Centrality in p-A collisions with the ALICE ZDCs: resuming old works and looking for new ideas!

C. Oppedisano
for the ALICE Collaboration

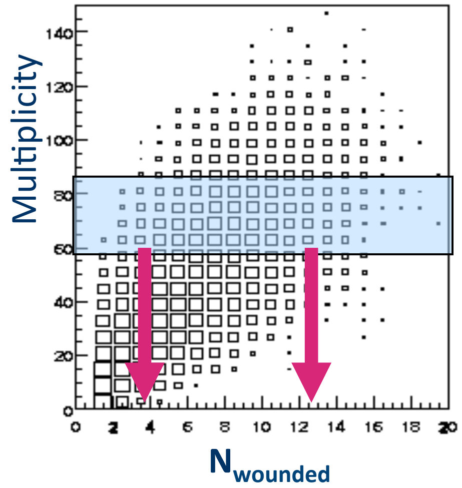
ALICE

CENTRALITY in p-A & SLOW NUCLEONS

Centrality in p-A interactions can be defined through the number of collisions N_{coll}

Inclusive measurement of charged particle multiplicity can be poorly correlated with N_{coll}

Measure particle multiplicity vs. centrality ➡ independent method to estimate centrality



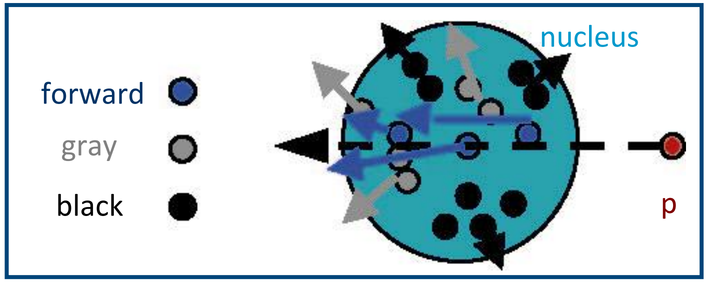
➡ At fixed target experiments centrality has been determined detecting slow nucleons

(classification from emulsion experiments)

Gray nucleons ➡ soft nucleons knocked out by wounded nucleons

Black nucleons ➡ low energy target fragments

SLOW NUCLEONS	β [c units]	p [MeV/c]	E_{kin} [MeV]
Black	0 ÷ 0.25	0 ÷ 250	0 ÷ 30
Gray	0.25 ÷ 0.70	250 ÷ 1000	30 ÷ 400

