FLUKA Status
and Preliminary Results from the
3, 5 and 10 GeV/A AGS July Runs

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FLUKA (For Newcomers)

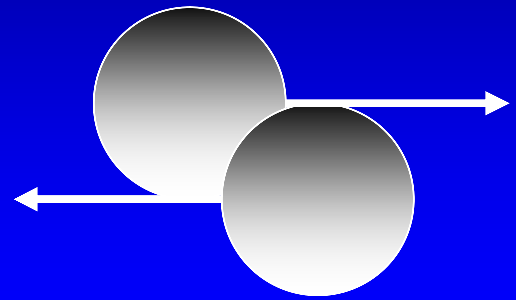
- Is A Fully Integrated Transport Code…
  - (Attempts To do All Relevant Physics Internally)
    - Includes Hadronic as well as EM Interactions
  - Accuracy v. Data is excellent and improving
- Inherently Includes Magnetic Field Transport…
- Is Widely Used at Accelerators Around the World for Shielding Calculations and Simulations…
- Is Widely Used for Simulation of Sea-Level Cosmic Rays due to Extensive Air Showers.
- An Evolving, Supported Code…

Heavy Ions in FLUKA

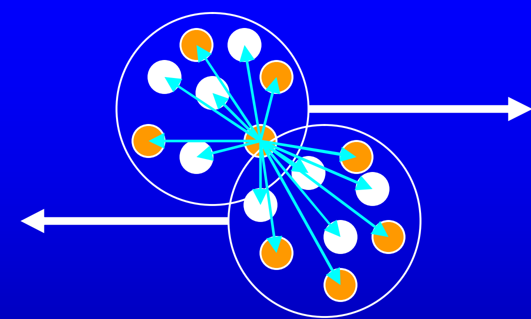
- > 5 GeV/A – Available — Using **DPMJET 3.0** Event Generator
  - (From: R. Engel, J. Ranft and S Roesler)
- < 5 GeV/A – Available, ….& Evolving
  (Simulating Both Target AND Projectile are Important)
  - *Current Solution – Use Heavily Modified version of* ***RQMD 2.4*** *(From H. Sorge) (Relativistic Quantum Molecular Dynamics Event Generator, which is Comparable to* ***JQMD*** *as used in* ***PHITS****).*
  - *Development Work in Progress – Improved versions of existing RQMD Models & Developing a New Hamiltonian Molecular Dynamics (HMD) Model (Neal Zapp's Ph.D. Thesis)*
- <100 MeV/A (Inelastic)–Nuclear Physics ***BME*** Model… (From E. Gadioli, et. al)—Beta version is in testing…
- **Unlike GEANT4 These are Full Event Generators that simulate all relevant physics (e.g. including photo disintegration…)**

RQMD
Relativistic Quantum Molecular Dynamics

- FLUKA employs a heavily modified version of RQMD 2.4 from H. Sorge. (The QMD scheme originally came from Chemistry…)
- RQMD is an evolution of the original Intra-Nuclear Cascade (INC) models, which iterated individual discrete particles (e.g. nucleons) in constant mean-value approximated potentials…
- RQMD adds a dynamic re-calculation of the intra-nuclear potentials at discrete intervals throughout the collision evolution iteration process. (Sorge uses many approximations...)
- When individual nucleons collide, both models use the Free-Particle Cross Sections.



Intra-Nuclear Cascade
Uses Mean-Field Approx.



RQMD
Recalculates Nuclear Potential

● Proton
● Neutron

Some Recent NASA-Related FLUKA Results

- Official **Release of FLUKA** as a CERN-Supported Code (July 2005)
  - Source Code Now Available via CERN/INFN License Agreement
  - Significant Pre-Release Improvements…
    - Embedded PEMF file creation
    - Improved Geometry Input options.
- 3, 5 & 10 GeV/A— C, Si and Fe Beams on C, Al, Fe and Cu Targets taken at the AGS…

The Rest of This Talk Will Focus On Heavy Ion Event Generator Issues

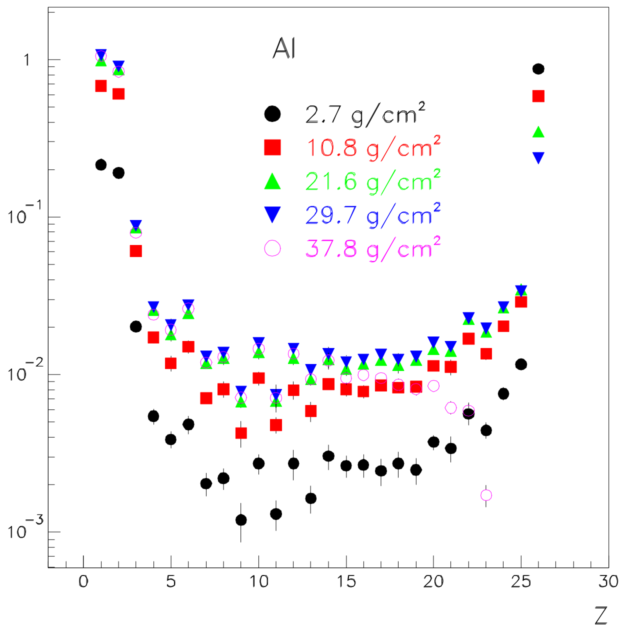
- We need accurate Physics-Based event generators because we cannot obtain enough data to make complete phenomenological models.
- We need data with which to validate and improve the existing event generators…

A Reminder of Some Points to Keep in Mind When Comparing the Event Generators to Data

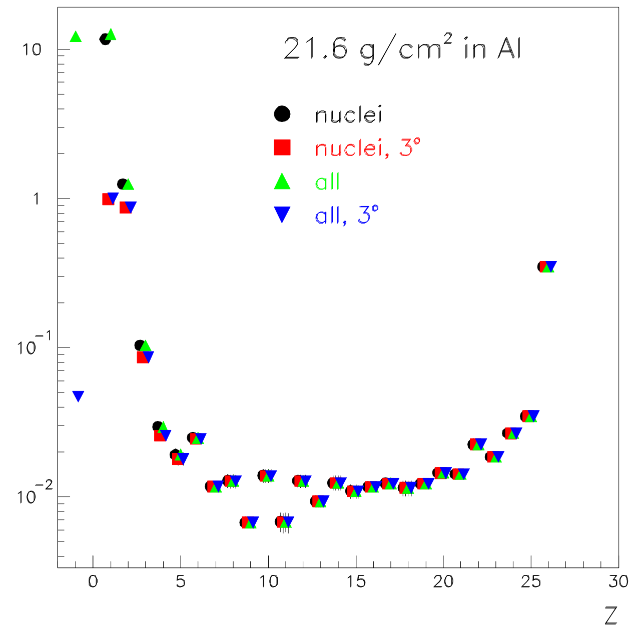
- Beamline confined measurements (0-3 degrees) tend to miss significant numbers of the light fragments and single charged particles.
- Measured “Track Average LET” is critically dependent upon detector details…

