SOME COMMENTS ON...

HARD PROCESSES IN URHIC

DARIUSZ MIŚKOWIEC, GSI DARMSTADT
RNM MEETING, DARMSTADT, JUNE 12, 2001

1. JET QUENCHING AT RHIC

- N_{part} and N_{coll}
- initial scattering
- Fermi motion
- EMC effect
- parton energy loss
- radial flow

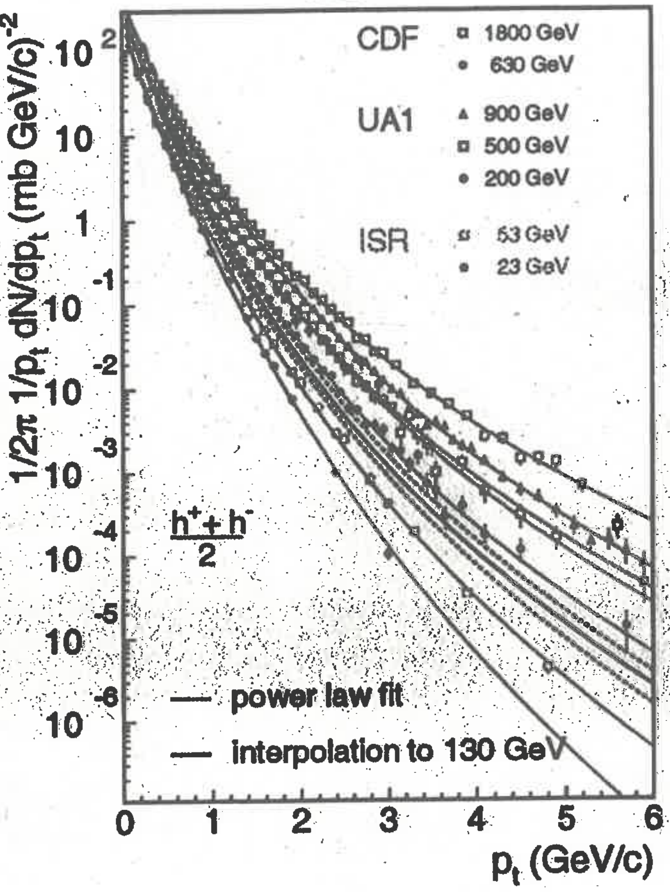
2. MEASURING JETS WITH ALICE

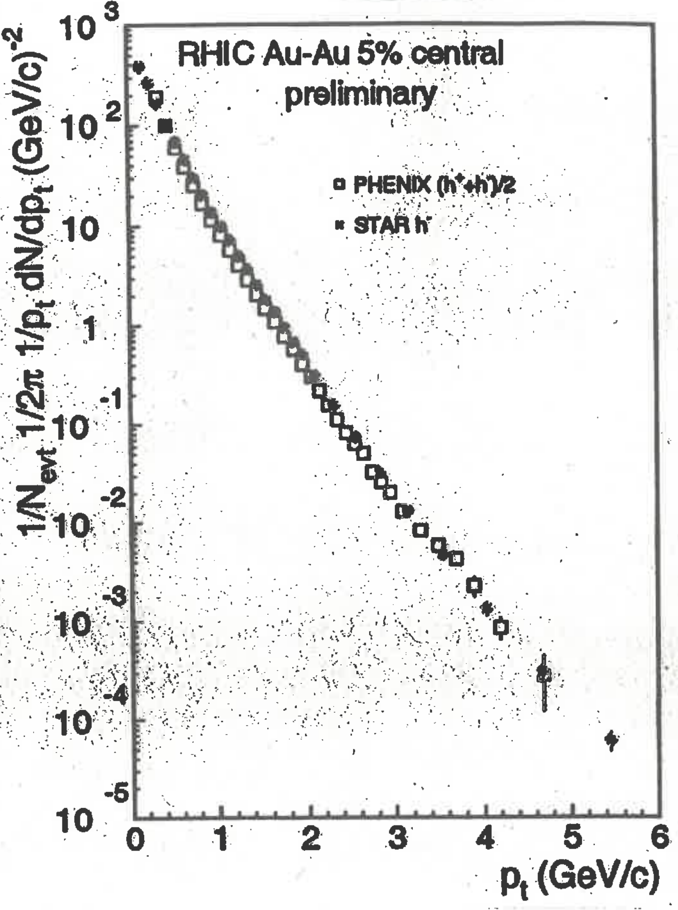
- will jets stick out of background?
- jet yield
- jet trigger with TRD

$p_\perp$ SPECTRUM OF CHARGED PARTICLES ...

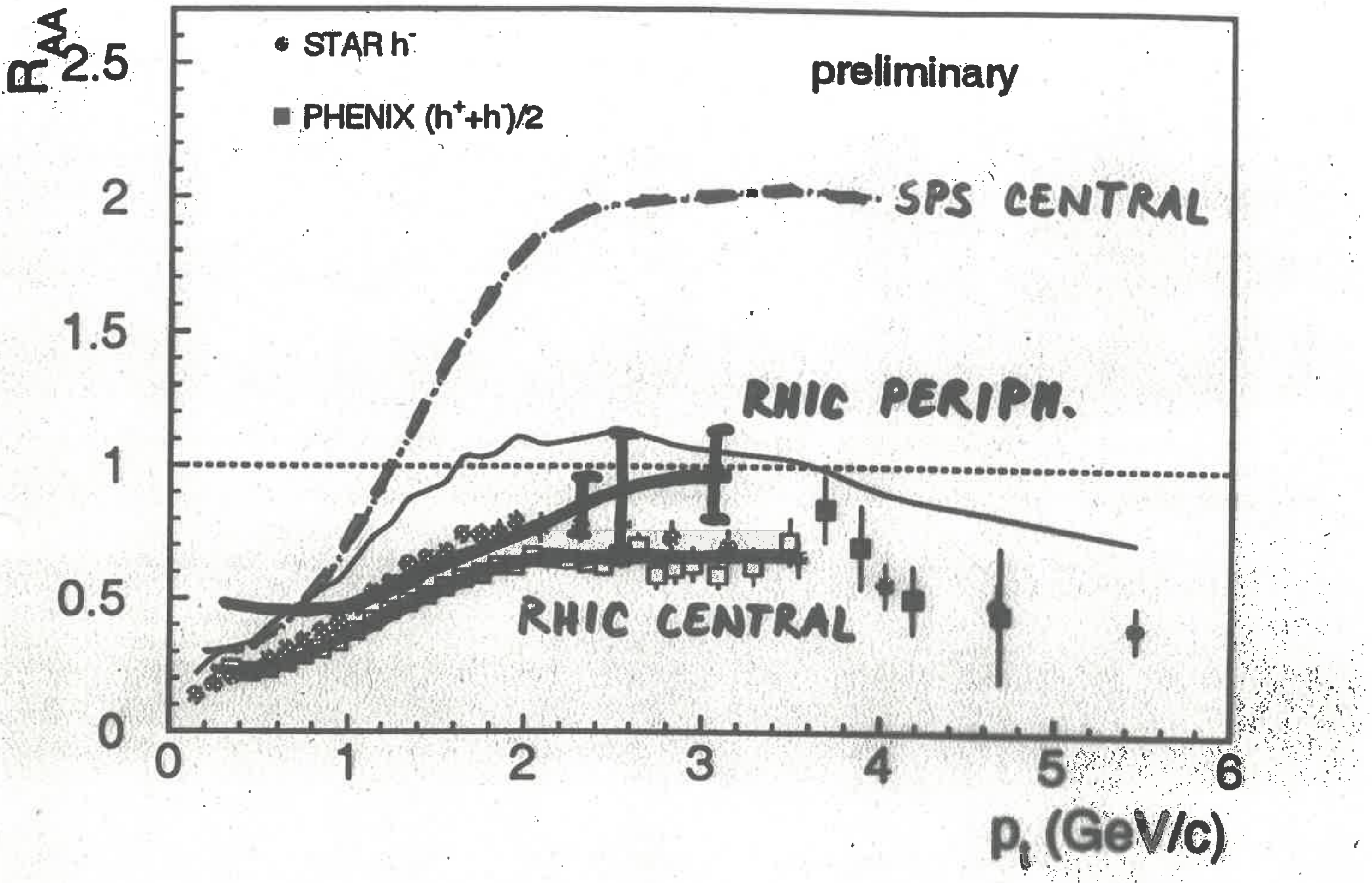
... in PP

in Au-Au





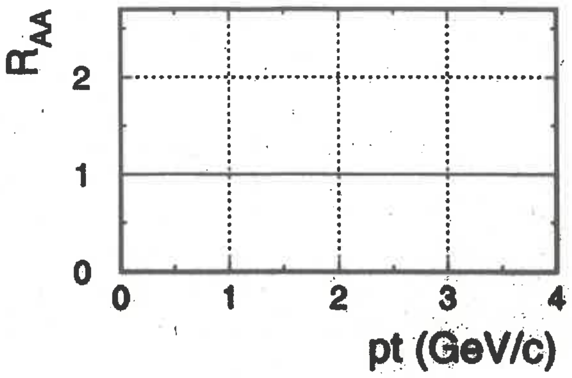
AXEL DREES, QM 2001



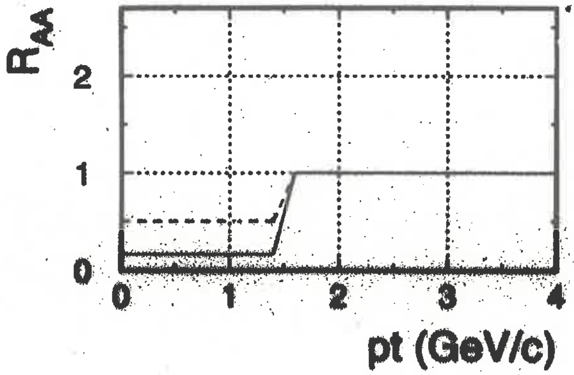
$$R_{AA} := \frac{N^{ch}_{AA}(p_\perp)}{N^{ch}_{pp}(p_\perp)\cdot N_{coll}}$$