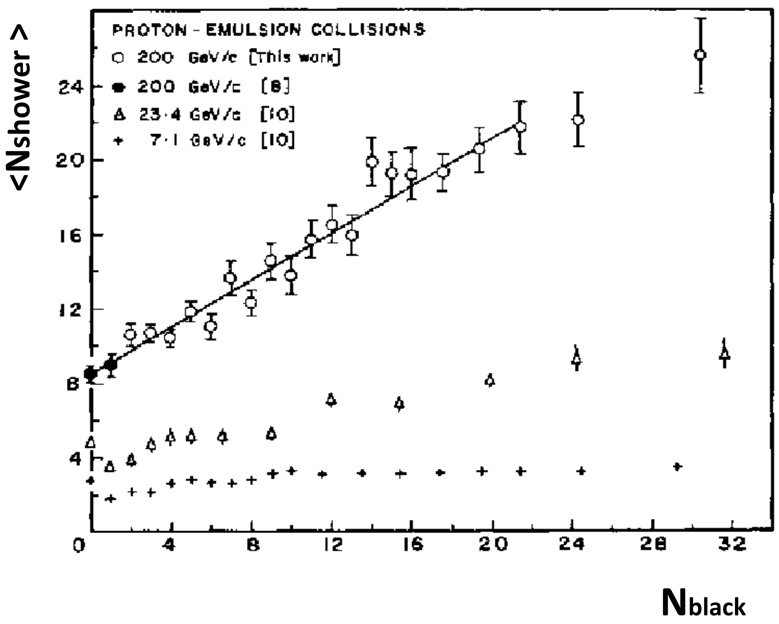


SLOW NUCLEONS AND MULTIPLICITY

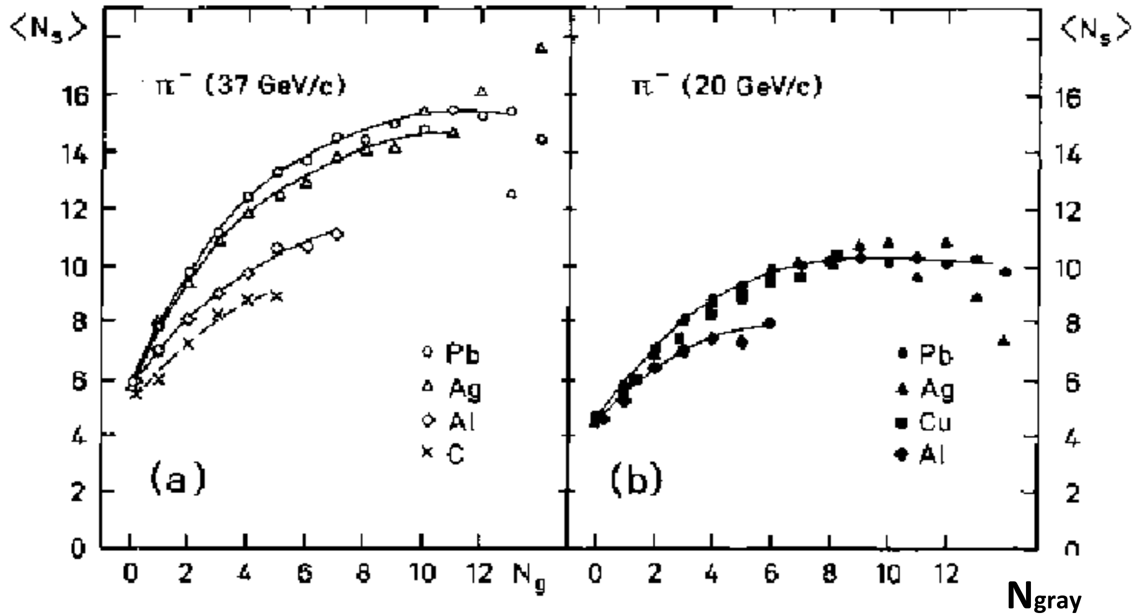
Results from existing experimental emulsion and fixed target results on slow nucleon production in hadron-nucleus interaction [F. Sikler, hep-ph/0304065]

➡ multiplicity of produced shower particles is correlated with the number of emitted slow particles