Fragment Spectrum from FLUKA for an “Ideal” Beam for 1 GeV/A Fe-Al Simulations

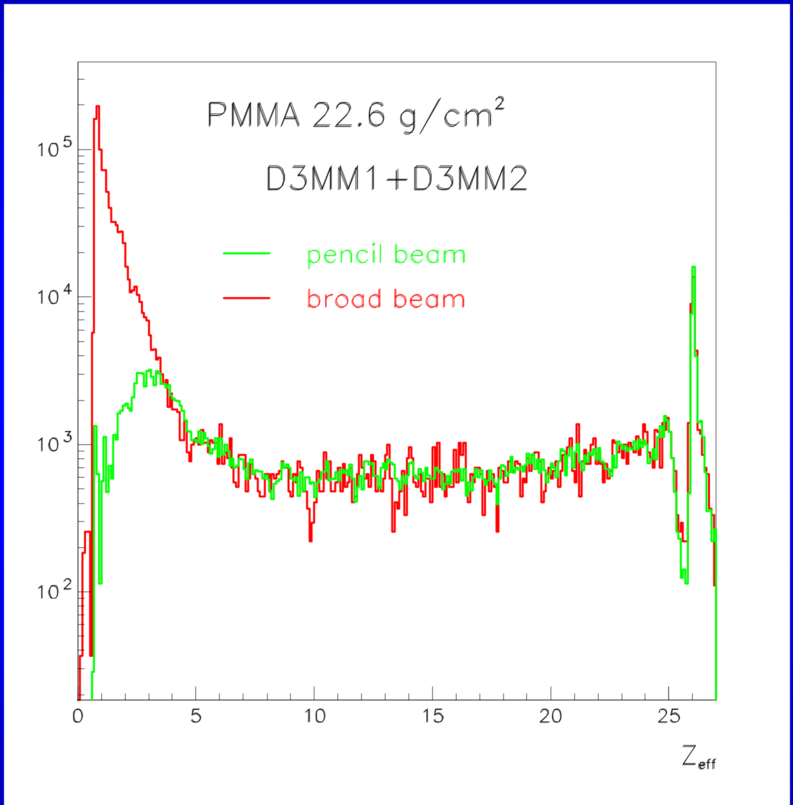
Fragments as a function of Depth

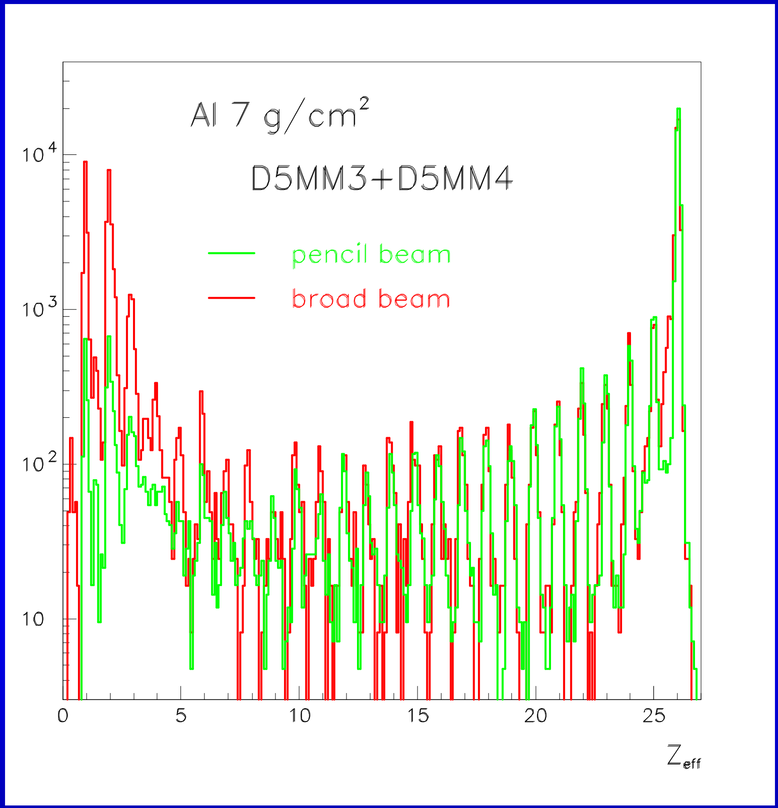


“All” & 3 Degree Detectors



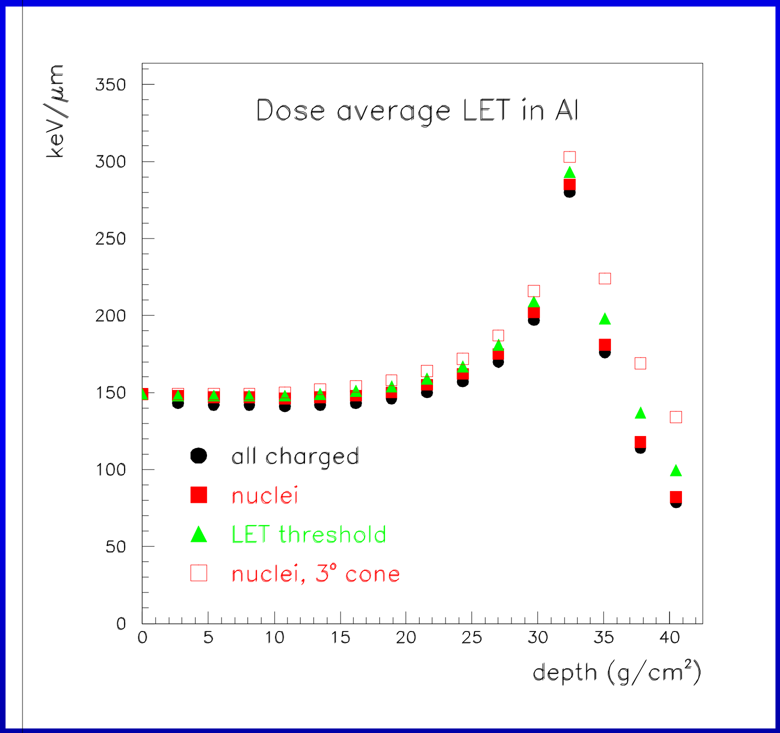
Beam/Detector Size Effects

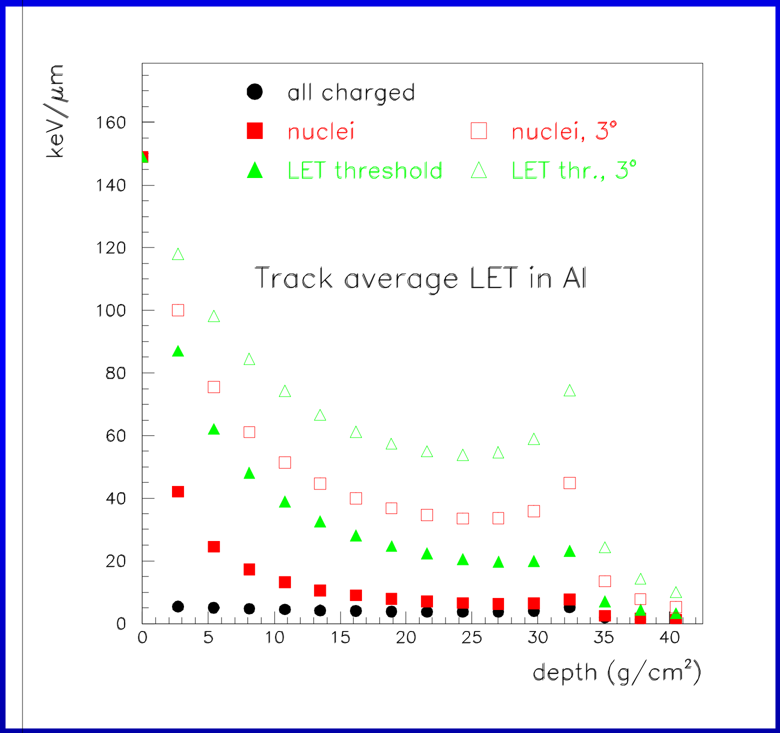