NUCLEAR MODIFICATION FACTOR

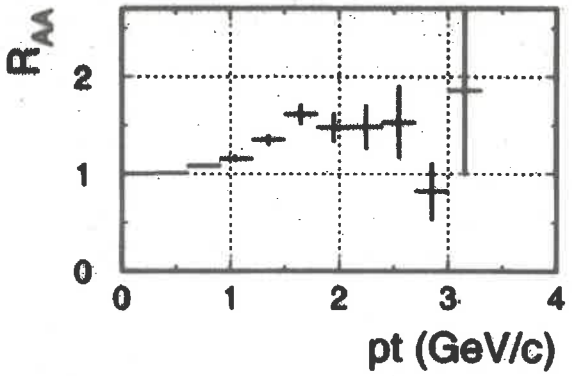
no nuclear effects



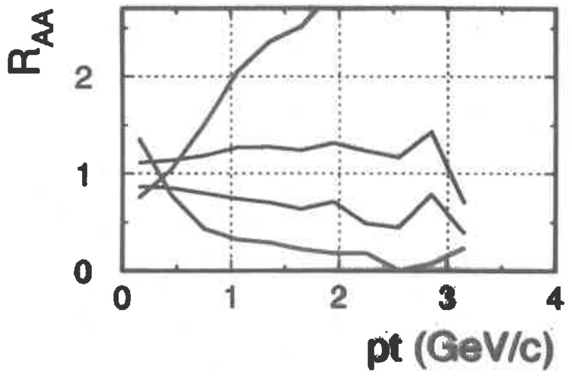
high pt like Ncoll, low pt like Npart



initial scattering (Cronin effect)

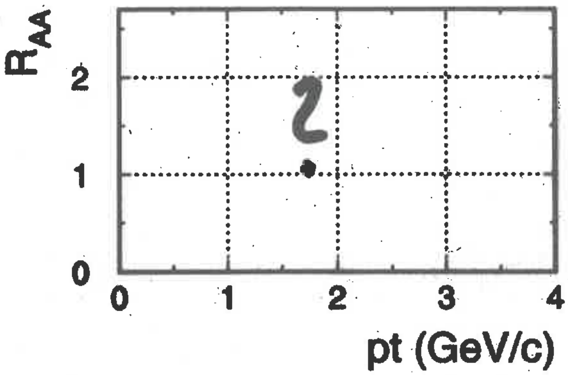


Fermi motion of nucleons in nucleus



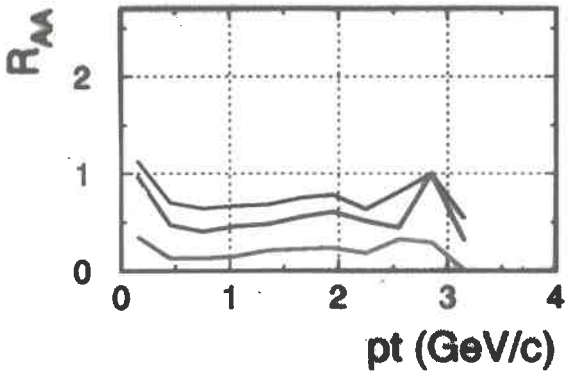
EMC effect

STRUCTURE FUNCTION
OF NUCLEON MODIFIED
WHEN IN NUCLEUS



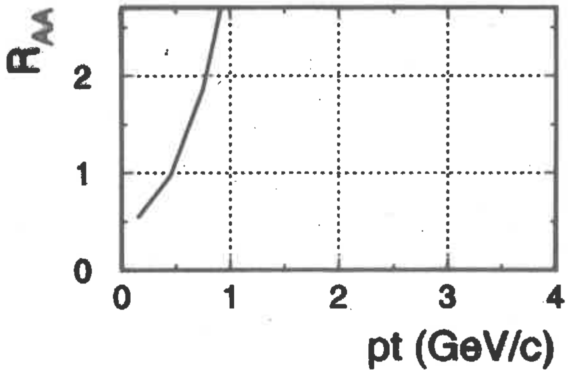
Parton energy loss

SUBTRACT 0.1, 0.2, 0.5
GEV FROM $P_\perp$

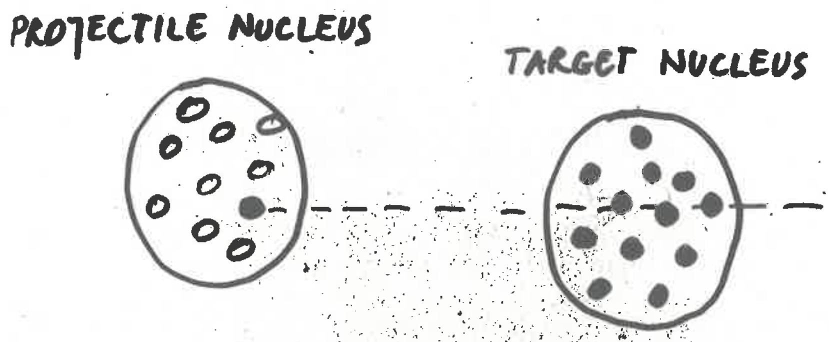


Transverse flow

BOOST PARTICLE OUTWARD
BY $\beta_\perp = 0.6$



NUCLEUS-NUCLEUS COLLISION GEOMETRY



LORENTZ CONTRACTION → SHORT TRAVERSAL TIME

		$y_B - y_{CM}$	γ_{CM}	14 fm/γ_{CM}
AGS		1.6	2.5	5.6 fm/c
SPS		2.9	9.2	1.5 fm/c
RHIC	56	4.1	30	0.47 fm/c
	130	4.9	70	0.20 fm/c
	200	5.4	107	0.13 fm/c
LHC	5500	8.3	2942	0.005 fm/c

FINITE COHERENCE TIME ~0.4 fm/c (KAPUSTA, QM99)

HARD AND SOFT BINARY COLLISIONS

HARD $\sim N_{COLL}$ (ESKOLA, NUCL. PHYS. B 323(89)37)

SOFT $\sim N_{PART}$ (BIAŁAS, CZYZ, NUCL. PHYS. B 111(76) 461)

$N_{WOUNDED} \equiv N_{PART}$

HARD COLLISIONS MAKE HIGH $p_\perp$ PARTICLES

SOFT COLLISIONS MAKE LOW $p_\perp$ PARTICLES

$$N^{CH}_{AA} = a\,\frac{N_{part}}{2} + b\,N_{coll}$$

$$N^{CH}_{pp} = \underset{\text{SOFT COMP.}}{\underset{\uparrow}{a}} + \underset{\text{HARD COMPONENT}}{\underset{\uparrow}{b}}$$

$$\begin{tikzcd} & \dfrac{a\,N_{PART}}{2} \\ N^{CH}_{AA} \arrow[ur, "p_\perp \to 0"] \arrow[dr, "p_\perp \to \infty"'] & \\ & b\,N_{COLL} \end{tikzcd}$$

$$\begin{tikzcd} & \dfrac{N_{PART}}{2\,N_{COLL}} \\ R \arrow[ur, "p_\perp \to 0"] \arrow[dr, "p_\perp \to \infty"'] & \\ & 1 \end{tikzcd}$$

N_{COLL} AND N_{PART}

$$N_{COLL}(b) = \underbrace{\int d^2s \overbrace{\int dz_A\, n_A(\vec{s}, z_A)}^{T_A(\vec{s})} \overbrace{\int dz_B\, n_B(\vec{s}-\vec{b}, z_B)}^{T_B(\vec{s}-\vec{b})}}_{\text{OVERLAP FUNCTION } T_{AB}(b)} \cdot \sigma_{pp}^{INEL}$$

$$N_{PART}(b) = \int d^2s\, T_A(\vec{s}) \left[1 - e^{-\sigma_{NN}^{INEL} T_B(\vec{s}-\vec{b})} \right]$$

$$+ \int d^2s\, T_B(\vec{s}) \left[1 - e^{-\sigma_{NN}^{INEL} T_A(\vec{s}+\vec{b})} \right]$$

AT $\sqrt{s} = 130$ GeV $\sigma_{NN}^{INEL} = 41$ mb.
IN A Pb+Pb COLLISION WE GET

	N_{PART}	N_{COLL}	$N_{PART}/2N_{COLL}$
0-5%	366 ± 20	1140 ± 88	0.16
60-80%	16 ± 7	17 ± 10	0.47
80-92%	4 ± 1.4	3.1 ± 1.3	0.65