Number of particle in the shower vs. number of black nucleons



Number of particle in the shower vs. number of gray nucleons

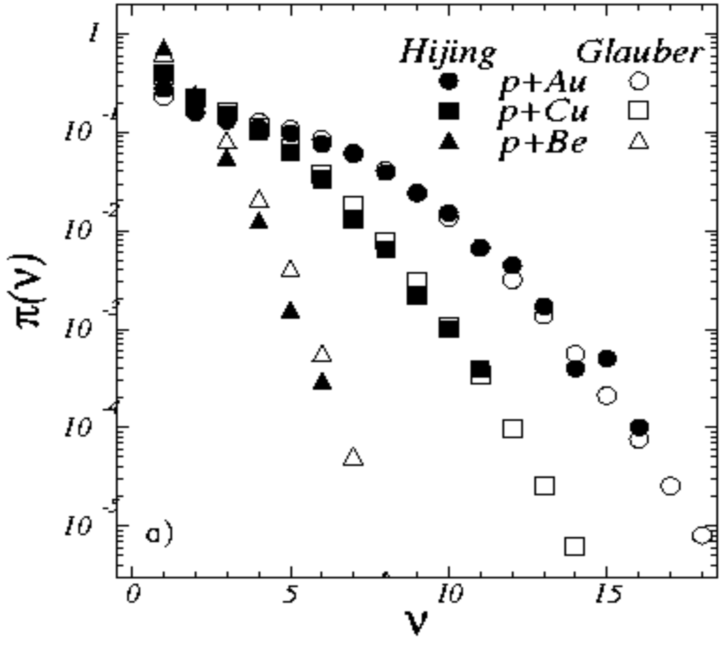


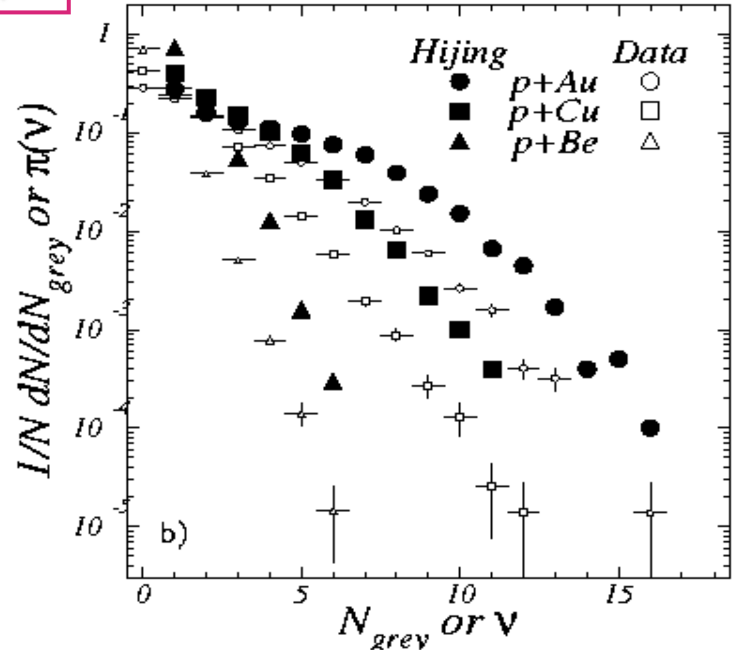
SLOW NUCLEONS & N_{coll}

Probability distribution for the proton to undergo N_{coll} collisions with target nucleons

N_{gray} ⇔ N_{coll}

N_{coll} (Hijing) and N_{gray} (data) distributions
➡ very similar distributions





Relationship between N_{coll} and N_{gray} [I. Chemakin *et al.*, Phys. Rev. C **60** 024902 (1999)]

➡ different models considered, E910 reproduce experimental data assuming

$$\bar{N}_{gray} \propto \bar{N}_{coll}$$

SLOW NUCLEON EMISSION MODEL

[F. Sikler, hep-ph/0304065]

- features of produced particles are highly independent of projectile energy from 1 GeV to 1 TeV
- slow nucleons emission dictated by nuclear geometry

- kinematical distributions described by independent statistical emission from a moving frame
- isotropic emission from a source moving with velocity β
- number distribution of black/gray nucleons follows binomial distributions

From N_{coll} to N_{gray} ➡ distribution of the number of projectile collisions from Glauber model
➡ probability distribution of the number of gray nucleons from geometric model

$$\Rightarrow \quad \overline{N}_{gray} \propto \overline{N}_{coll}$$

From N_{coll} to N_{black} ➡ emission from equilibrated nucleus
➡ black nucleon multiplicity connected to target excitation

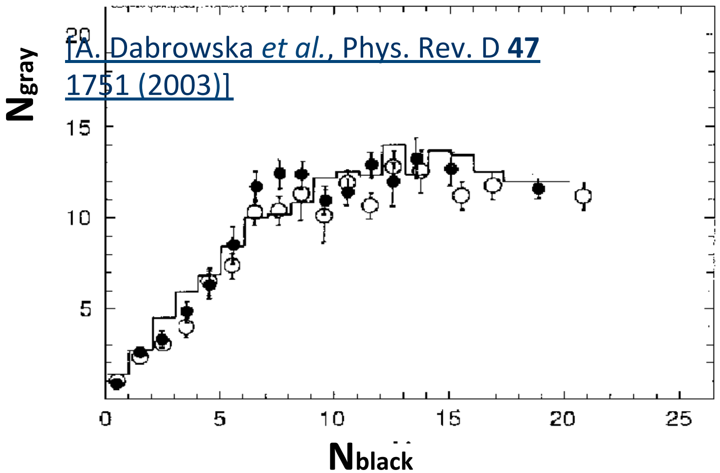
$$\Rightarrow \quad \overline{N}_{black} \propto \overline{N}_{coll}$$

Minimum bias p-A collision ➡ $\overline{N}_{black} \approx 0.08A \quad \overline{N}_{gray} \approx 1.2A^{1/3}$

Centrality selected collisions on Pb target: values (per collision) ➡ $\overline{N}_{black} \approx 4N_{coll} \quad \overline{N}_{gray} \approx 2N_{coll}$

EXPERIMENTAL RESULTS (I)

➡ experiments with lighter ions (O, S) report a saturation effect in N_{black} vs. N_{gray}



[A. Dabrowska *et al.*, Phys. Rev. D **47** 1751 (2003)]