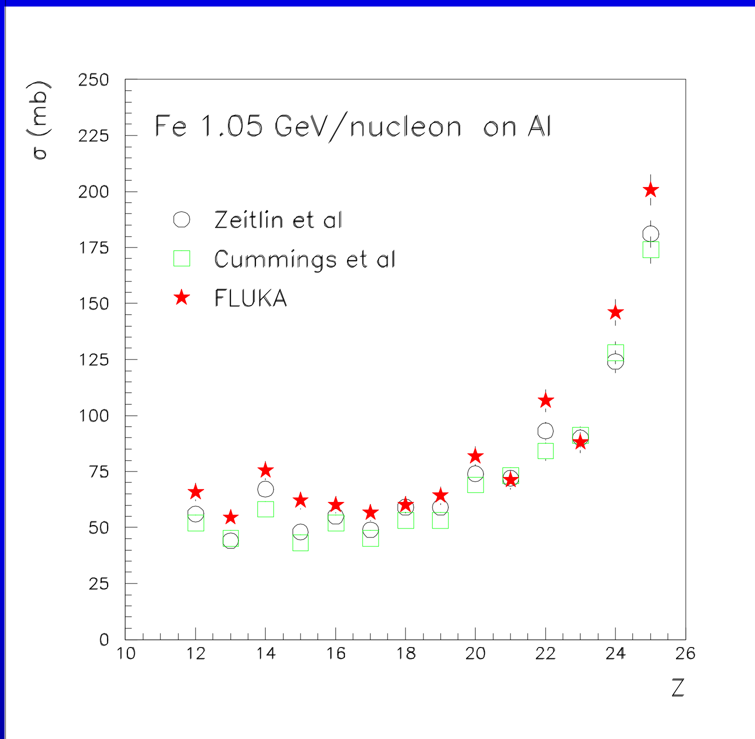
Pencil v. 7 cm Radius Beam on Nominal Zeitlin Setup with Simple Cuts

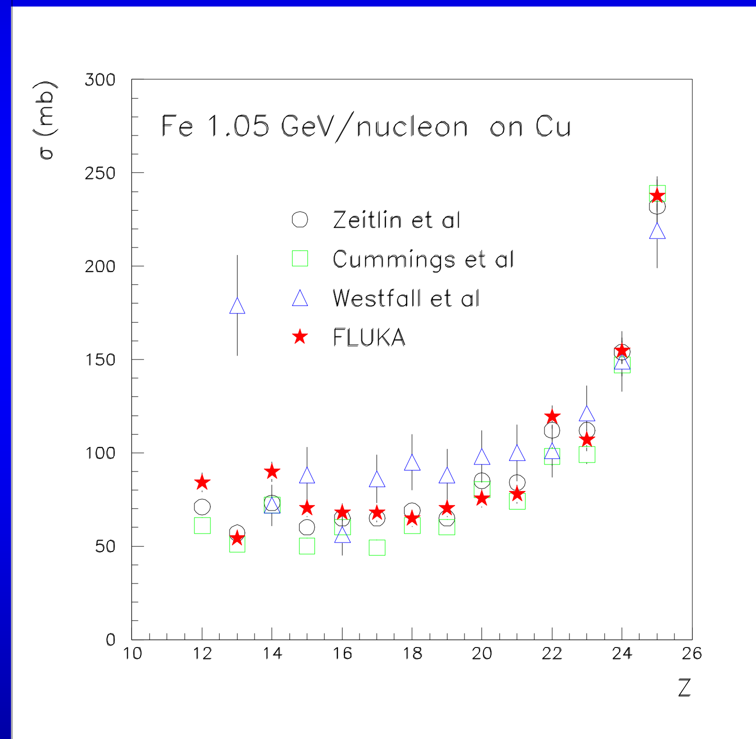
"Track Average LET" is Problematic [Dependent on Detector Details]



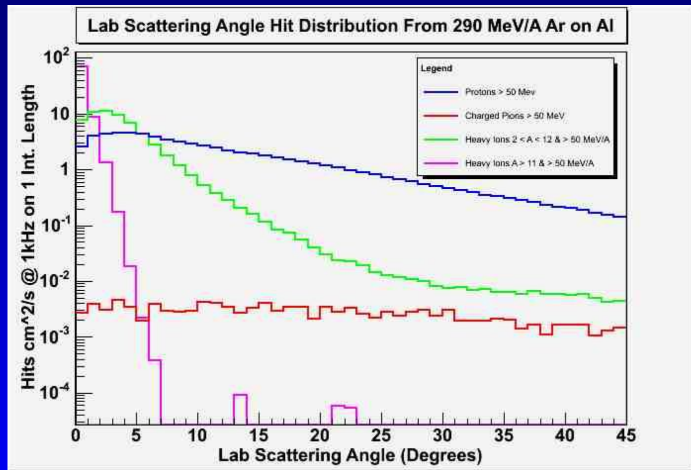


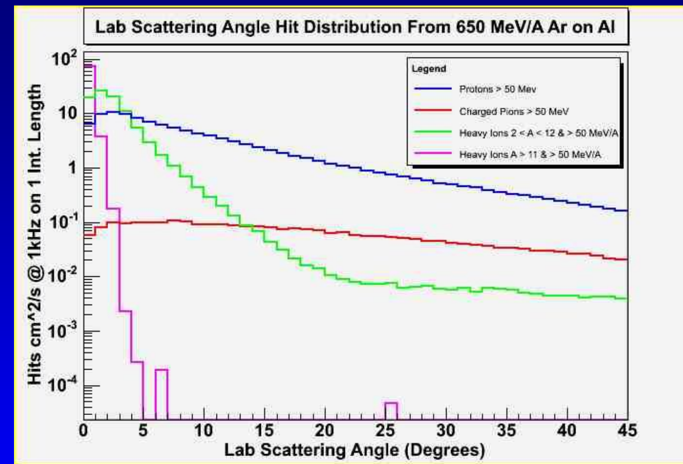
Prior Existing Fits: FLUKA (RQMD) v. Published 1.05 GeV/A Fe