A- DEPENDENCE OF N_{PART} AND N_{COLL}

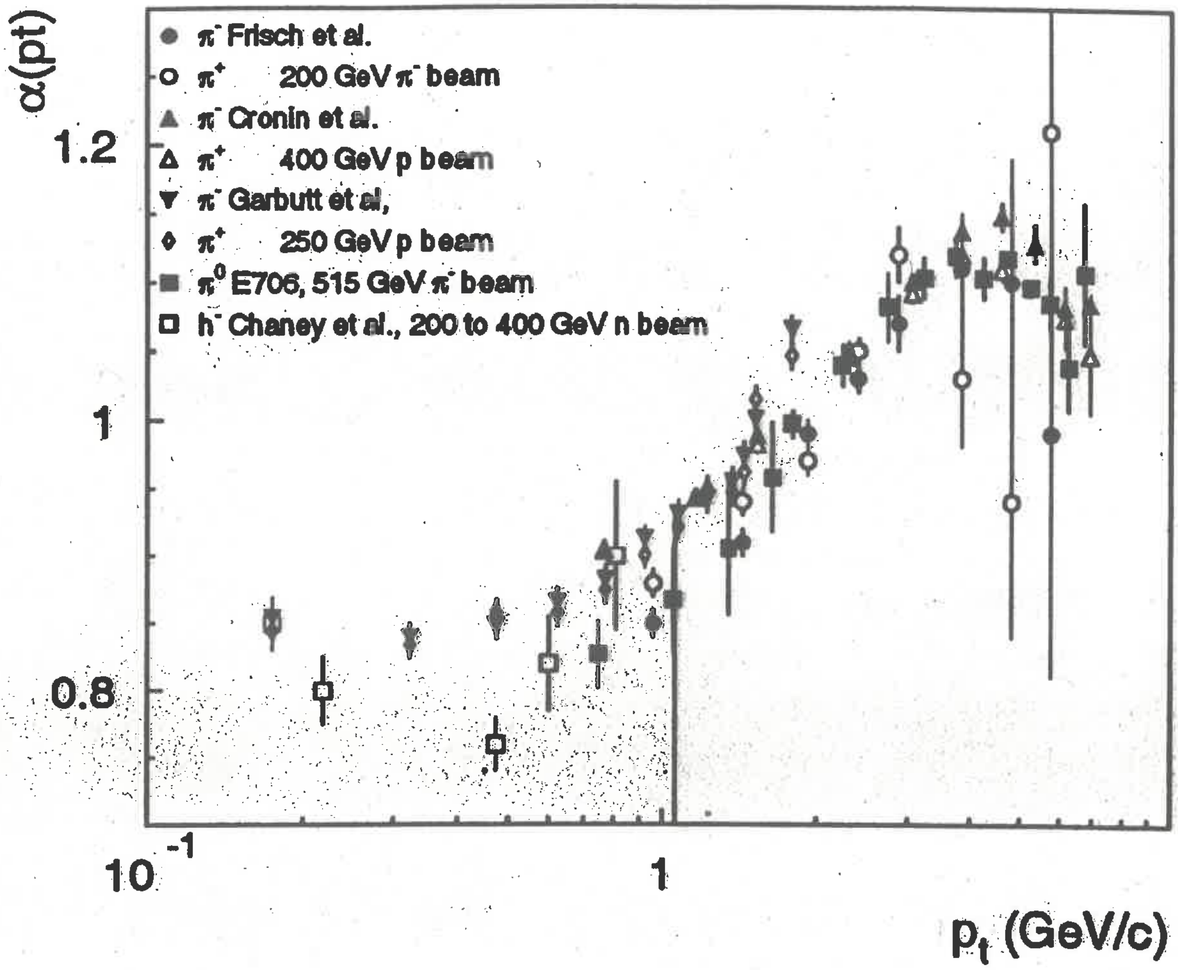
$$N_{COLL} \sim A^{4/3}$$

$$N_{PART} \sim A \quad \longrightarrow \quad N_{COLL} \sim N_{PART}^{\;4/3}$$

WHEN COMPARING DIFFERENT A'S,
BUT ALSO WHEN COMPARING
DIFFERENT CENTRALITIES!
(NOT TOO PERIPHERAL...)

	N_{coll} ↓	N_{part} ↓				
	hard n	soft n	kamikaze n	hard σ	soft σ	kamikaze σ
pA	$A^{1/3}$	$A^{1/3}$	1	A	A	$A^{2/3}$
AA	$A^{4/3}$	A	$A^{2/3}$	A^2	$A^{5/3}$	$A^{4/3}$

CRONIN EFFECT



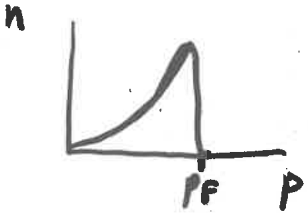
ANTREASYAN ET AL., PRD 19 (79) 764

LEV, PETERSSON, Z. PHYS. C 21 (83) 155

FERMI MOTION OF NUCLEONS IN NUCLEUS

$p_F = 260$ MeV/c $\longrightarrow$ $\beta_F = 0{,}27$

$\gamma_F = 1.04 \sim 1.0$



LONGITUDINAL

$$p_z' = \gamma_F\,(p_z \pm \beta E) \simeq (1+\beta_F)\cdot p_z$$

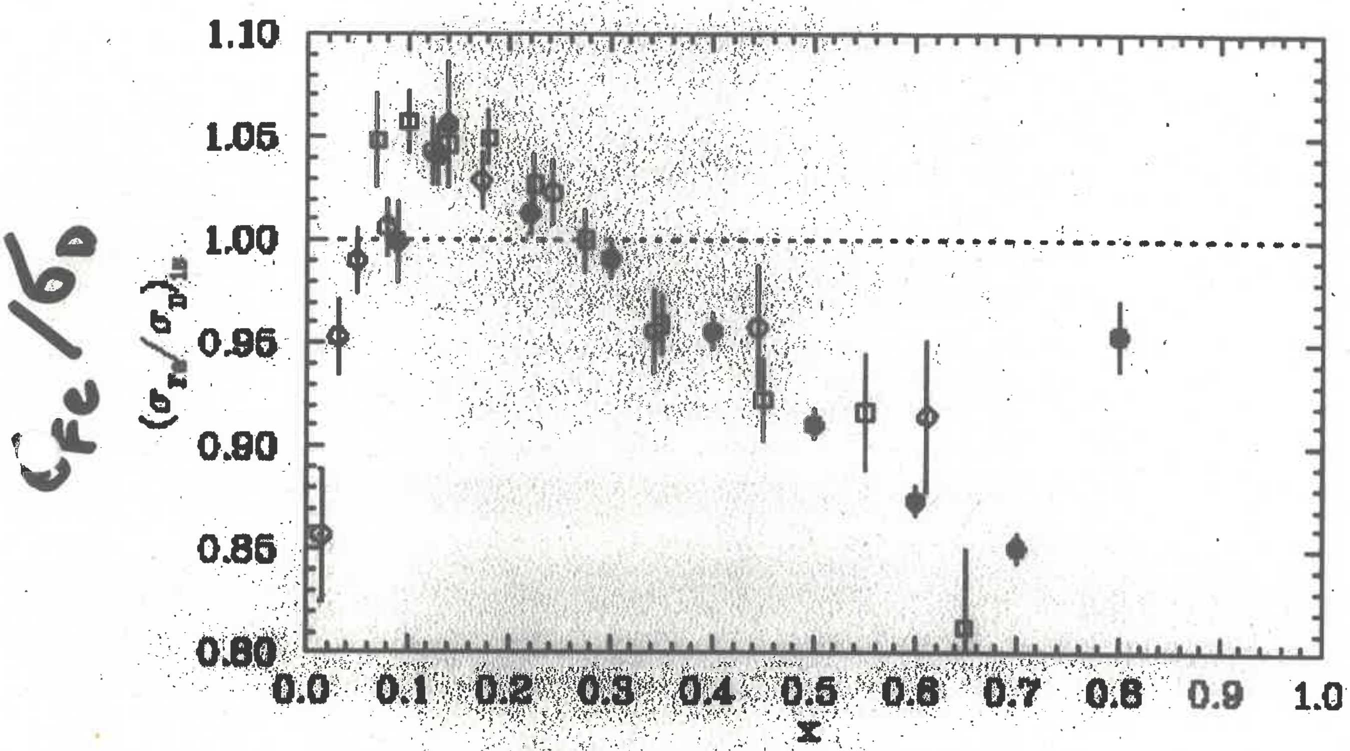
$\sqrt{s} = 130$ GeV $\longrightarrow$ $\sqrt{s} = 165$ GeV

