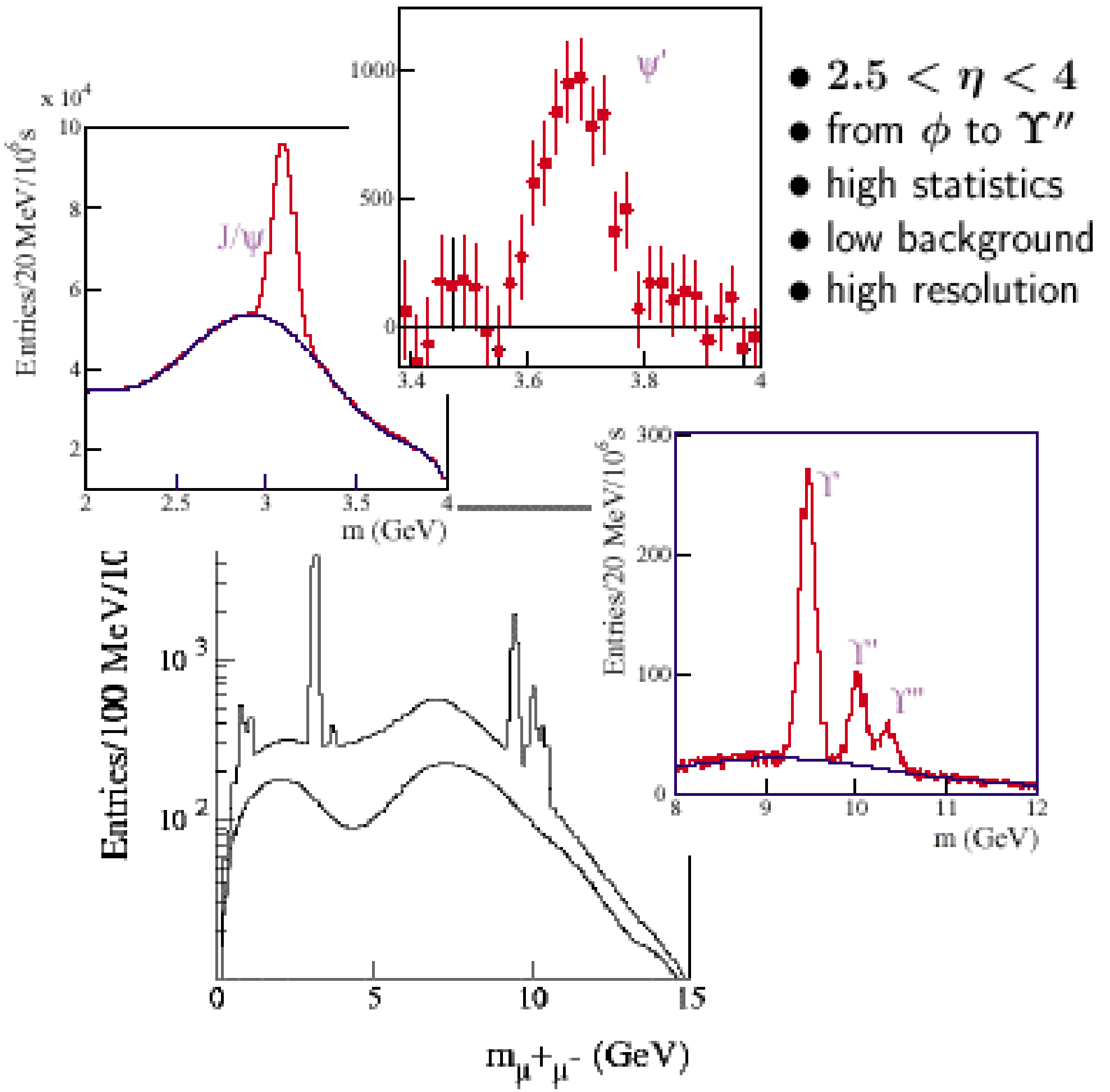
down to ~ 1 GeV/c

down to ~ 0 GeV/c

Quarkonia

- The Suppression of the heavy quark resonances J/ψ, ψ', Y, Y', Y'' is one of the most promising signals for the QGP. In order to rule out other suppression mechanisms (nuclear absorption, comovers ...) we have to measure the suppression
  - For the whole family of resonances
  - As a function of transverse momentum down to p_T = 0 GeV.
  - As a function of the energy density by varying
  - Impact parameter
  - Collision system (pp, pA, AA heavy and intermediate)