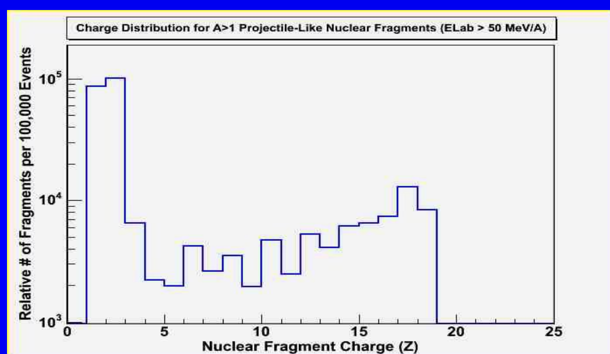
Scattering Angle Distributions

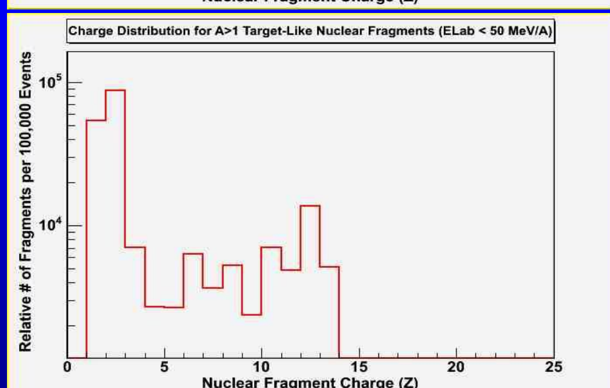




Scattering Angle Distributions

290 MeV/A



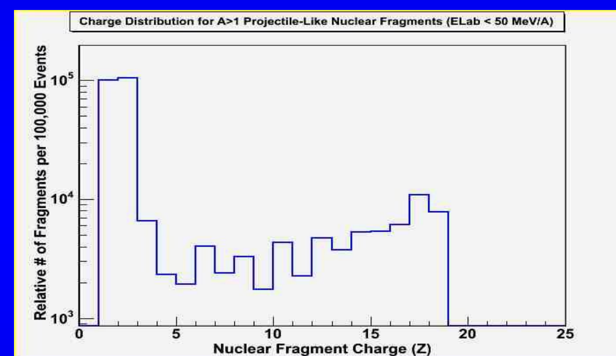


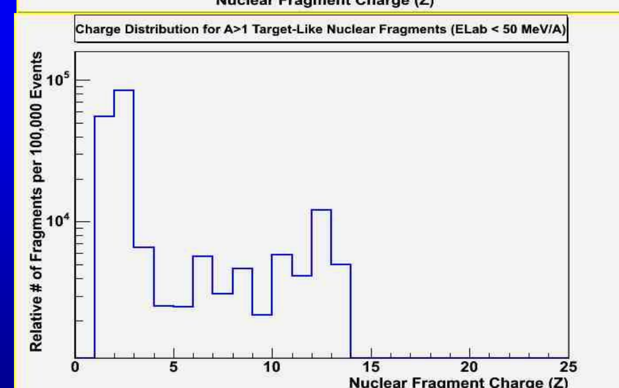
Ar-Al

Projectile Fragments

Target Fragments

650 MeV/A

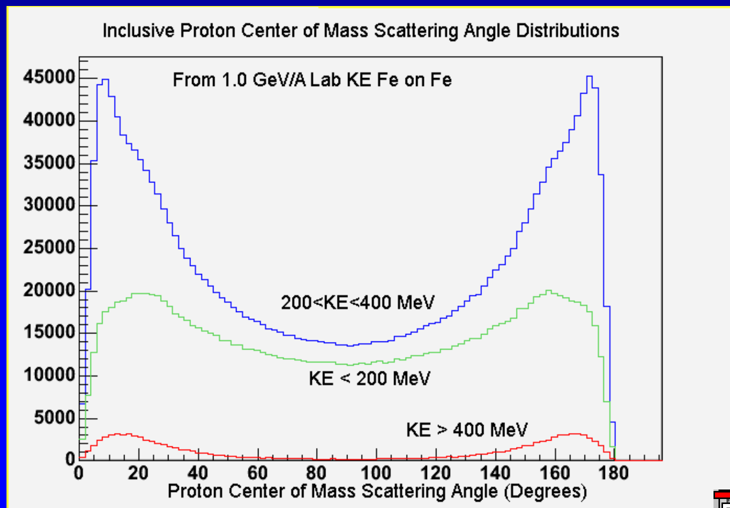


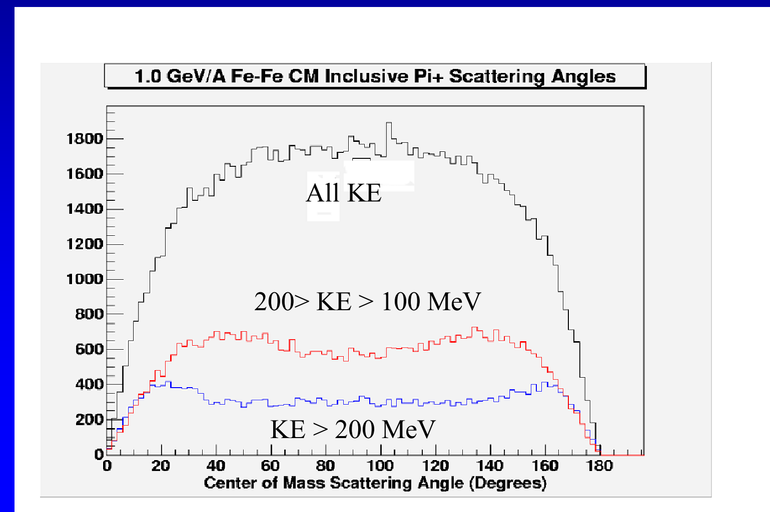


For Feb. 2005 HIMAC Runs

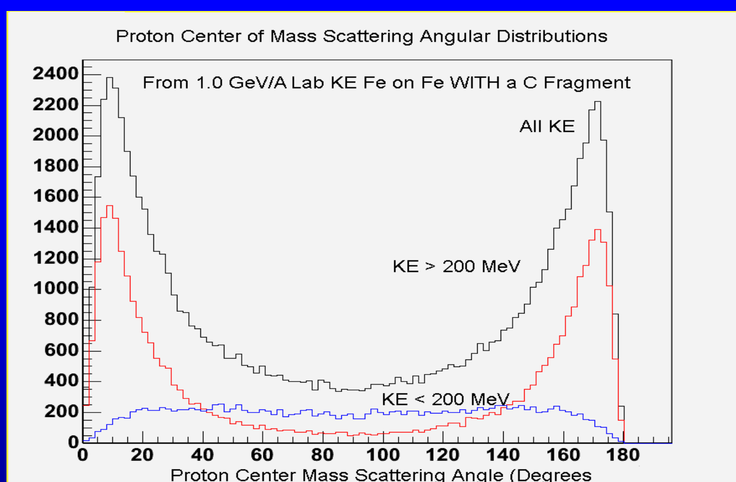
FLUKA/RQMD 1.0 GeV/A (Lab KE) Fe – Fe
CM Proton and Pion Angular Distributions