95 GeV

TRANSVERSAL

BOOST BY $\beta = \pm 0{,}27$

EMC EFFECT

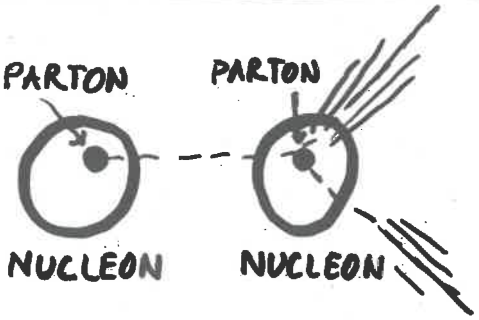


μ SCATTERING OF NUCLEAR TARGETS

ANNU. REV. NUCL. PART. SCI. 45(95)337

MEASURING JETS WITH ALICE

JETS



ALICE

Pb + Pb AT $\sqrt{s}/A = 5.5$ TeV

$45° < \theta < 135°$

$0° < \varphi < 360°$

THIS PRESENTATION

USE PYTHIA TO GENERATE JETS

USE HIJING OR SHAKER TO GENERATE THE REST, $dN_{CH}/dy \simeq 8000$

JETS IN $p\bar{p}$ AT $\sqrt{s} = 1.8$ TeV, CDF

HEP-PH/0102074

FIGURES

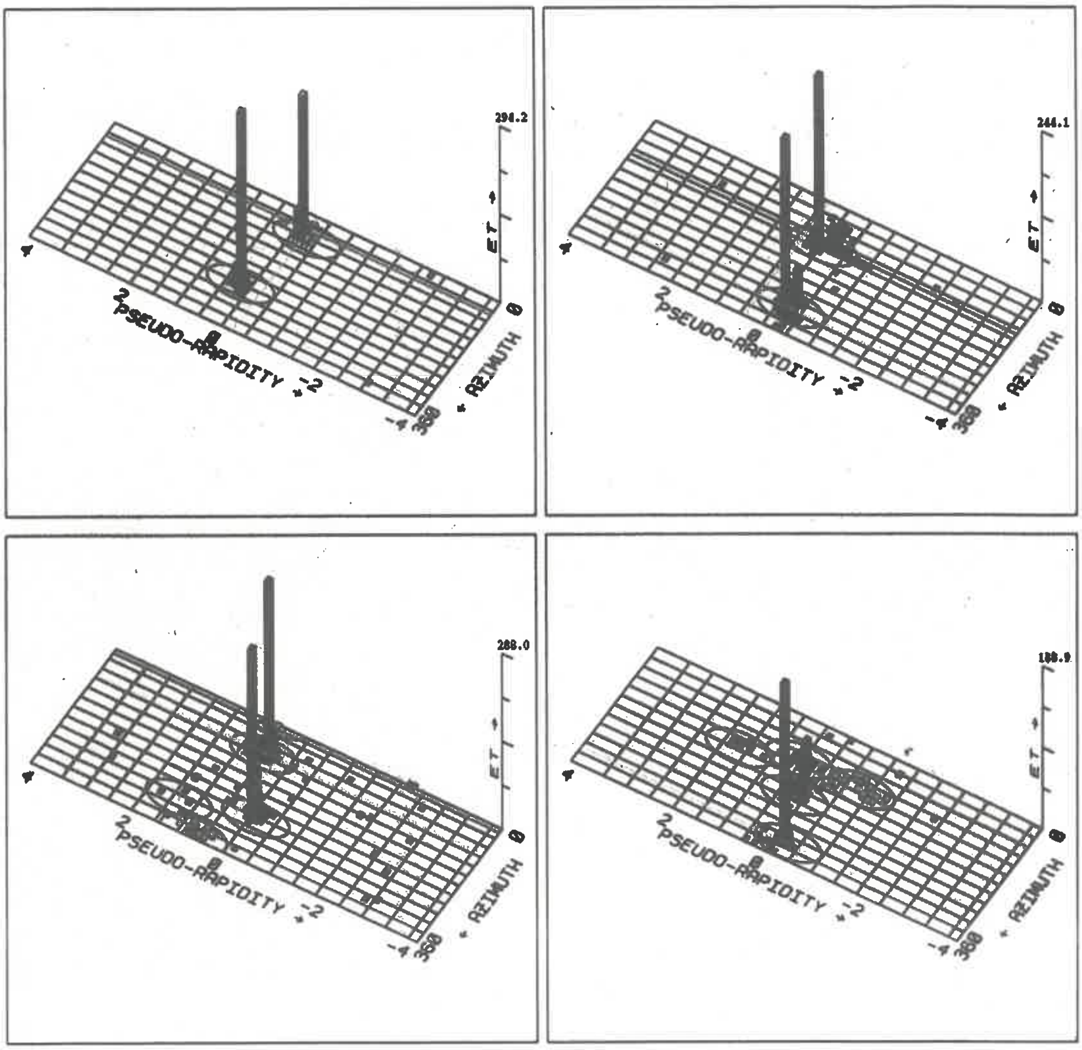
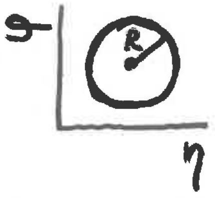


FIG. 1. Jet events in the CDF calorimeter. A jet clustering cone of radius 0.7 is shown around each jet. Clockwise from the upper left they are identified as two-jet, two-jet, five-jet and three-jet. Tracks for these events are shown in Figure 2.

JET RADIUS

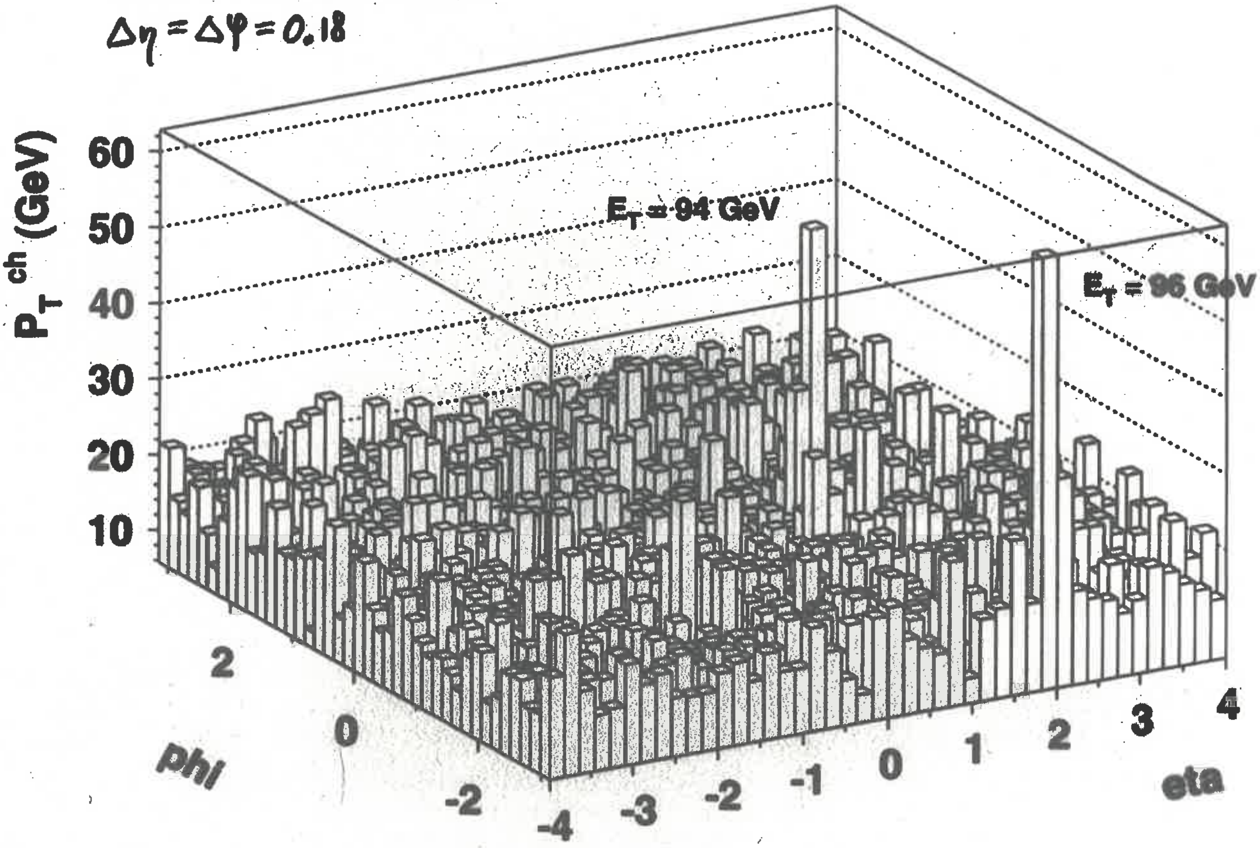


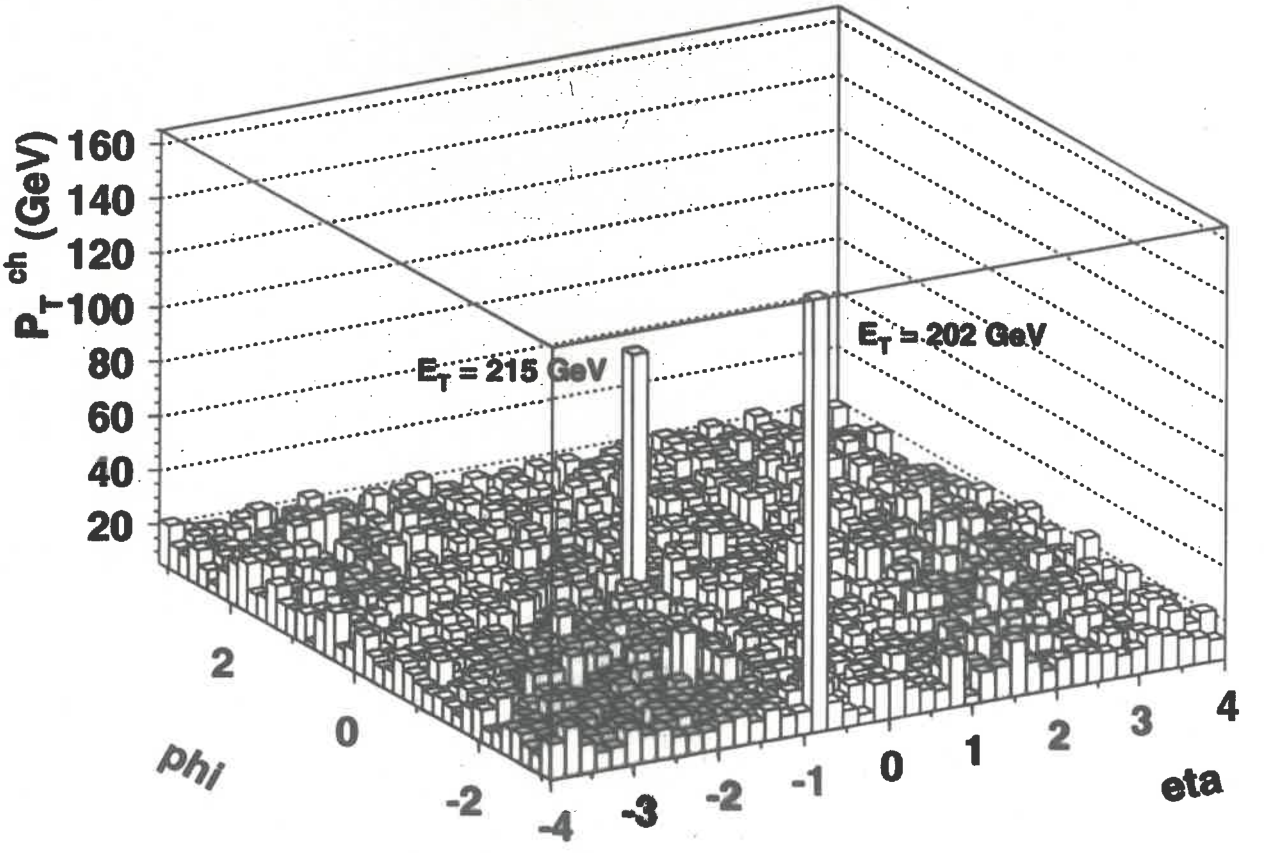
$R = 0.7$
(SNOWMASS CONVENTION)