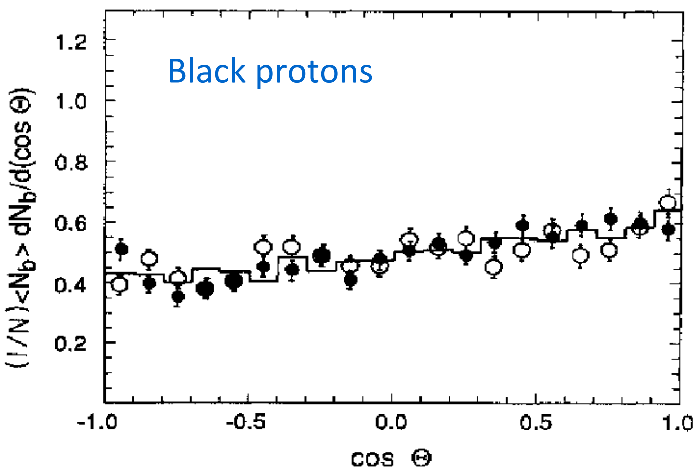
Saturation values ➡ $<N_{black}> = 12$ for $N_{gray} > 7$

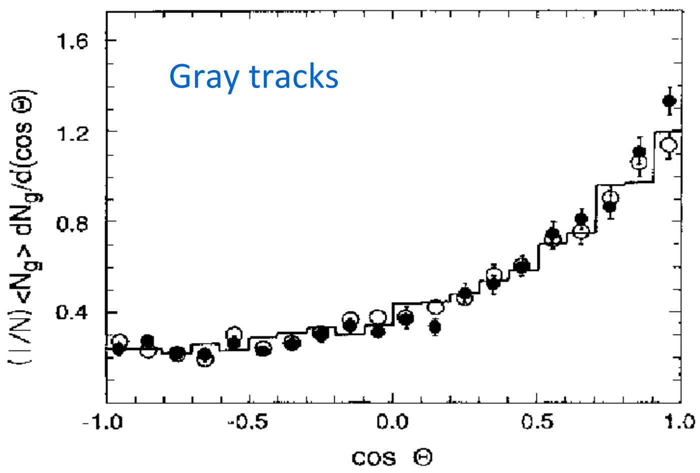
No experimental data for Pb nuclei

Supposing the number of emitted slow nucleons proportional to the target nucleus thickness ➡ rescaled values for Pb nucleus

$<N_{black}> \sim 28$ for $N_{gray} > 15$

➡ the gray track angular distribution is strongly forward peaked





[M. L. Cherry *et al.*, Phys. Rev. D **50** 4272 (1994)]