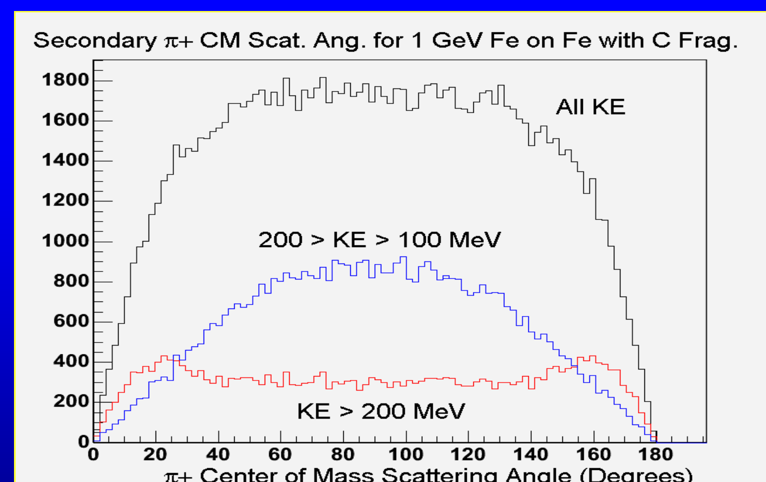
Inclusive





w/Carbon Fragment



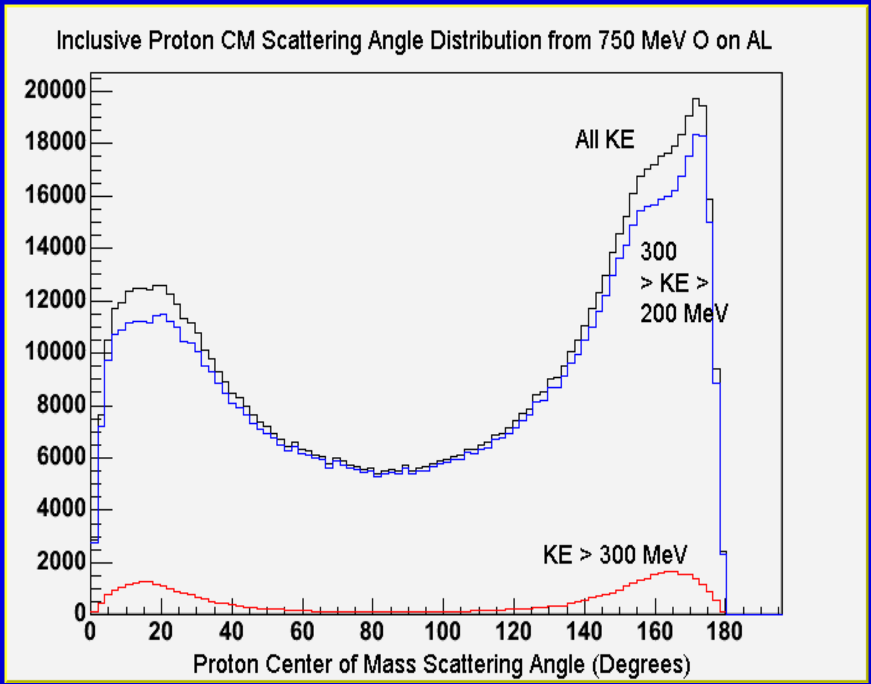


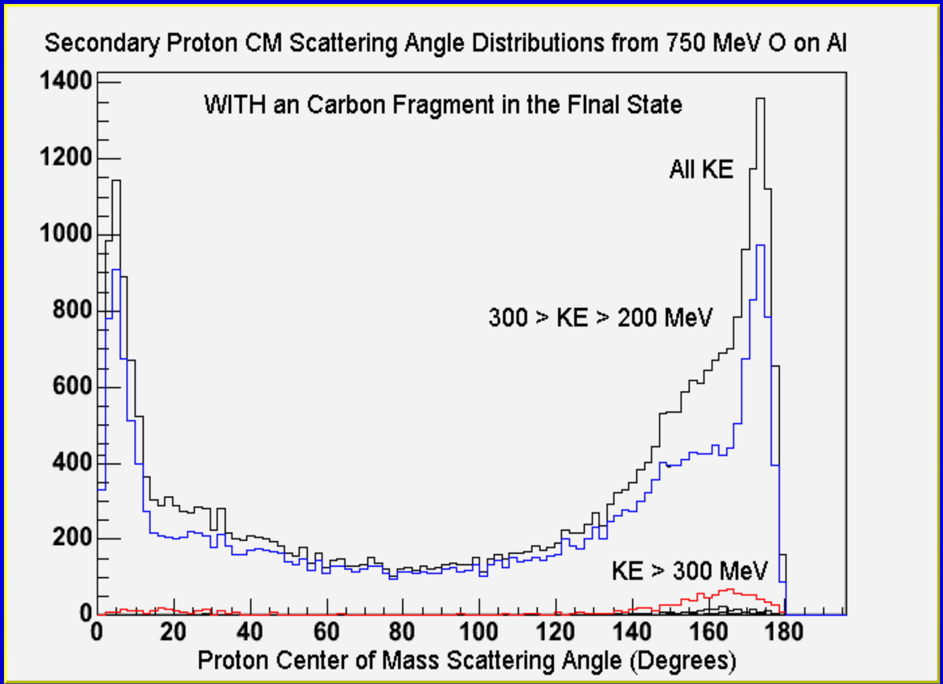
Protons

π+

Pions DO matter behind Thick Targets
BUT are REALLY Needed for Physics

FLUKA/RQMD Event Generator
750 MeV/A Oxygen on Aluminum
Proton CM Scattering Angle Distributions