Pythia jets sticking out of shaker background

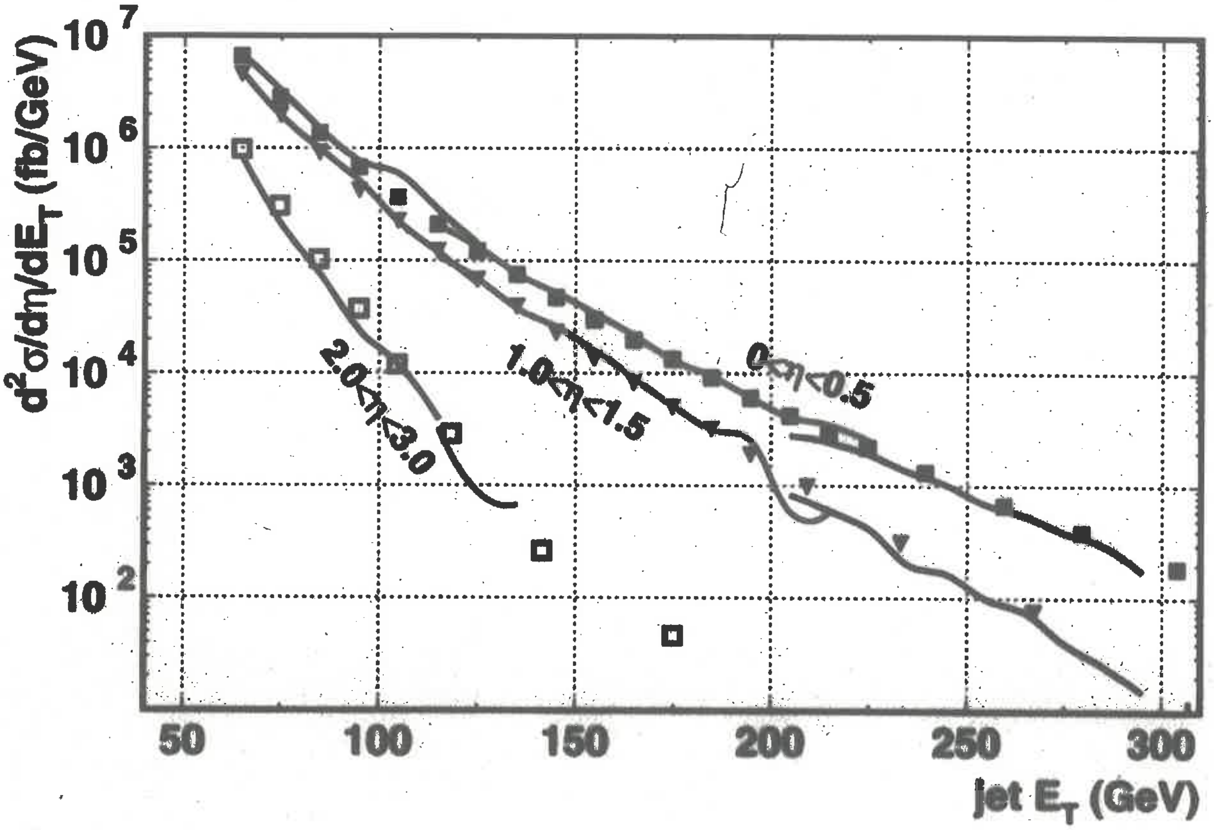
one bin = 1/4 TRD module

$\Delta\eta = \Delta\varphi = 0.18$





Jet production in p-pbar at sqrt(s)=1.8 TeV



points: D0 PRL 86(2001)1707

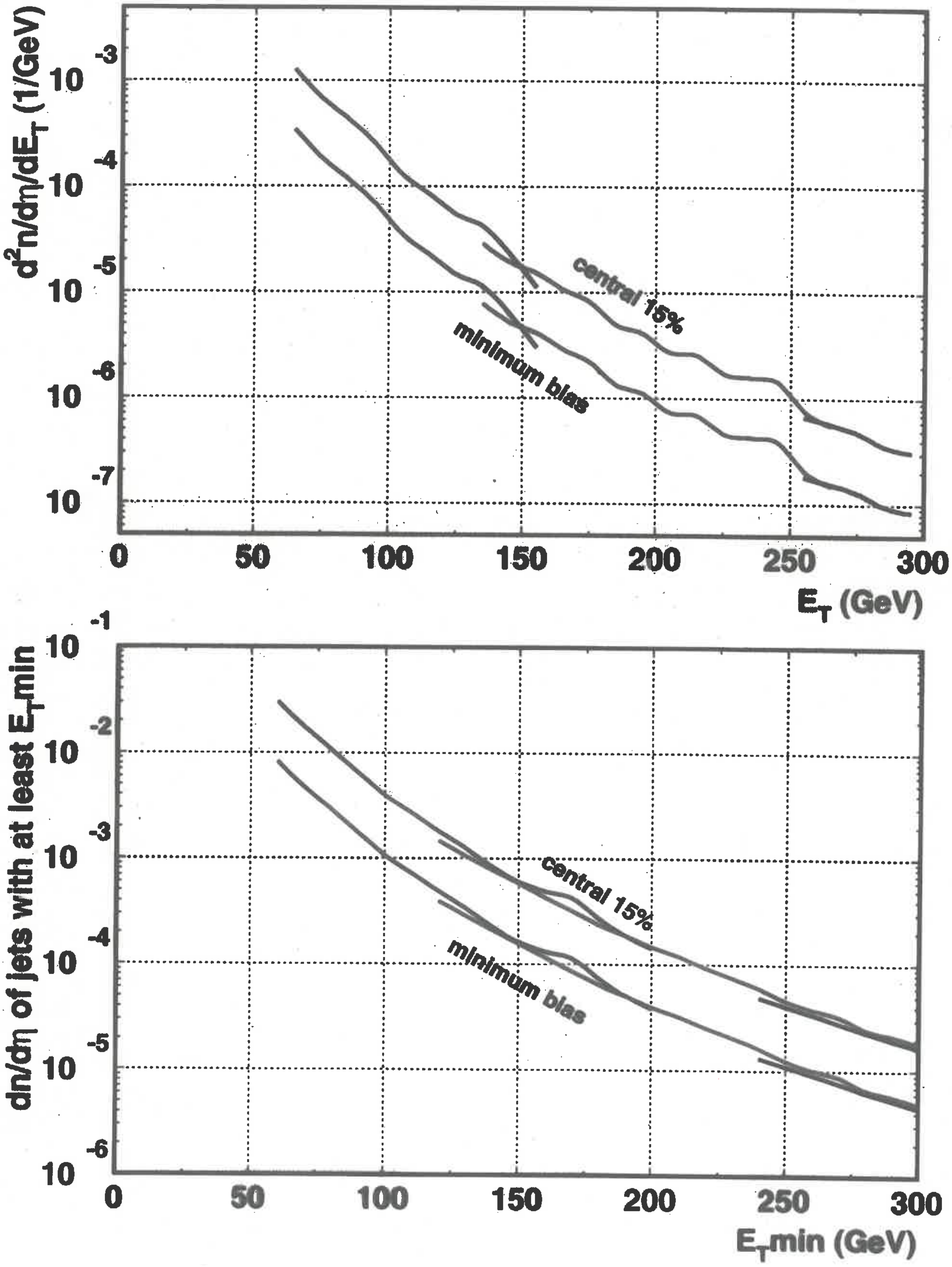
red line: 1.5 x PYTHIA with CTEQ4HJ, CKIN(3)=50