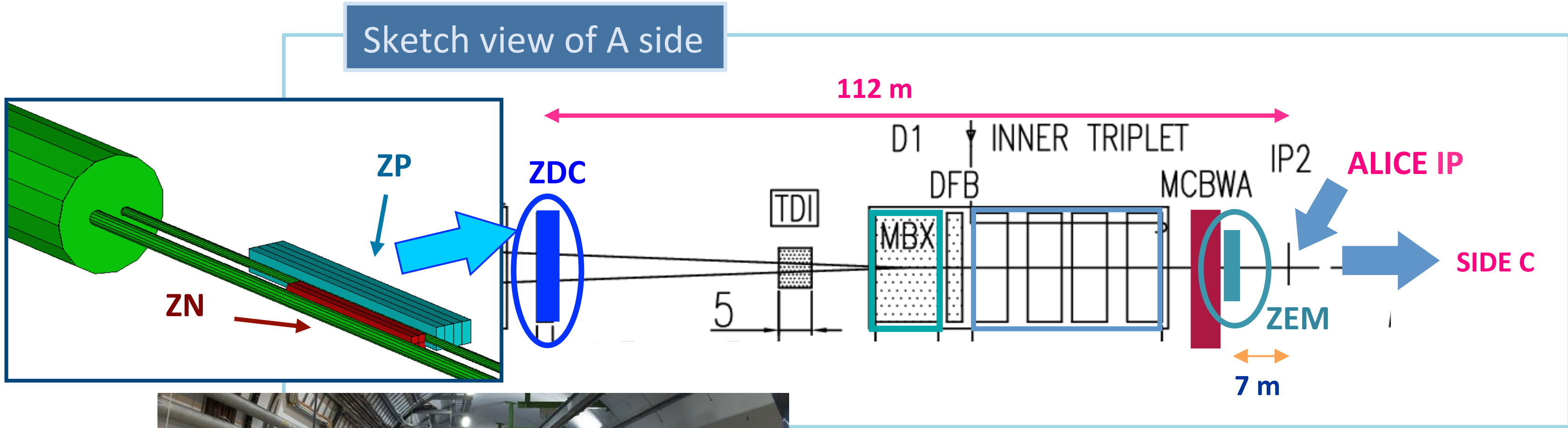
ALICE ZDCs

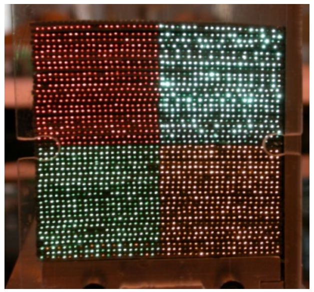
ALICE ZDCs

- placed at 0° w.r.t LHC axis, ~112 m far from IP on both sides, quartz fibre calorimeters
- on both A and C sides we have a proton (ZP) and a neutron (ZN) ZDC

The ZDC system is completed by:

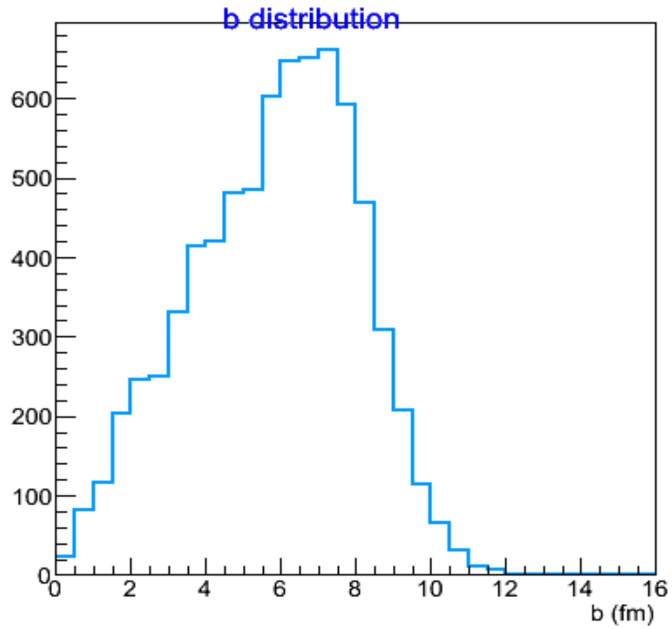
- 2 small (7x7x21) cm^3 EM calorimeters (ZEM1, ZEM2) placed at ~7.5 m from the IP, at ±8 cm from LHC axis, only on A side covering the range $4.8<\eta<5.7$

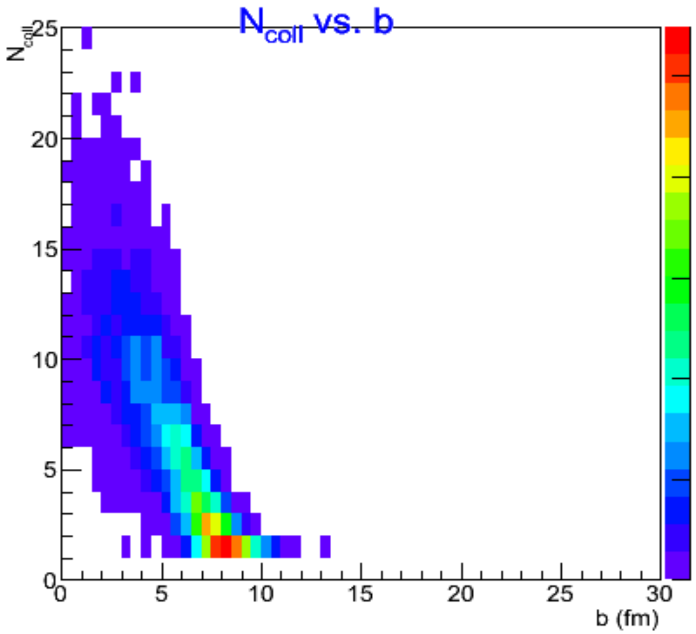




p-A MC (I)

HIJING + slow nucleon model generator (saturation and forward peaked distribution)