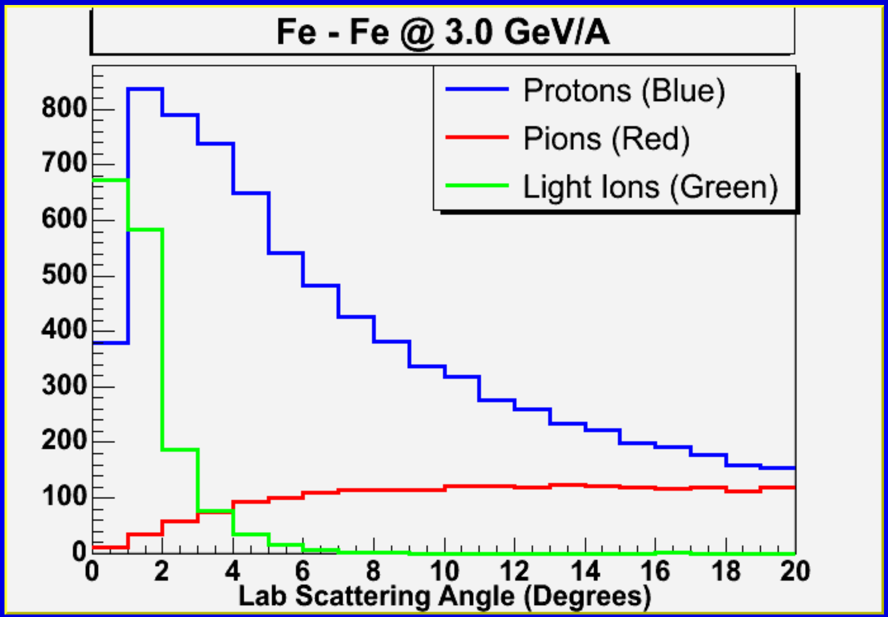


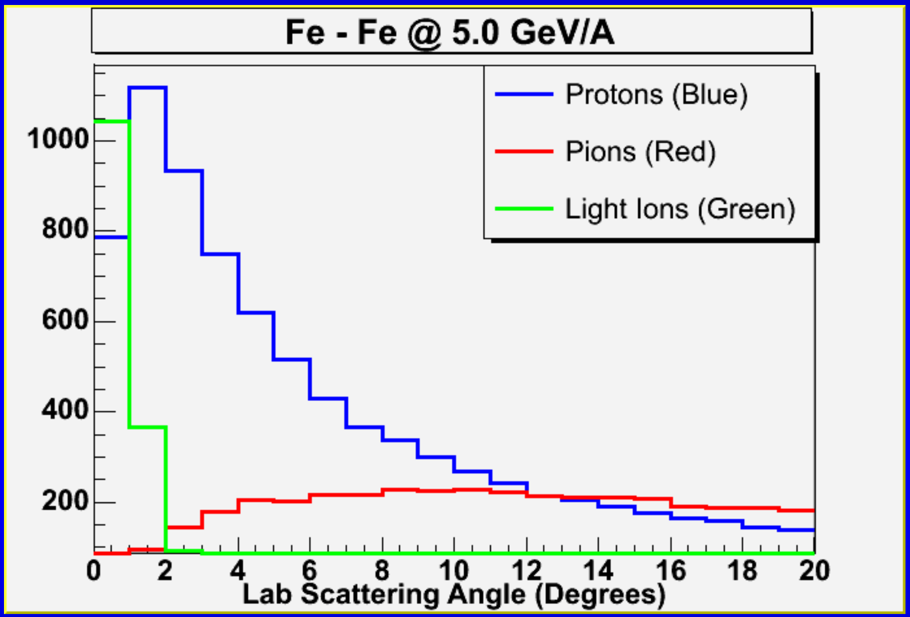


Inclusive Spectra

Only Events with a C Fragment
In the Final State

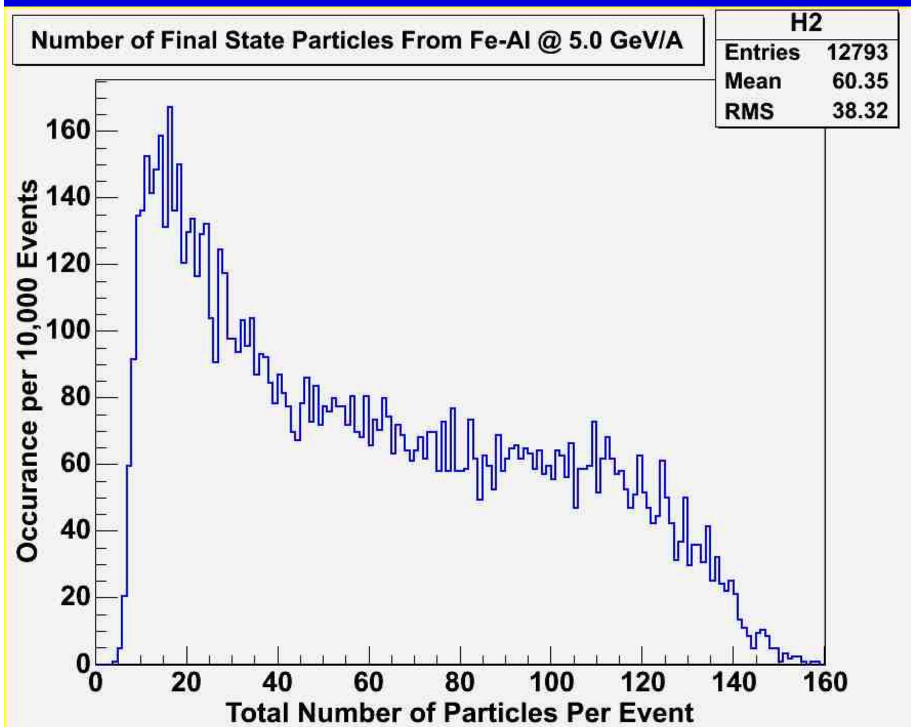
FLUKA RQMD 3 & 5 GeV/A Predictions



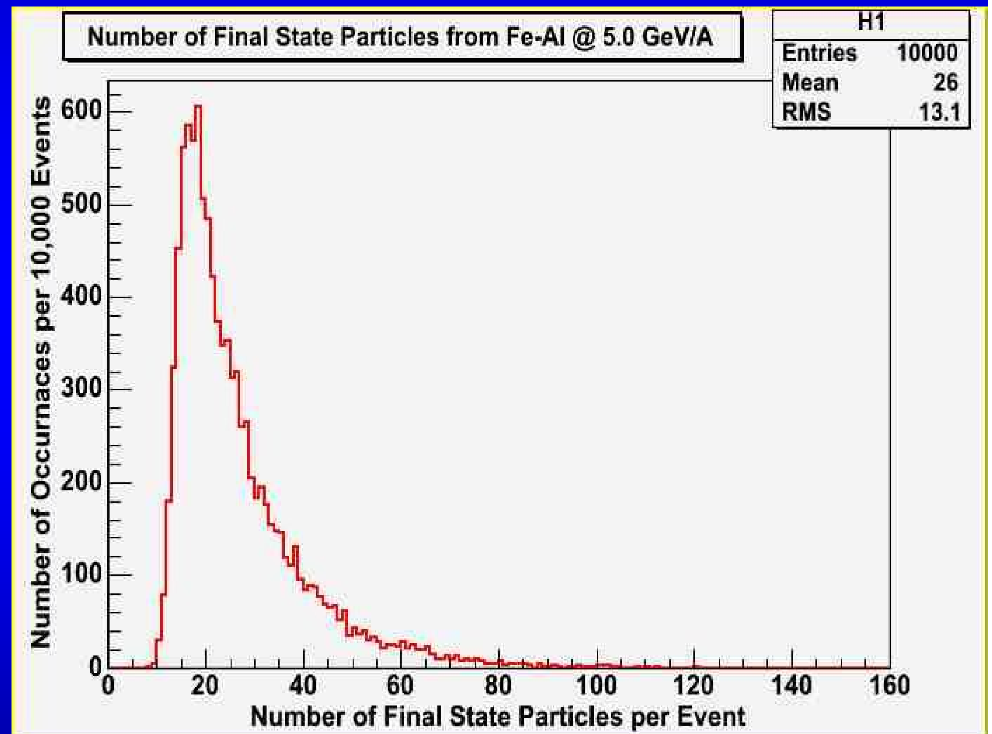


- RQMD Generator Predictions of Scattering Angle Distributions at 3 & 5 GeV/A Fe-Fe Collisions