green line: 1.5 x PYTHIA with CTEQ4HJ, CKIN(3)=100

blue line: 1.5 x PYTHIA with CTEQ4HJ, CKIN(3)=200

K-FACTOR NEEDED TO REPRODUCE THE D0 DATA

Jet multiplicity in Pb+Pb at sqrt(s)=5.5 TeV

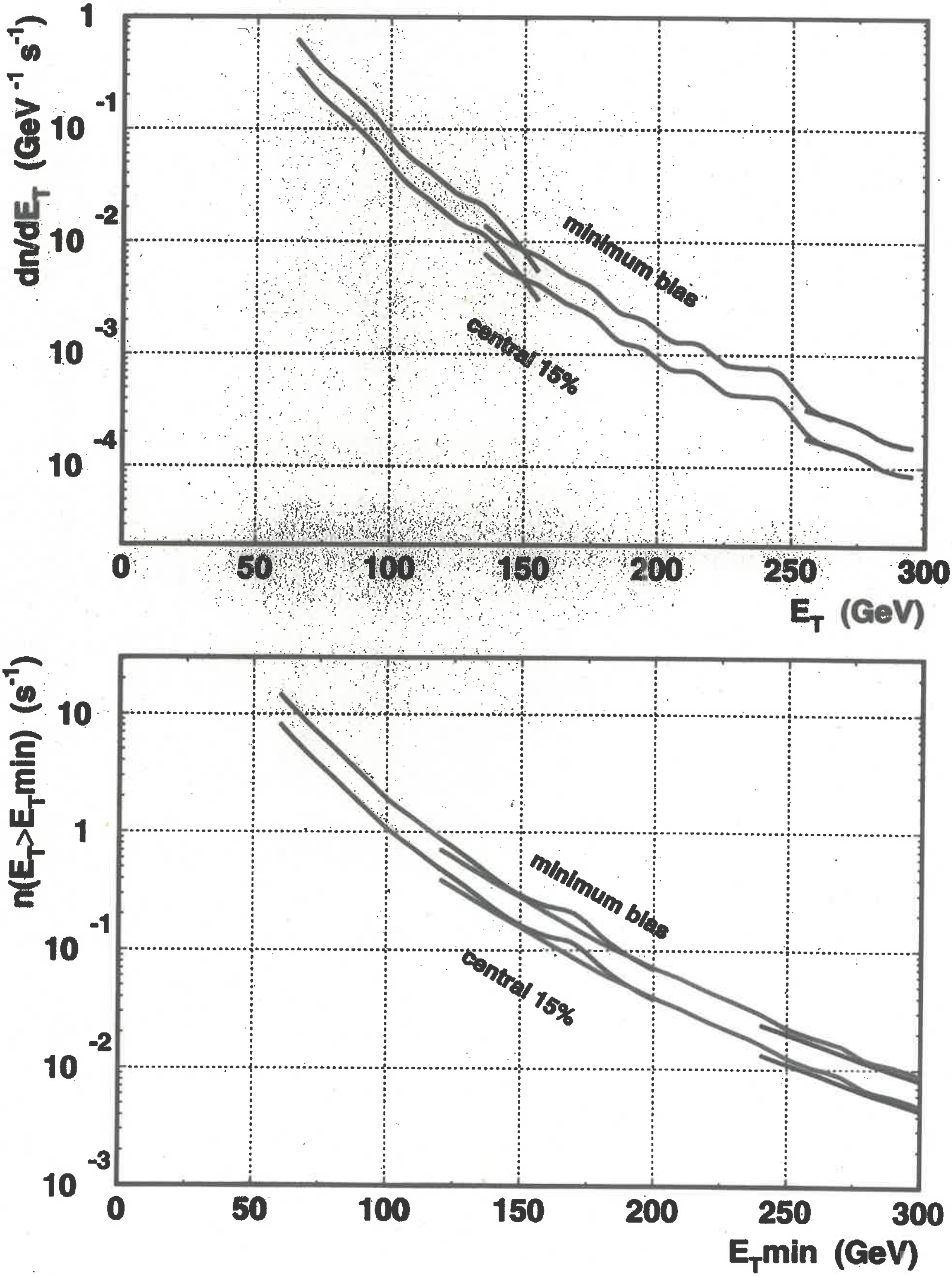


n (minimum bias PbPb) = 6 mb^{-1} * 1.5 * $\sigma(pp)$

n (central 15% PbPb) = 22 mb^{-1} * 1.5 * $\sigma(pp)$

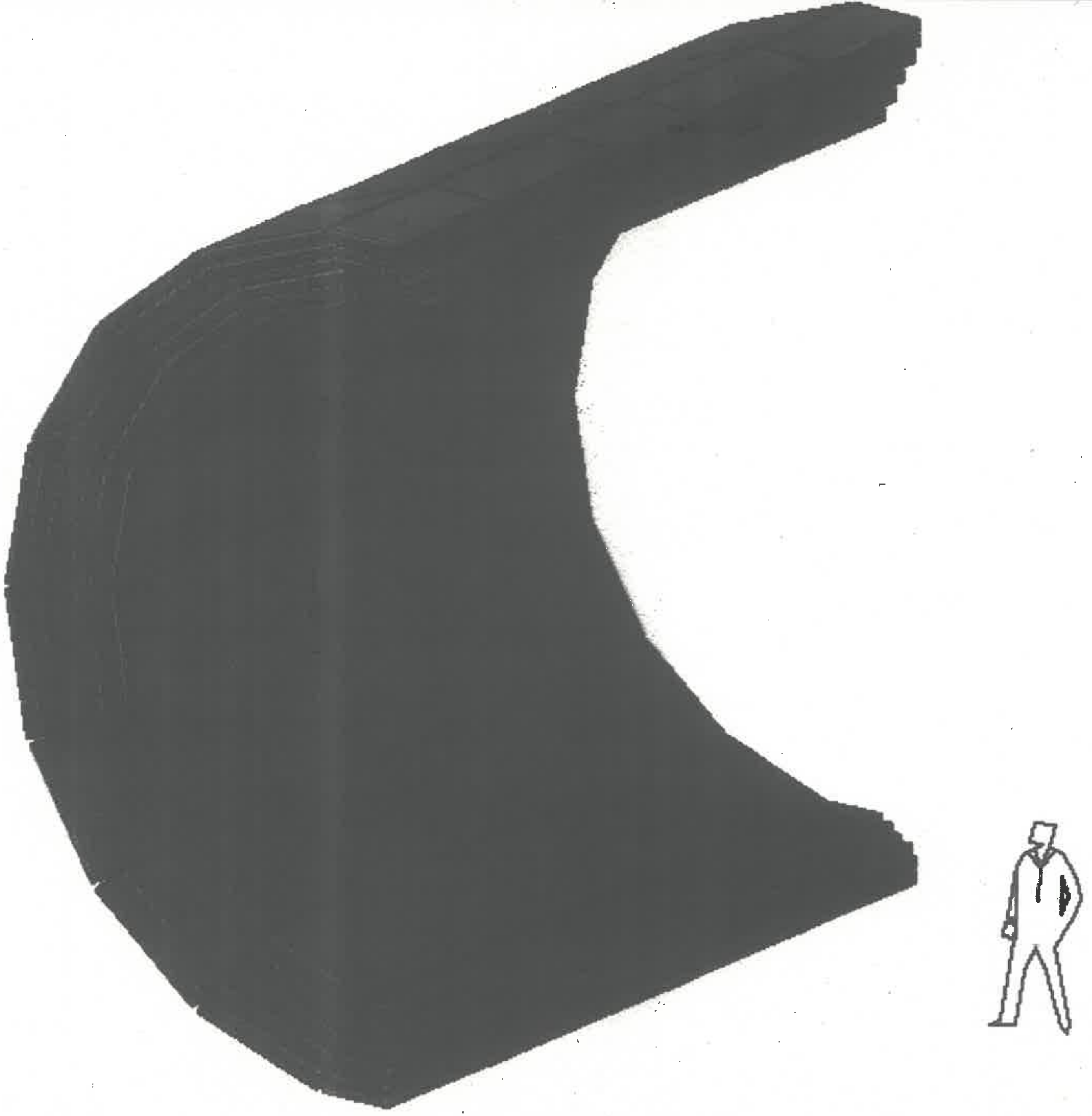
nuclear overlap model → K-fac ← Pythia

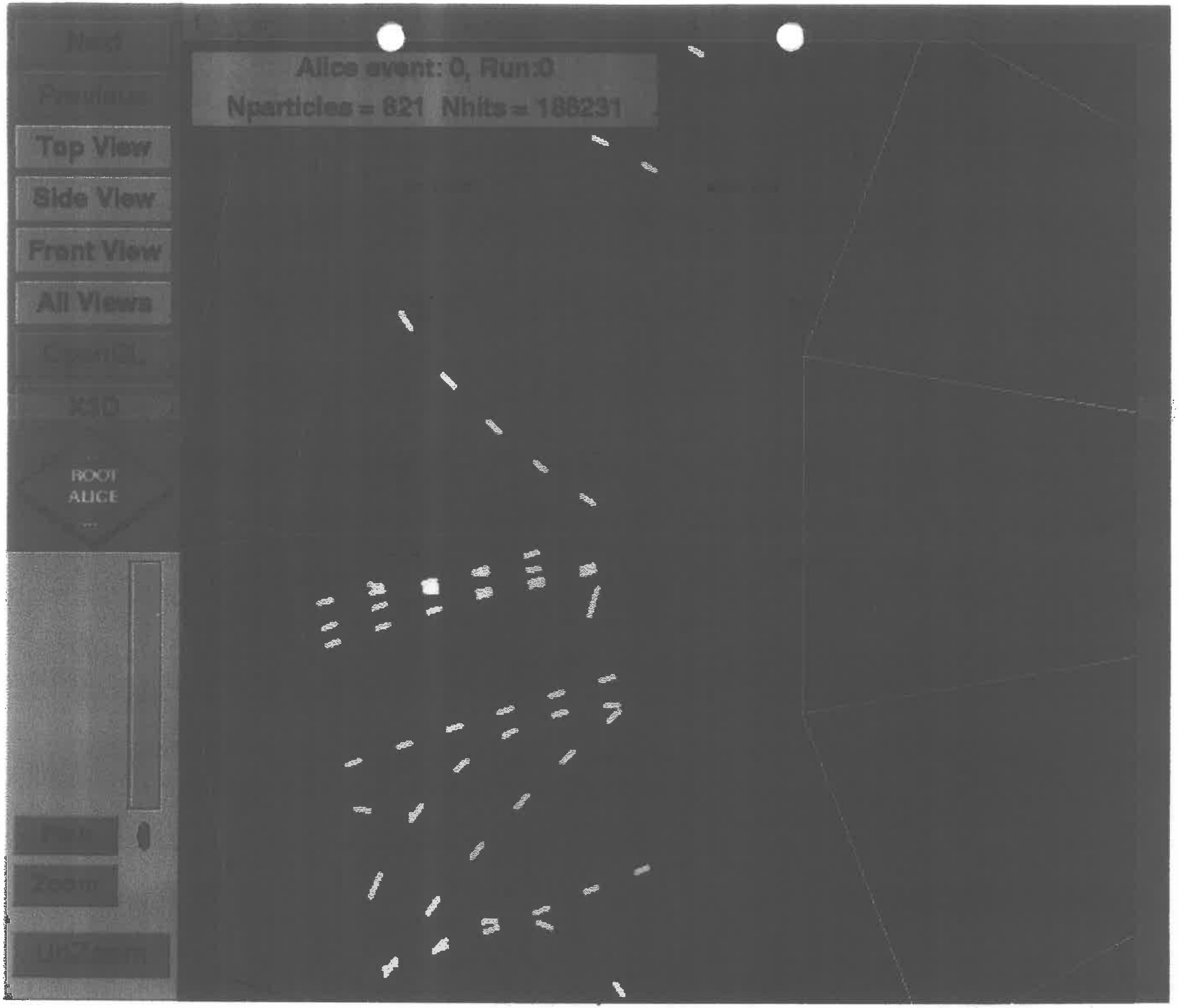
Jet into TPC rate in Pb+Pb at sqrt(s)=5.5 TeV