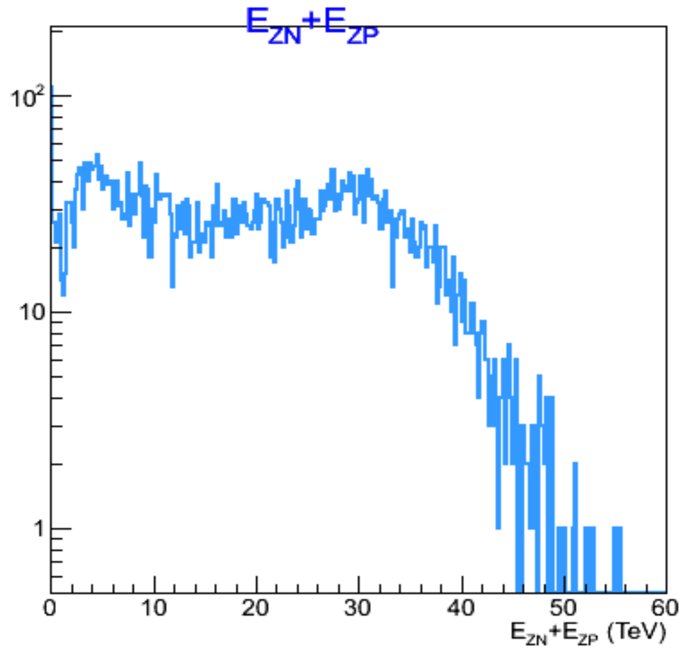


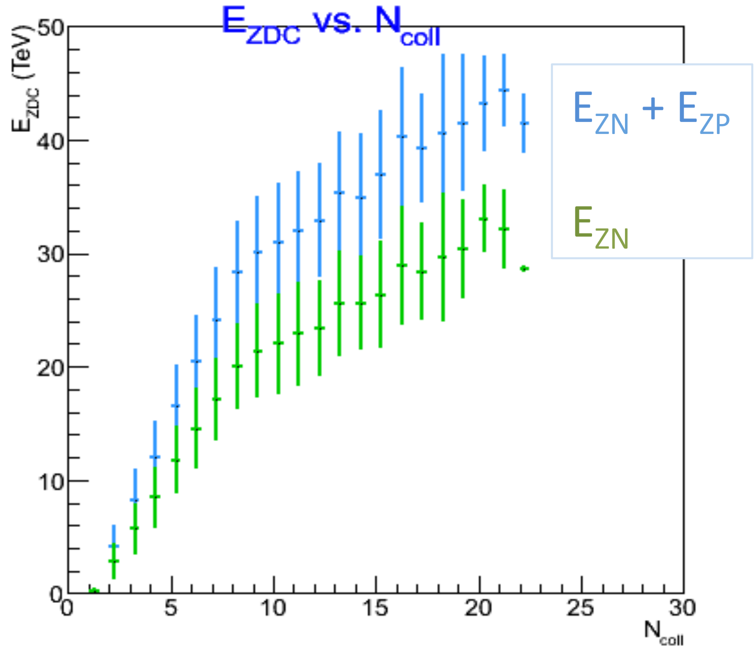
QUESTIONS

- what generator is better to use for p-A to have both the nucleus and the proton accurately simulated?
- how to take into account the EM processes (particularly important for γ-p)

p-A MC (II)

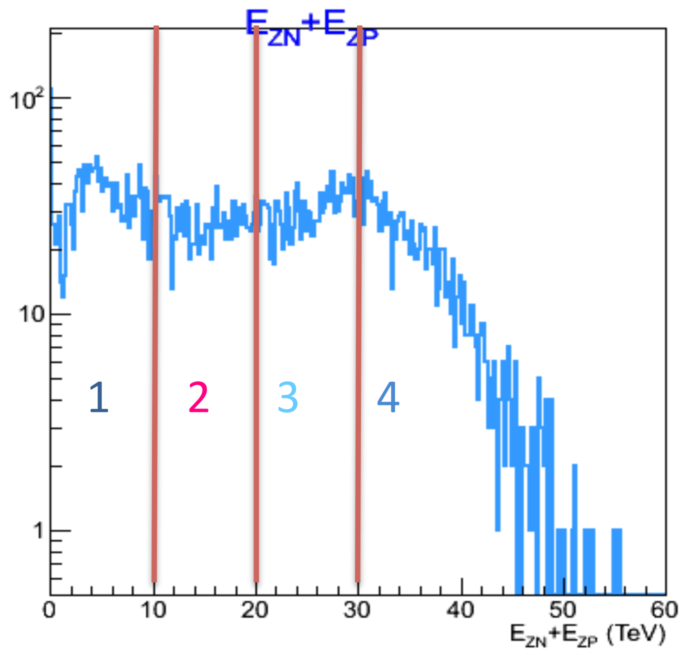
ZN + ZP calorimeter energy spectrum for minimum bias p-A collisions at p_p = 4 TeV