Number of Particles Per Event RQMD v DPMJET for Fe-Al @ 5 GeV/A



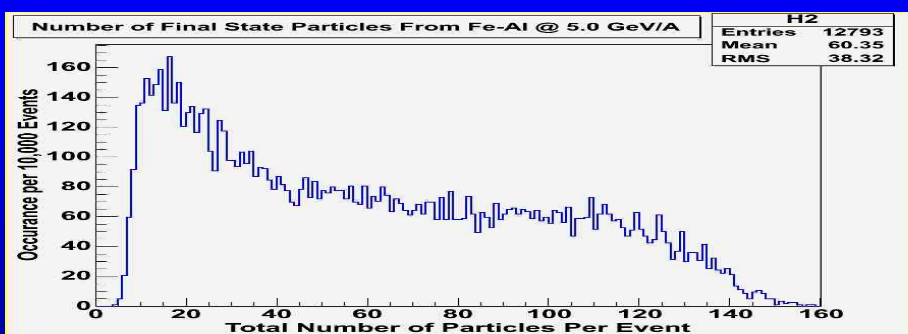
RQMD

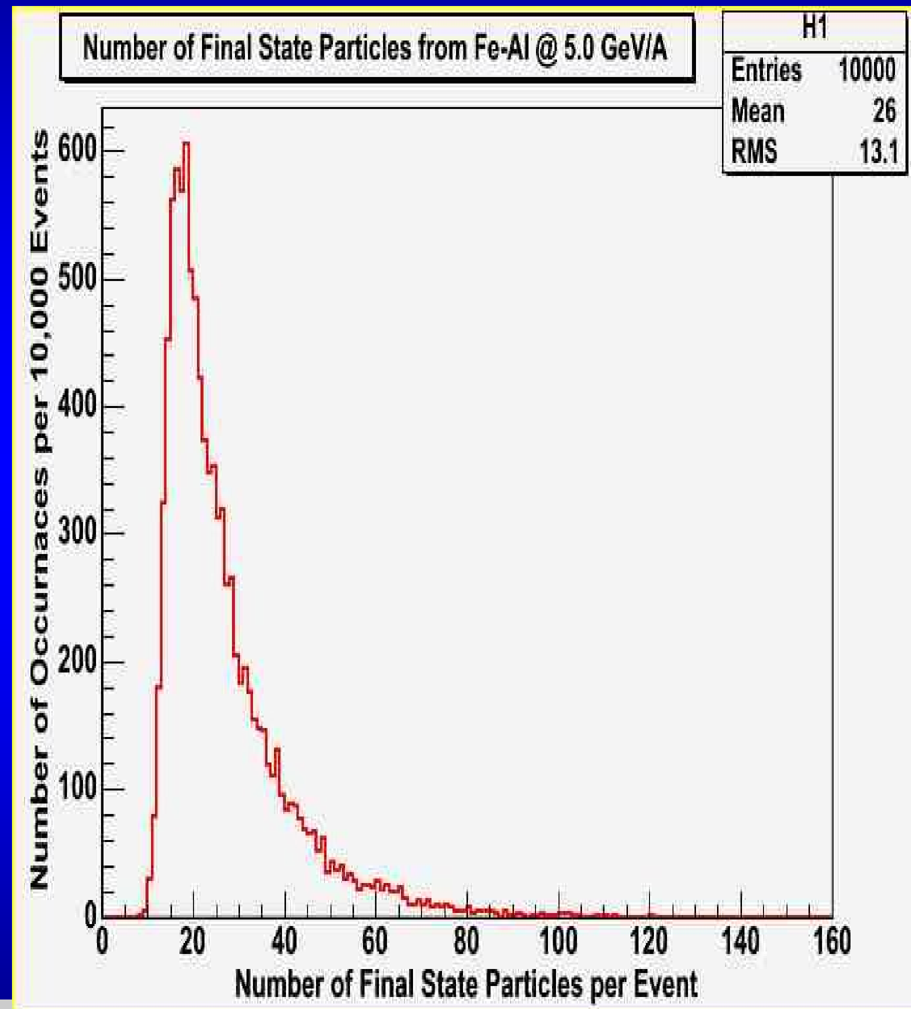


DPMJET

But…
Its Worse!