1000 minimum bias collisions per second assumed

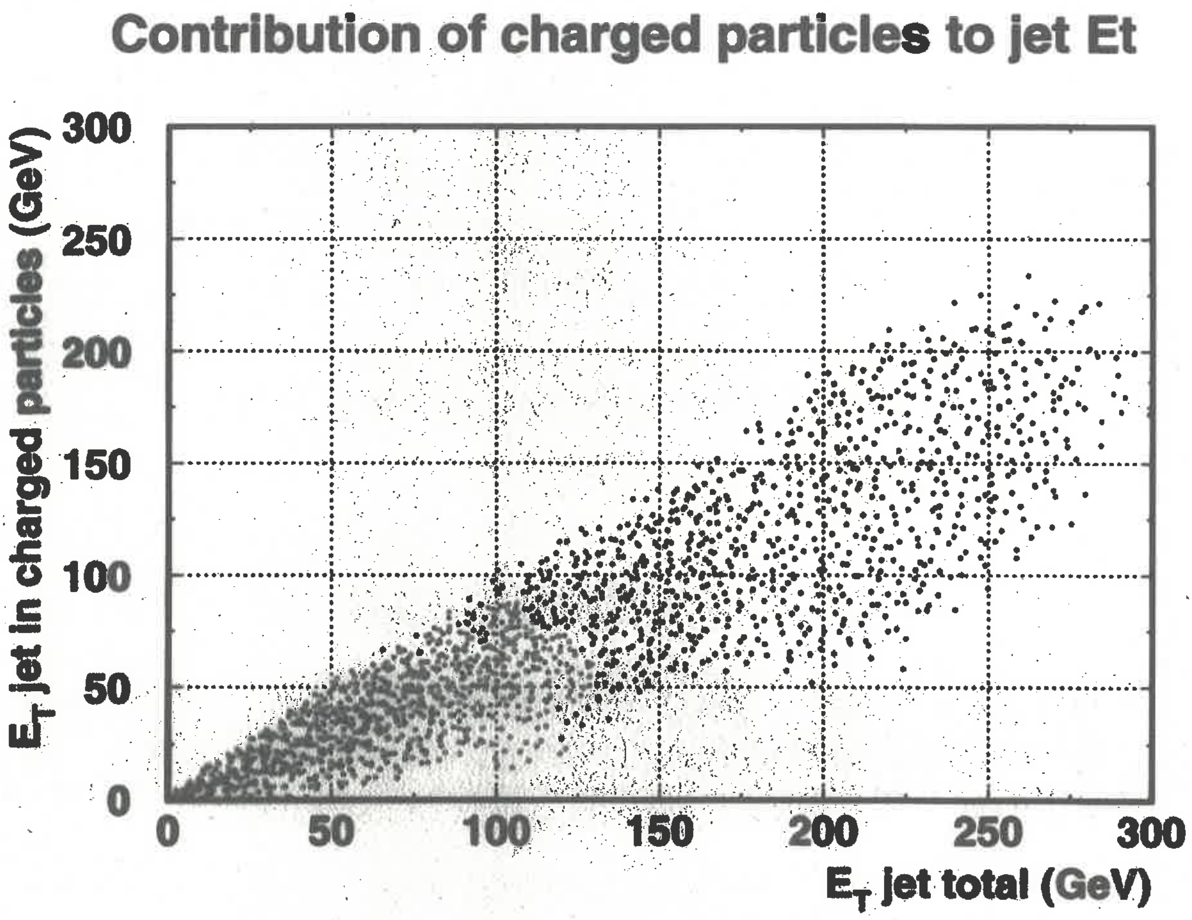
Transition Radiation Detector



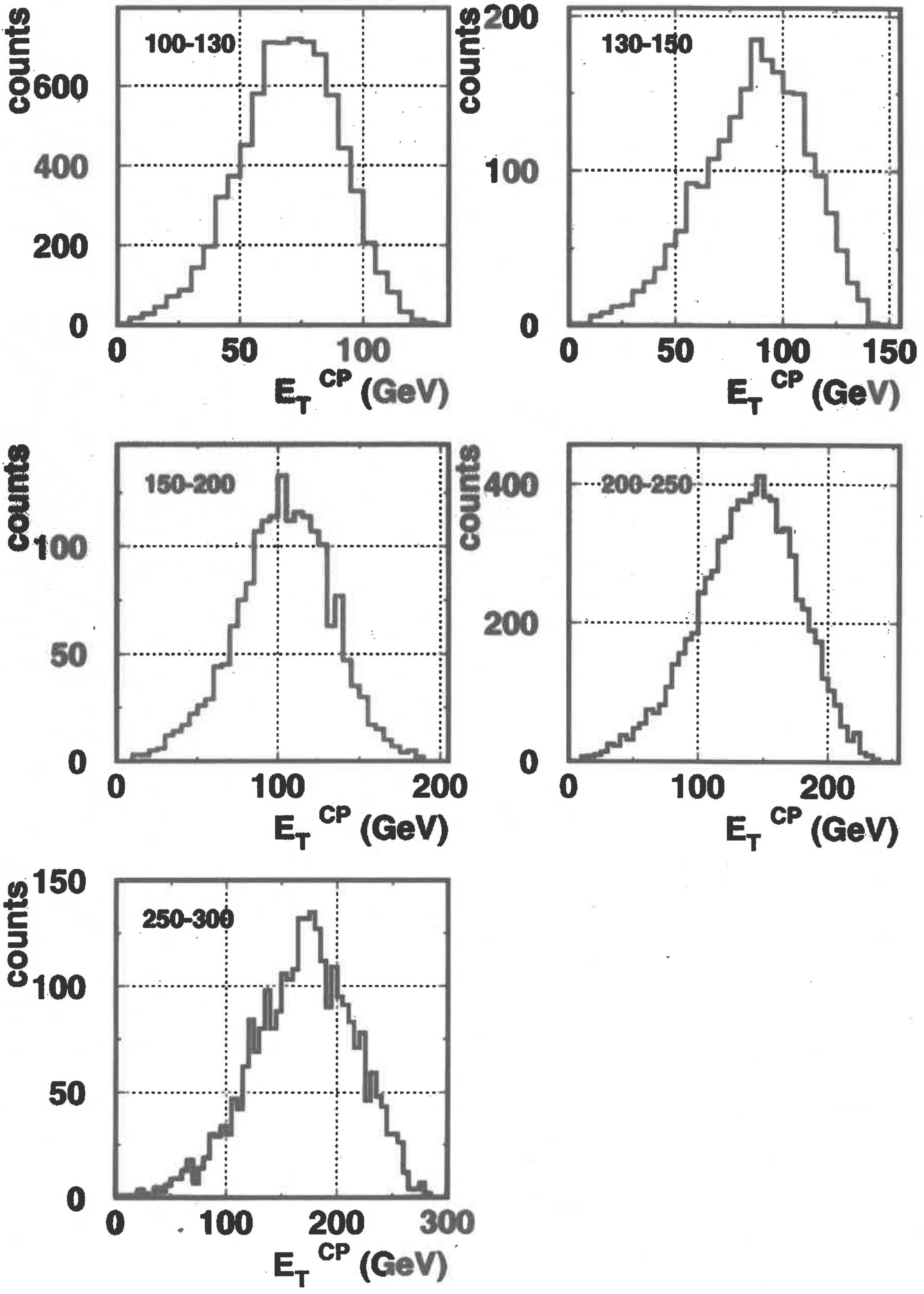


Alice event: 0, Run:0

Nparticles = 821   Nhits = 188231


Contribution of charged particles to jet Et
E_T jet in charged particles (GeV)
300
250
200
150
100
50
0
0
50
100
150
200
250
300
E_T jet total (GeV)