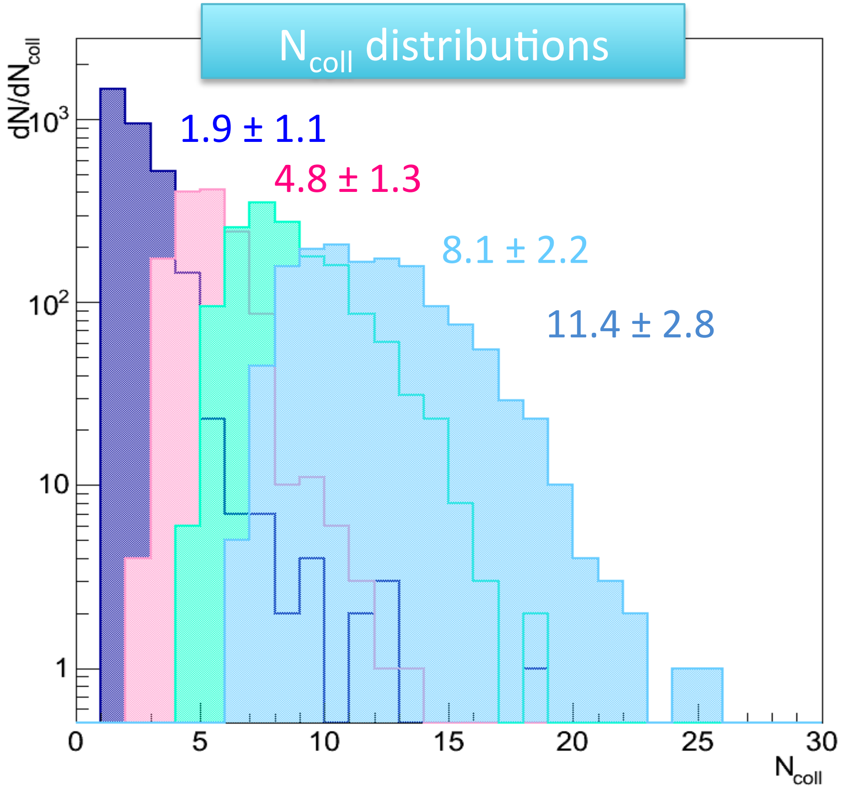




p-A MC (III)

➡ sharp cuts in E_{ZDC}





➡ not more than 3/4 centrality classes can be defined

➡ inputs for the slow nucleon model and more in general suggestions about the generators to be used are more than welcome!

BACKUP

EXPERIMENTAL RESULTS (I)

Relationship between N_{coll} and N_{gray} ➡ different models considered

(1) geometric cascade model (GCM) ➡ $\bar{N}_{grey} \propto \bar{\nu}$

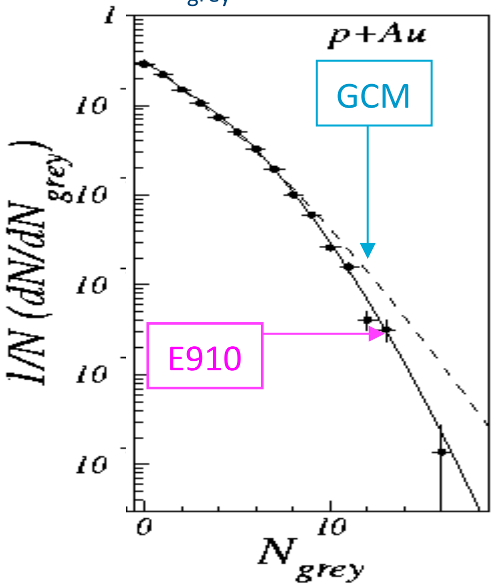
(2) intranuclear cascade (IC) ➡ $\bar{N}_{grey} \propto \bar{\nu}^2$