$\mu^+ \mu^-$ Channel



- σ_M =94.5 MeV/c^2 at the Υ
- Separation of Υ, Υ', Υ''
- Total efficiency ~ 75%
- Expected statistics (significance/1 yr):

	central	min. bias
J/ψ	310	574
ψ'	12	23
Υ	39	69
Υ '	19	35
Υ ''	12	22

from min. bias events:

~ 8k Υ and ~700k J/ψ /yr

Quarkonia Simulation

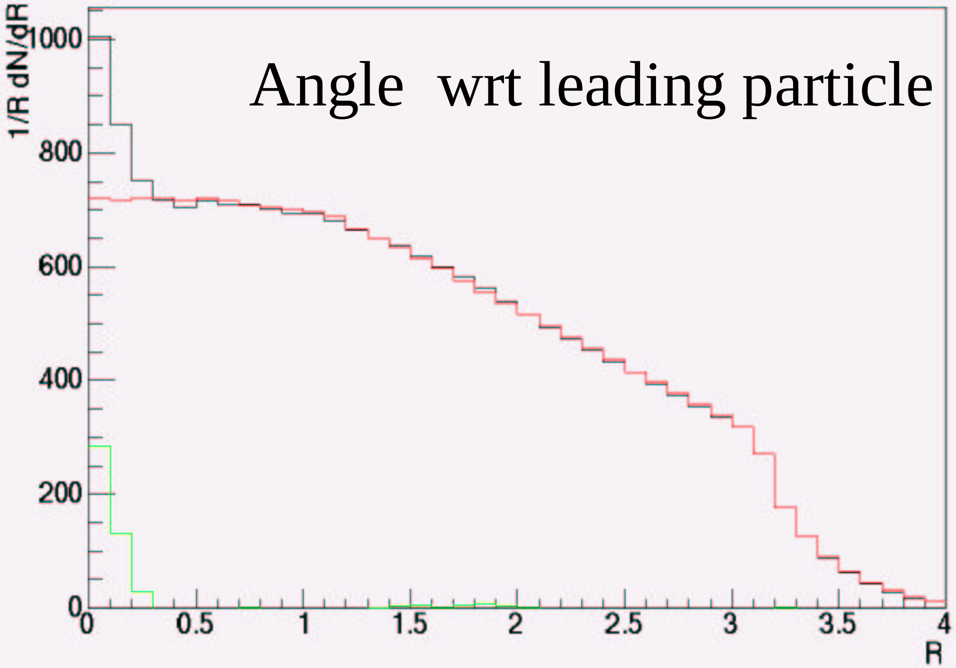
- Resonances
  - pT and y from Color Evaporation Model
  - Continuum
    - Semi-muonic charm and beauty decays from PYTHIA
    - Pion and Kaon decays using CDF parameterisation (pessimistic)