Contribution of charged particles to jet Et



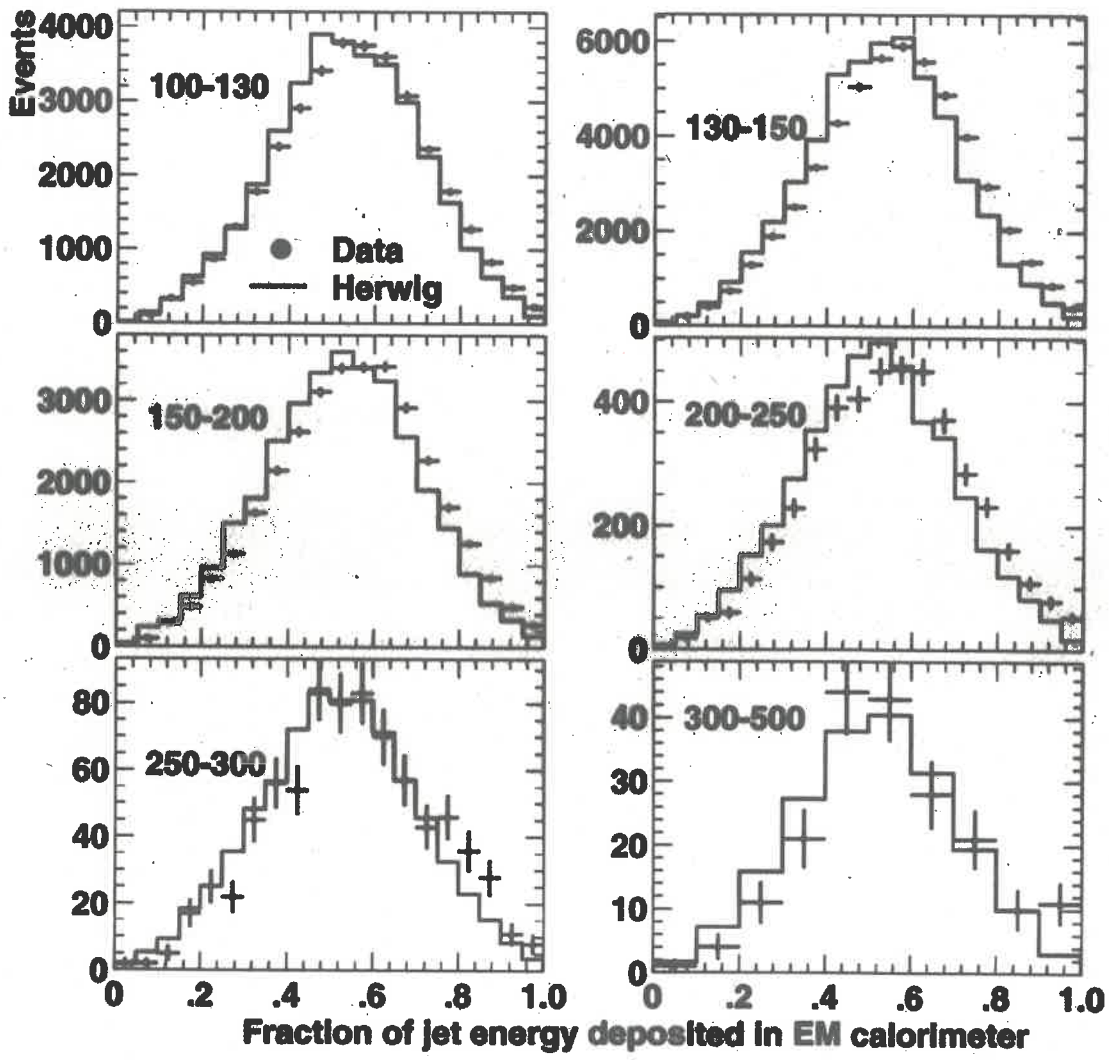
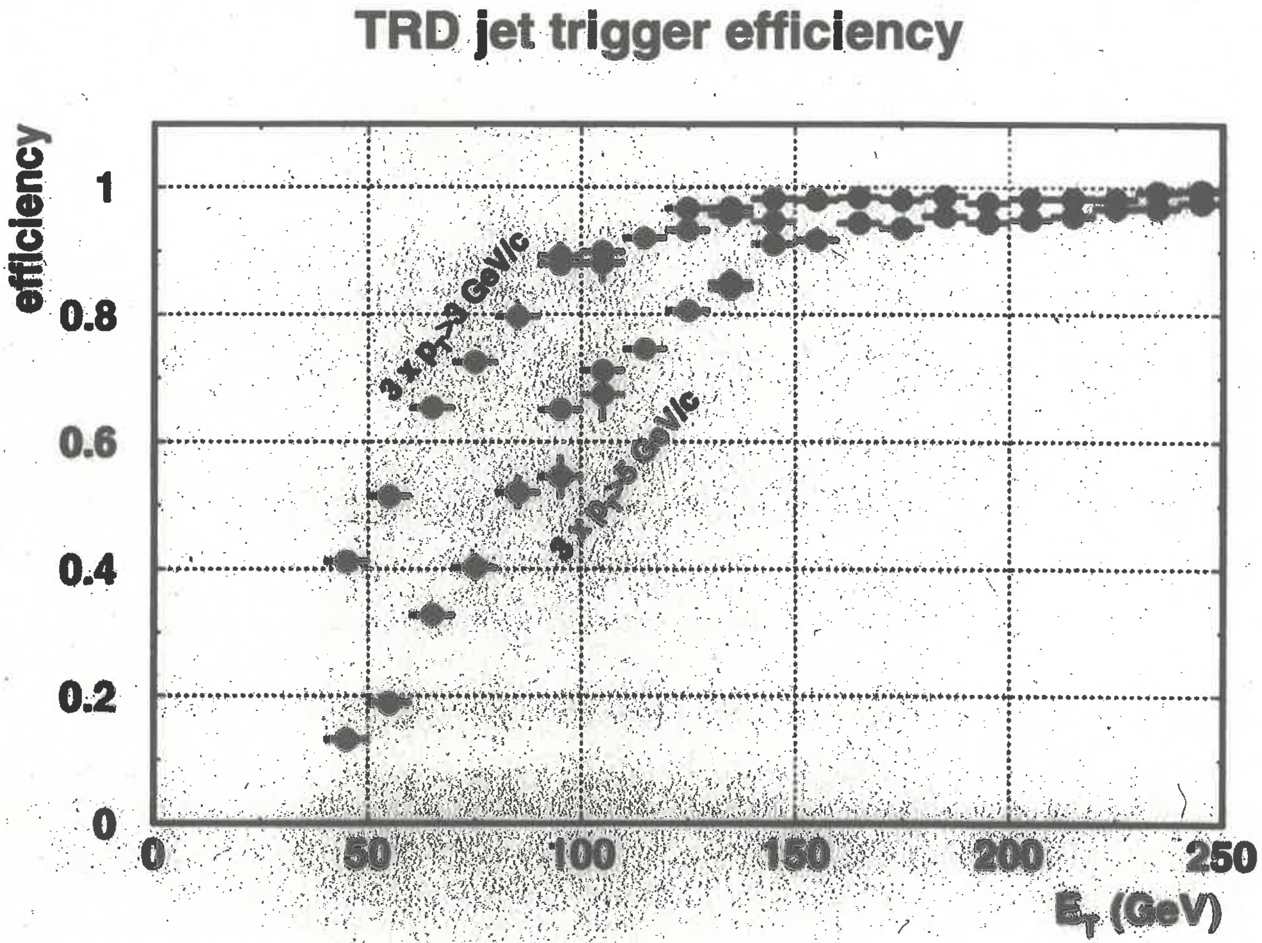


FIG. 15. Fraction of electromagnetic energy in jets for data (points) and simulation (histogram). The labels on the individual plots (e.g. 100-130 GeV) indicate the E_T range of the leading jet.



trigger condition:

3 charged particles with $p_T > p_T$min in one TRD module

SUPRESSION OF EVENTS WITHOUT JETS

CENTRALITY	$3 \times p_\perp > 3$	$3 \times p_\perp > 5$
0-15%	0.18	$2.3 \cdot 10^{-3}$
MINB	0.031	$4.0 \cdot 10^{-4}$

EVENT RATES WITH TRD JET TRIGGER

TRIGGER	EVENTS WITHOUT JETS	EVENTS WITH $E_T > 100$ GeV JETS
MINBIAS	1000/s	2.0/s
JET3	31/s	1.8/s
JET5	0.40/s	1.3/s
CENTRAL	150/s	1.0/s
CENTRAL·JET3	27/s	0.9/s
CENTRAL·JET5	0.35/s	0.7/s

THESE NUMBERS MAY BE HIGHER IN REALITY; FULL SIMULATION IS NEEDED

EXPLANATION OF TERMS:

CENTRAL ≡ MOST CENTRAL 15%

JET3 ≡ $3 \times p_\perp > 3$ GeV/c IN ANY OF TRD MODULES

JET5 ≡ $3 \times p_\perp > 5$ GeV/c —— " ——

TRD jet trigger suppression factor for events without jets

1. Extract single particle multiplicities in central Pb+Pb from Hijing:
   0.192 charged particles with pt>3 GeV/c per TRD module
   0.0433 charged particles with pt>5 GeV/c per TRD module

2. From this, estimate mean multiplicities as a function of centrality:

centrality	<Ncoll>	<n(pt>3)>	<n(pt>5)>
0-15%	1320	0.192	4.3e-2
15-30%	619	9.0e-2	2.0e-2
30-45%	256	3.7e-2	8.4e-3
45-60%	90.0	1.3e-2	3.0e-3
60-75%	24.2	3.5e-3	7.9e-4
75-90%	5.2	7.6e-4	1.7e-4
90-100%	0.9	1.3e-4	3.0e-5

3. Use these mean multiplicities to calculate the probability of having at least 3 such particles. Assume independent production and use Poisson.

centrality	3 x pt>3	3 x pt>5
0-15%	1.0e-3	1.3e-5
15-30%	1.1e-4	1.3e-6
30-45%	8.2e-6	9.8e-8
45-60%	3.6e-7	4.5e-9
60-75%	7.1e-9	8.2e-11
75-90%	7.3e-11	8.2e-13
90-100%	3.7e-13	4.5e-15
minbias	1.7e-4	2.2e-6

   How good is the assumption of independence? Not very good because the multiplicity distributions in Hijing are not exactly Poissonian. A direct valuation of the probability of having 1,2, and 3 particles with pt>3 GeV/c yields 0.17, 0.020, and 0.0022 respectively, compared to the Poissonian 0.18, 0.016, and 0.00102. Let us take care of this by multiplying all the obtained probabilities for n>=3 by 2.

4. Calculate the fake trigger probabilities. The trigger condition is to have at least 3 pt>ptmin particles in any of the TRD modules. For this, multiply the above values by 90 (number of TRD modules) and 2 (correction for non-Poissonian multiplicity distributions):

centrality	3 x pt>3	3 x pt>5
0-15%	0.18	2.3e-3
minbias	0.031	4.0e-4

5. Calculate event rates, assuming 1000 minbias/s. Notation:
   central - central 0-15%
   jet3 - at least 3 charged particles with pt>3 GeV/c in any TRD module
   jet5 - at least 3 charged particles with pt>5 GeV/c in any TRD module
   Assumed trigger efficiency for Et>100 GeV jets: 100% for central, 90% for jet3, and 66% for jet5.

trigger	events without jets	Et>100 GeV jet events
minbias	1000/s	2.0/s
jet3	31/s	1.8/s
jet5	0.40/s	1.3/s
central	150/s	1.0/s
central and jet3	27/s	0.9/s
central and jet5	0.35/s	0.7/s

****

JETS WITH ALICE – SUMMARY

IN Pb + Pb

IN 10^7 CENTRAL EVENTS WE WILL HAVE

500 000	JETS WITH	$E_\perp \geqslant 50$ GeV
50 000	JETS WITH	$E_\perp \geqslant 100$ GeV
7000	JETS WITH	$E_\perp \geqslant 150$ GeV

USING <u>TRD</u> TO TRIGGER ON JETS WE GET SIMILAR NUMBERS OF JETS PER DAY

(ALL CENTRALITIES)