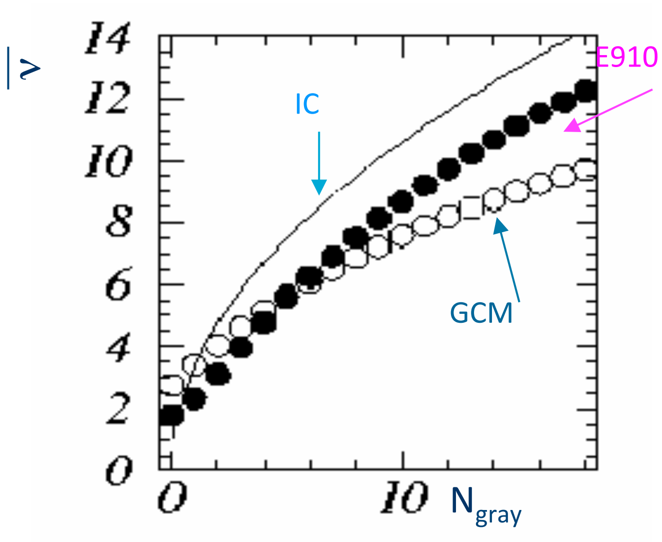
(3) polynomial model (E910) ➡ $\bar{N}_{grey} = c_0 + c_1\nu + c_2\nu^2$

Fit of data ➡ $c_2 \sim 0$

➡ $\bar{N}_{grey} \propto \bar{\nu}$

N_{grey} distribution





Polynomial model is the more accurate to determine centrality (<ν>)

SLOW NUCLEON MODEL

Slow nucleons momentum distributions can be parametrized by Maxwell-Boltzmann distributions

➡ particles emitted isotropically from a source moving with velocity β

Invariant cross section

$$E\frac{d^3\sigma}{dp^3} \propto \exp\left({}^{-E_{kin}}\!/\!{}_{E_0} \right)$$

Black nucleons emitted from a stationary source ➡ $\beta = 0$, $E_0 = 5$ MeV

Black nucleons emitted from a frame moving slowly in beam direction ➡ $\beta = 0.05$, $E_0 = 50$ MeV

From N_{coll} to N_{gray}

Glauber model assuming Wood-Saxon nuclear density ➡ distribution of number of projectile collisions in the nucleus

Geometric model ➡ probability distribution of number of slow nucleons

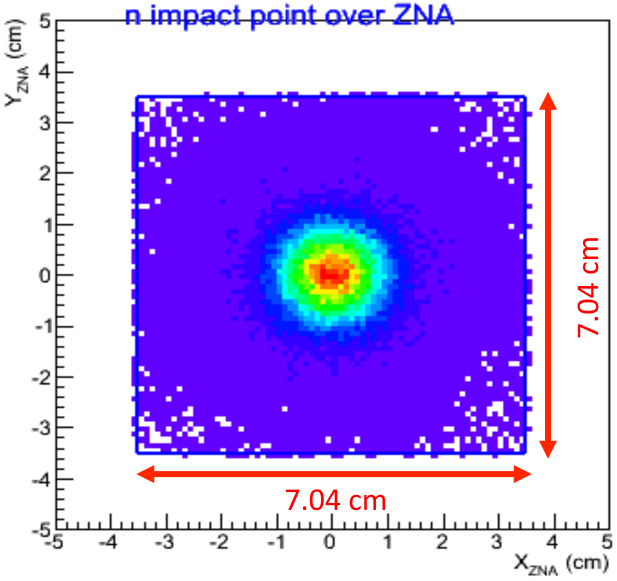
From N_{coll} to N_{black}

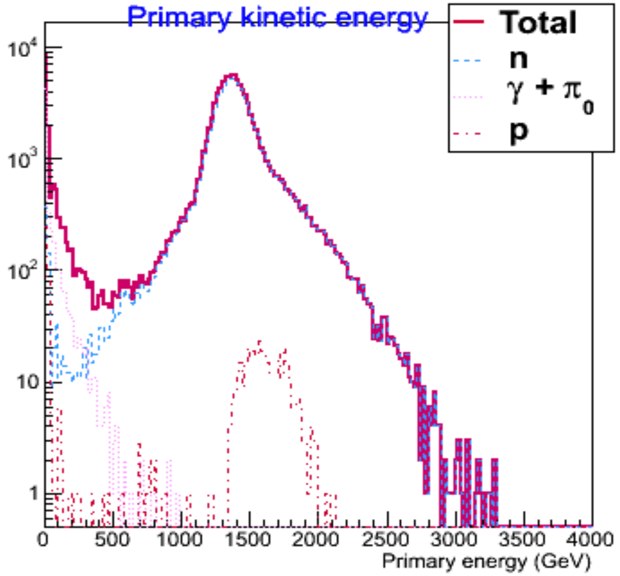
Black nucleons production described by thermodynamic or statistical models (remnants undergoes equilibration before breakup)

Each collision provides independent production of prompt gray nucleons with identical excitation of the nucleus, leading to the emission of black nucleons

pA MC RESULTS (I)

ZN





ZP