Measuring Centrality in pA/dA Collisions at RHIC with Grey Protons

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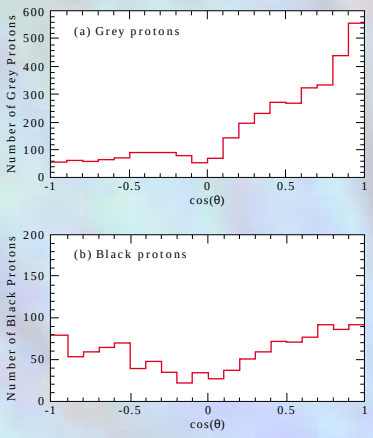
Abstract **Traditionally, the centrality in proton-nucleus collisions has been determined from the number of knock-out (grey) and evaporation (black) nucleons. Unfortunately, none of the current RHIC experiments have the capability to measure grey nucleons. We propose a modest calorimetric upgrade located at the ZDC z-position and utilizing an hadronic calorimeter previously used by experiment E864 at the AGS to measure these forward protons. The upgrade will be placed at the PHENIX interaction region for the upcoming run cycle at RHIC. However, there are enough calorimeter modules to instrument an identical hadron calorimeter in all 4 interaction regions. This upgrade will allow systematic comparisons and extrapolations of a variety of signatures from p-A and d-A collisions to A-A.**

What are grey and black nucleons?

A proton-nucleous collision in emulsion. The "black" tracks are low momentum, isotropic, evaporation protons; "grey" tracks are higher momentum and forward directed.

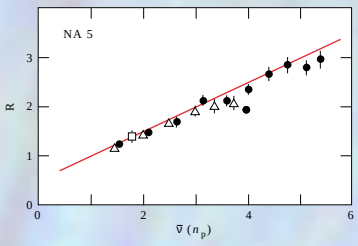


Angular distribution of identified protons with respect to the beam direction for (a) grey protons with momentum >0.3 GeV/*c* and (b) black protons with momentum <0.3 GeV/*c* measured in the Hybrid Spectrometer[6].

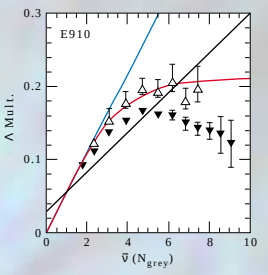
References (on p-A centrality)

1. **W. Busza,** *et al.* **Phys. Rev. Lett. 34 (1975) 836.**
2. **Anderson, Otterlund, and Stenlund, Phys. Lett. B37 (1978) 343.**
3. **Hegab and Hufner, Phys. Lett B105 (1981) 103.**
4. **Stenlund and Otterlund, Nucl. Phys. B198 (1982) 407.**
5. **C. DeMarzo,** *et al.* **(NA5) Phys. Rev. D29 (1984) 2476.**
6. **D.H. Brick,** *et al.* **(Bubble Chamber Hybrid Spectrometer) Phys. Rev. D39 (1989) 2484.**
7. **R. Albrecht,** *et al.* **(WA80) Z. Phys. C57 (1993) 37.**
8. **T.A. Armstrong,** *et al.* **(E864) Nucl. Inst. Meth. A406 (1998), 227.**
9. **I. Chemakin,** *et al.* **(E910) Phys. Rev. C60 (1999) 024902.**
10. **I. Chemakin,** *et al.* **(E910) Phys. Rev. Lett 85 (2000) 4868.**
11. **T. Susa for the NA49 Collaboration, Nucl. Phys. A698 (2002) 491c.**

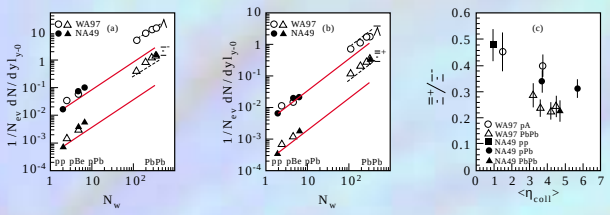
Grey protons have been used in previous p-A experiments to extract interesting physics



The ratio $R = 2h^-_{pA}/h^-_{pp}$ versus the average number $\bar{\nu}$ (n_p) of projectile collisions for *p*Xe (circles), *p*Ar (triangles), and *p*Ne (squares) collisions. A line of the form $R = 0.5\ [\bar{\nu}(n_p)+1]$ is shown for comparison[5].



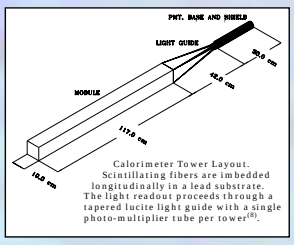
Λ multiplicity versus the average number of binary collisions measured by E910 through the number of grey protons[10].