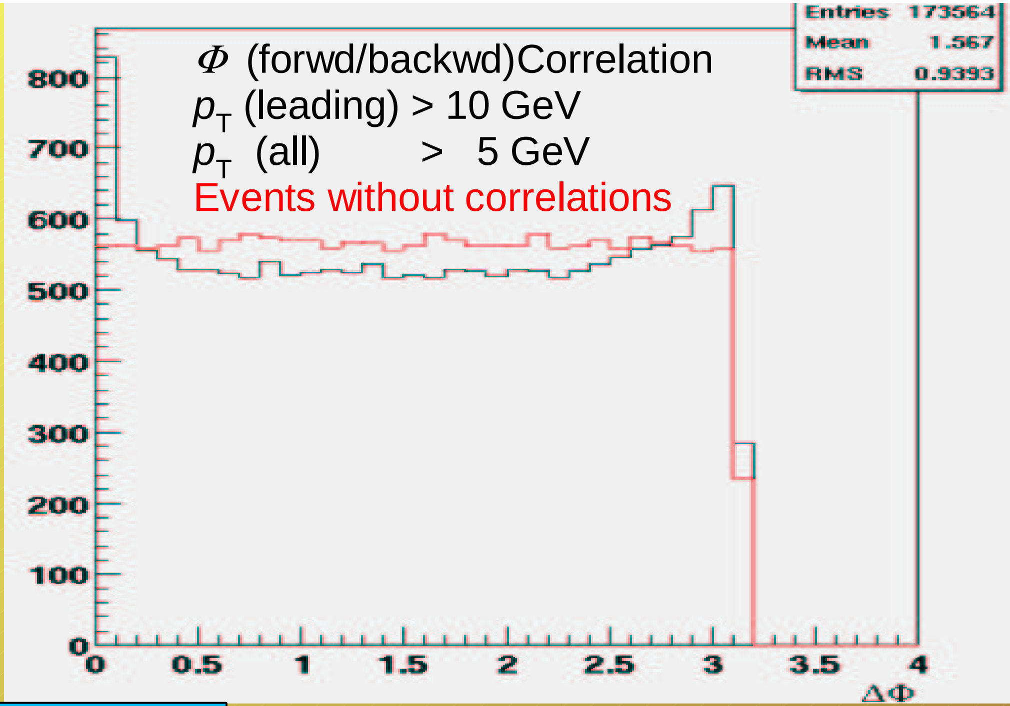
Jets

- Observe in-medium modification of the jet structure
  - Longitudinal: Jet quenching
  - Transverse: Transverse heating
- For
  - Low E_T (2 – 30 GeV) using inclusive correlation spectra
  - High E_T (30 GeV))using reconstructed jets

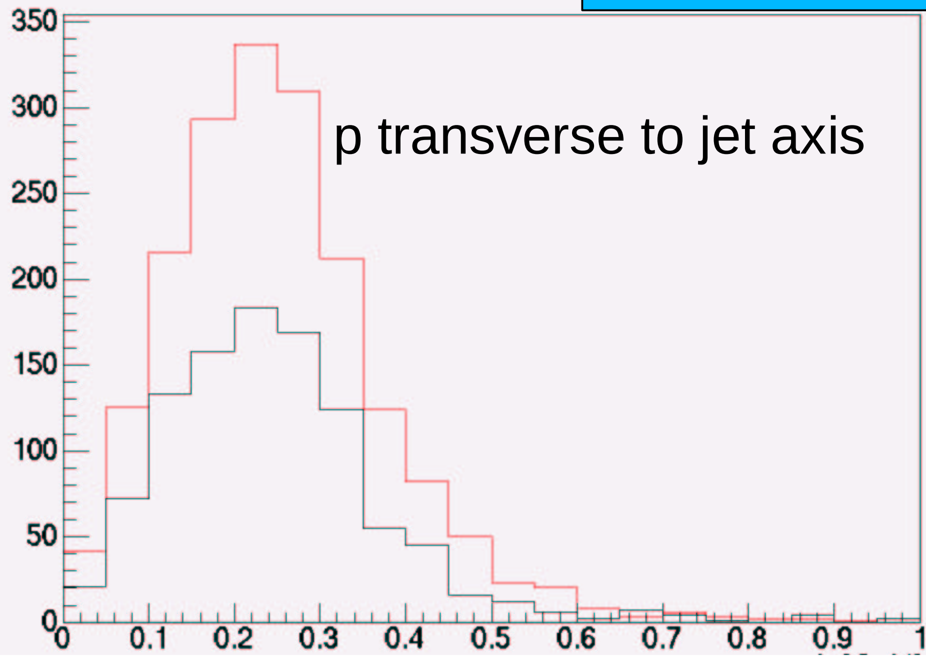
Jet Simulation

- Particle correlations
  - HIJING
- High Et reconstructed jets
  - PYTHIA jets embedded into HIJING

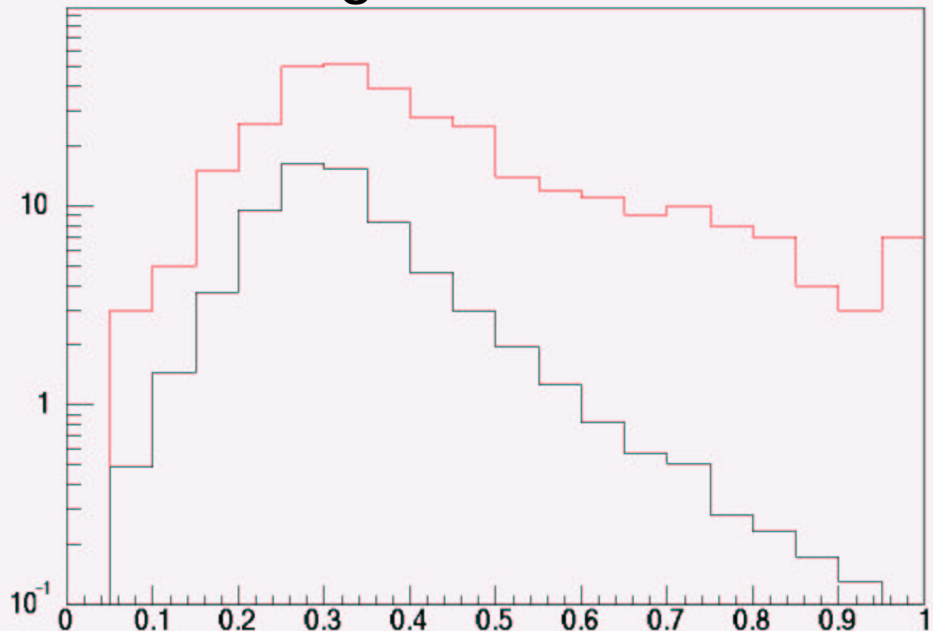




Inclusive Spectra



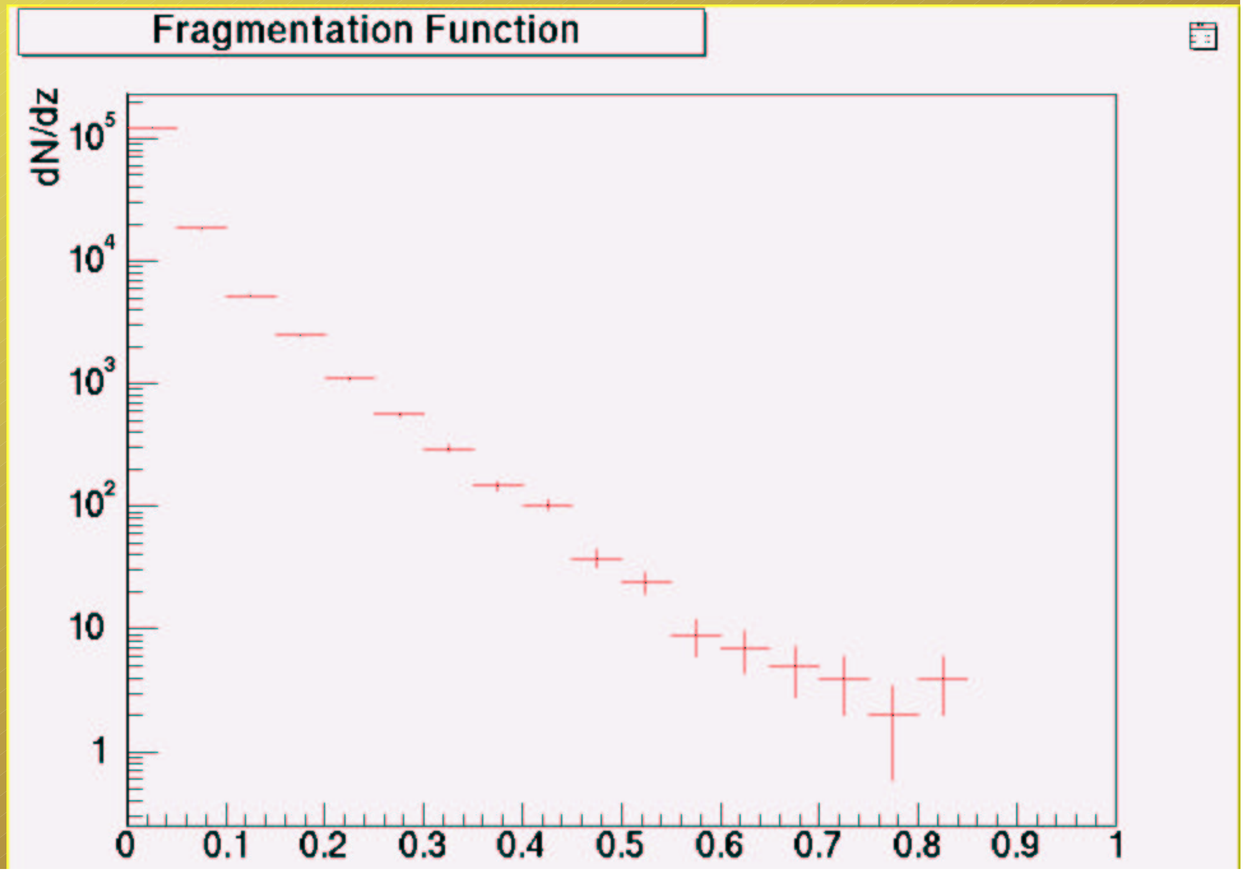
Fragmentation function



High E_T Jets

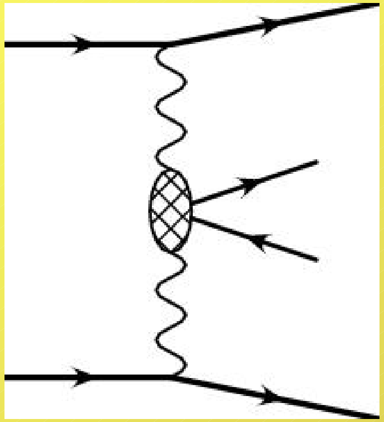
- Charged jet studies a la CDF
- With EMCAL $\Delta E/E \sim 25\text{-}30\%$