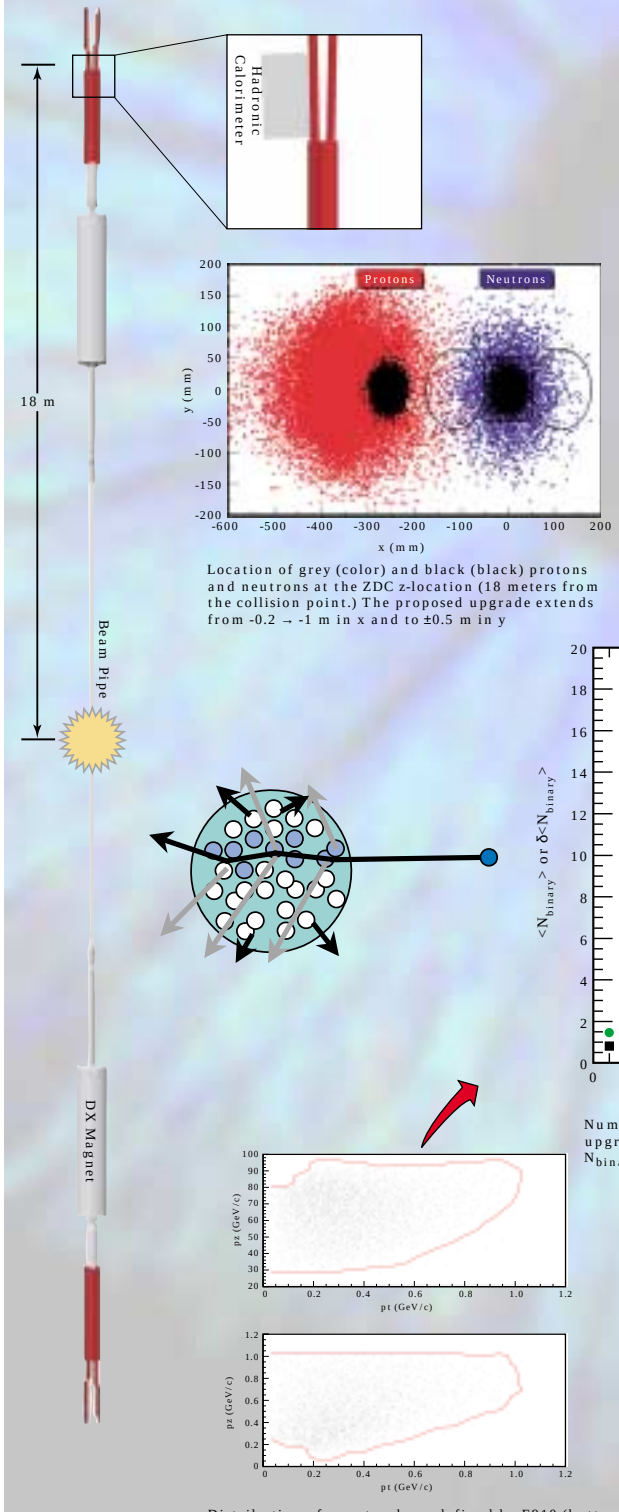
Strangeness yields measured by NA49[11]

Hadron Calorimeter provides best measure of $N_{grey/black}$

Scrounge-a-cal: Adopt E864 hadron calorimeter, unused for several years at Brookhaven. Place at location of ZDC to measure forward protons.



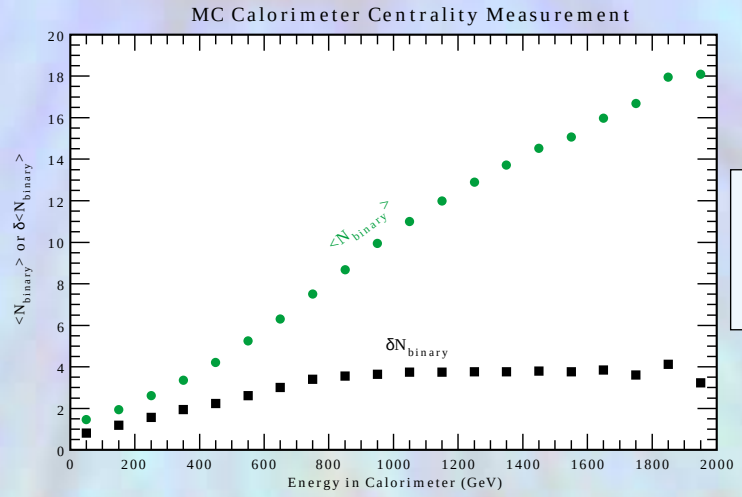
Calorimeter Tower Layout. Scintillating fibers are imbedded longitudinally in a lead substrate. The light readout proceeds through a tapered lucite light guide with a single photo-multiplier tube per tower[8].



Location of grey (color) and black (black) protons and neutrons at the ZDC z-location (18 meters from the collision point.) The proposed upgrade extends from -0.2 → -1 m in x and to ±0.5 m in y

$\frac{\delta E}{E} = 3.5\% + \frac{34\%}{\sqrt{E}}$

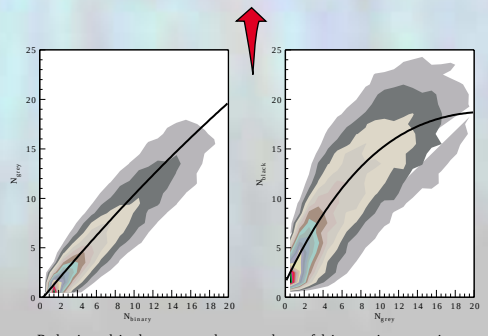
MC Calorimeter Centrality Measurement



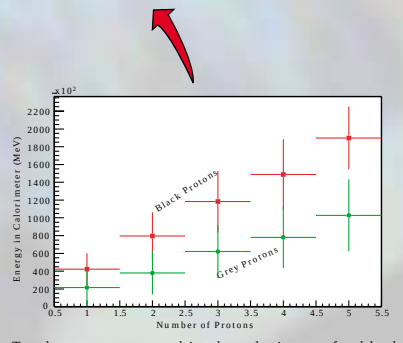
Number of binary collisions versus the total energy deposited in the hadron calorimeter upgrade (green). The black points are the RMS widths of the relationship between N_{binary} and the energy.

PHENIX will instrument this upgrade for the upcoming run — other experiments have expressed an interest in an identical instrumentation in the near future

Distribution of grey tracks as defined by E910 (bottom). The top plot shows the same distribution boosted into the RHIC frame.



Relationship between the number of binary interactions and the number of grey and black tracks[4 + 9].



Total energy measured in the calorimeter for black and grey protons from the E910 definition.

LDRD #03-ERD-005

P02262-scj-a-001

This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.