Measured fragmentation function for 100 GeV Jet

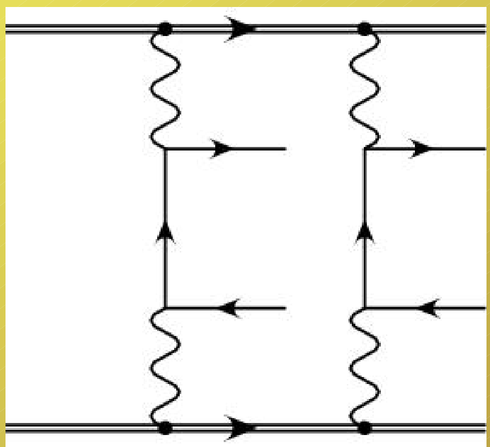


Ultra-peripheral Collisions

$AA \rightarrow AA\,\gamma\gamma \rightarrow AA\,X$

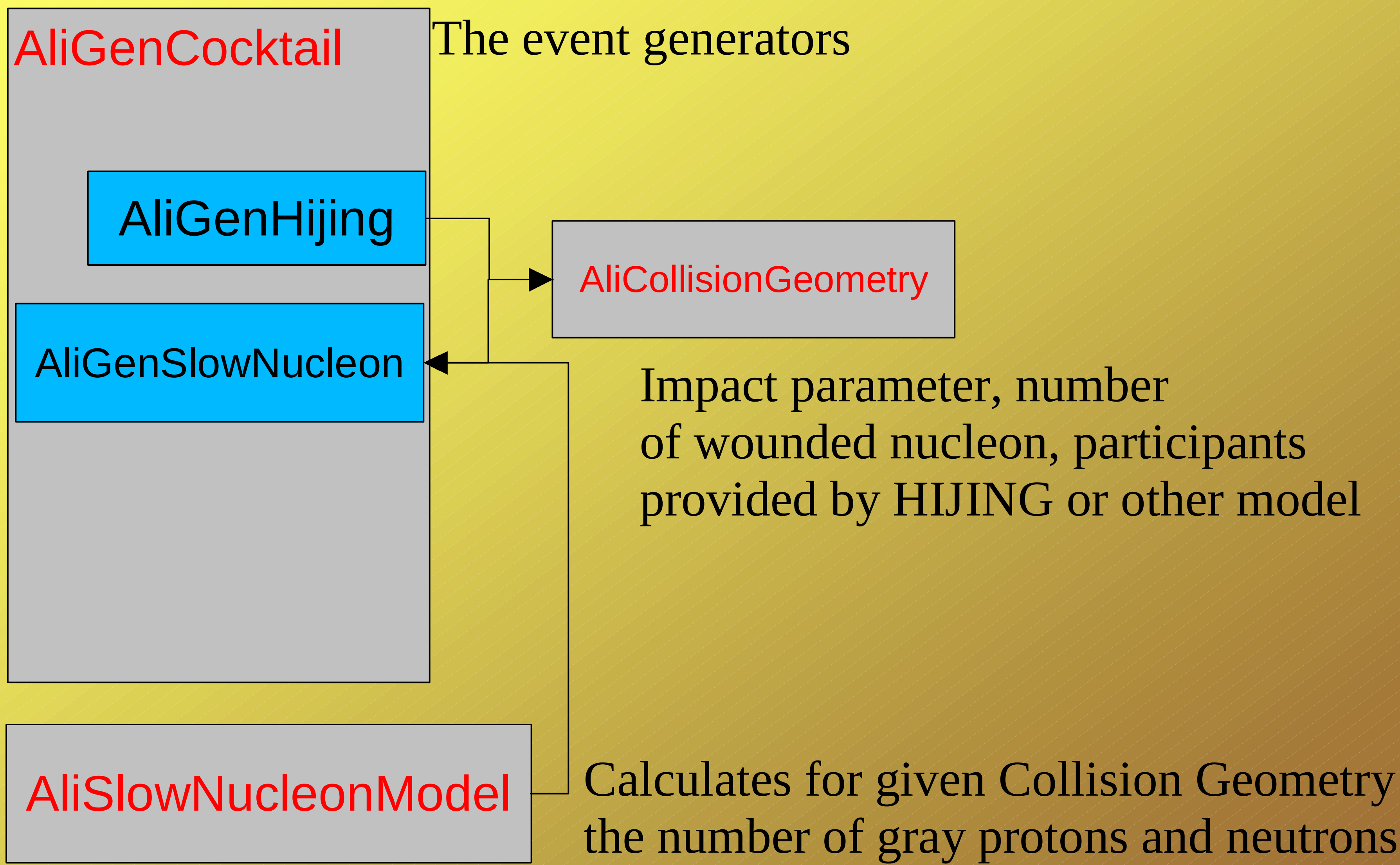


$AA \rightarrow AA\,e^+e^-$



- K. Hencken et al.
- TPHIC
  - Massive particle production described in Equivalent Photon Approximation
- TEPEM
  - Electron positron pair production in UPC

pA Collisions



Conclusions

- Shortcomings of present generators for Heavy Ion Collisions
  - Most interesting observables are nor simulated
- Solution
  - Hard probes: Assemble events as signal + underlying event
  - Soft probes: Afterburners, parameterisations, ...
  - Jet quenching ?
- The ALICE simulation framework provides a collaborating classes tailored to these needs.