- Same Scale Comparison
- RQMD v. DPMJET
- Fe – Al @ 5 GeV/A

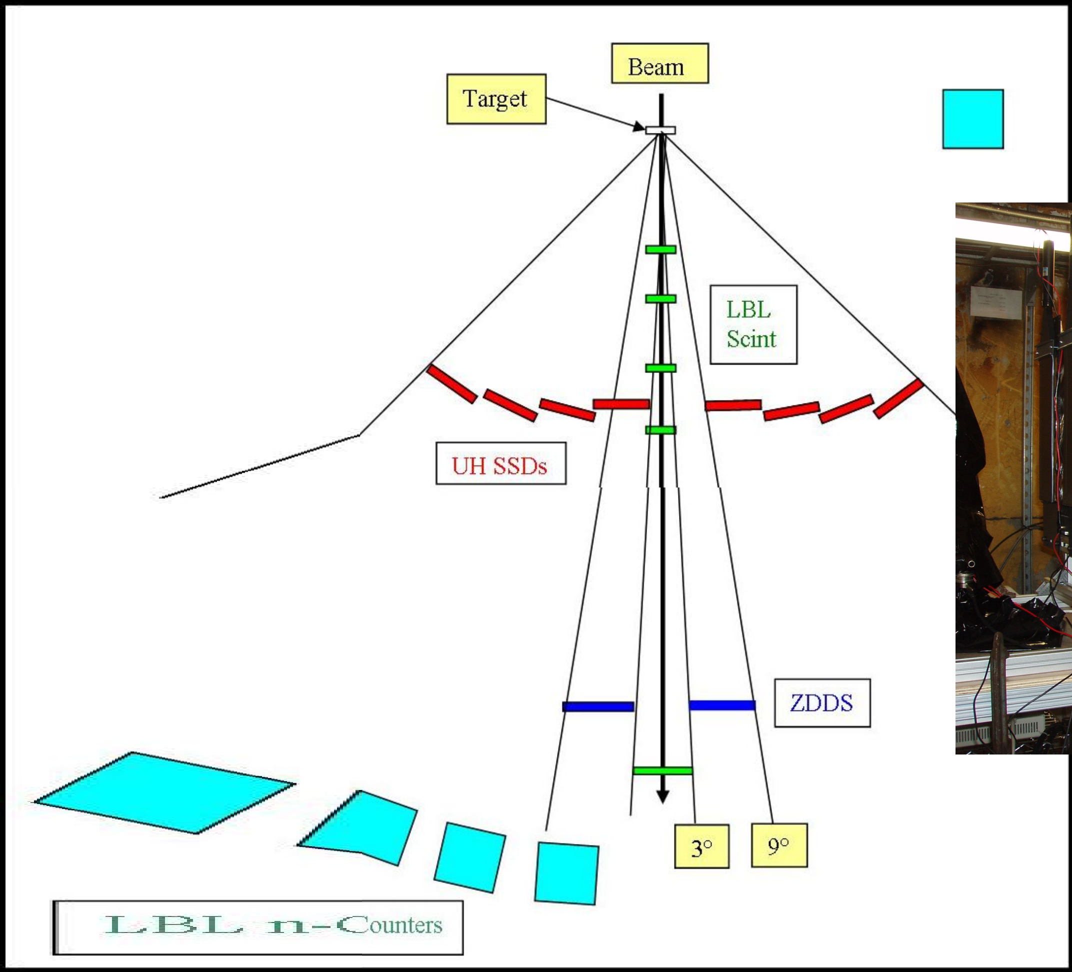


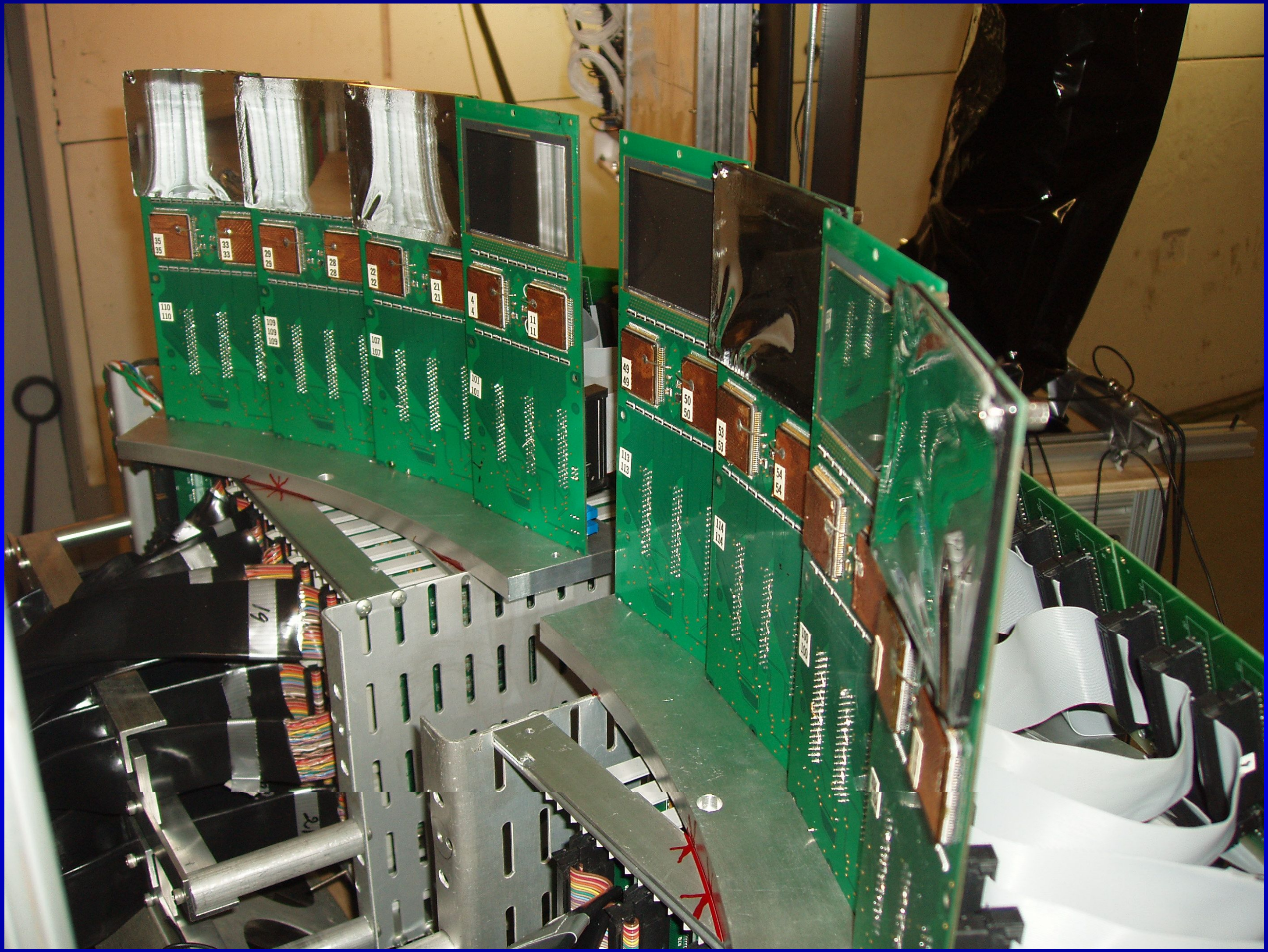


So, Why Did We Need to Take Data Around 5 GeV/A?

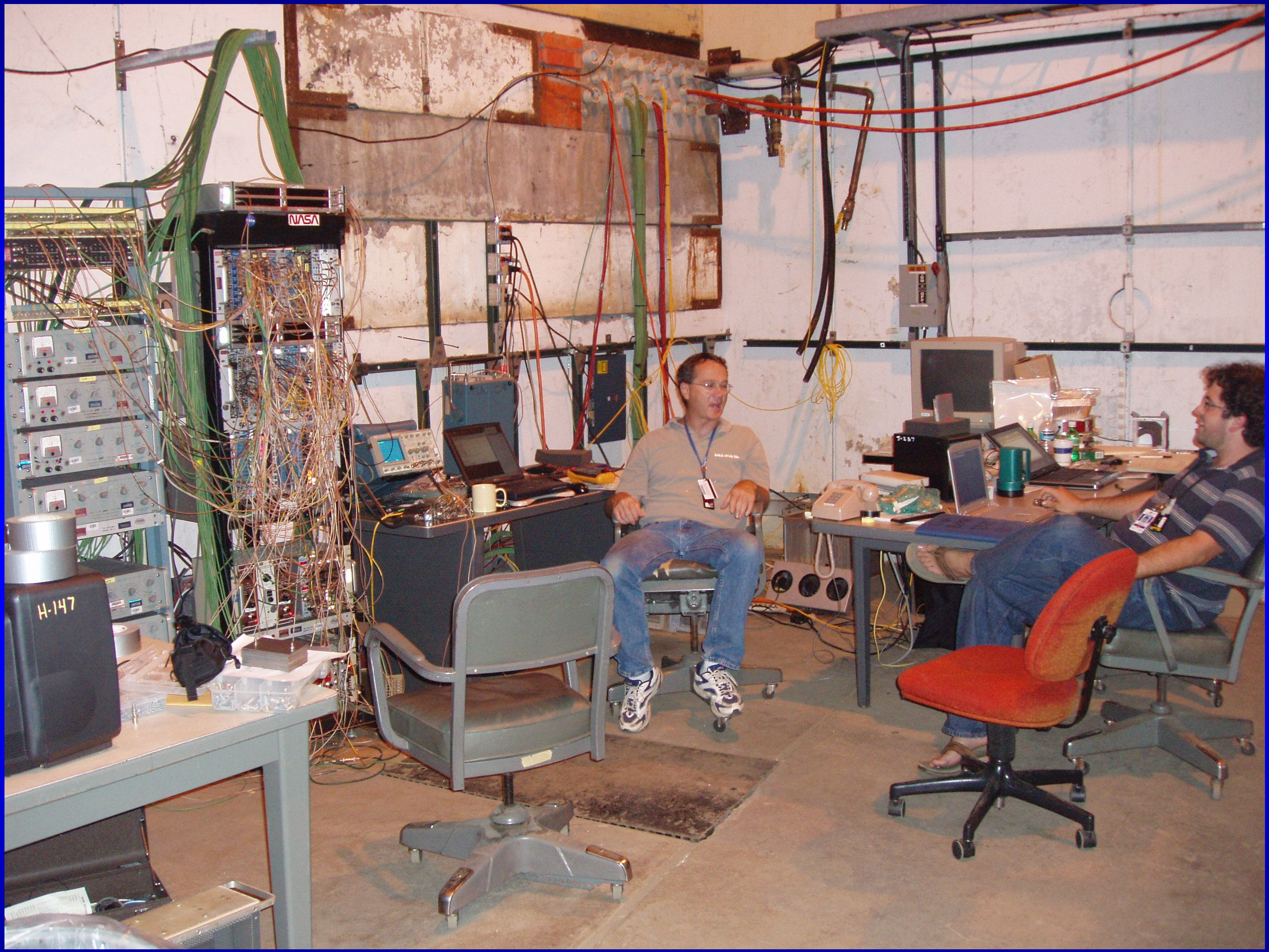
- To resolve the **RQMD-DPMJET** disagreements…
- To allow us to gather the most useful data to guide us as to the physics changes needed in the model
- To do that best, we need as much **Exclusive** data as possible…

AGS Setup-LBL, MSFC & UH





UH Detector Array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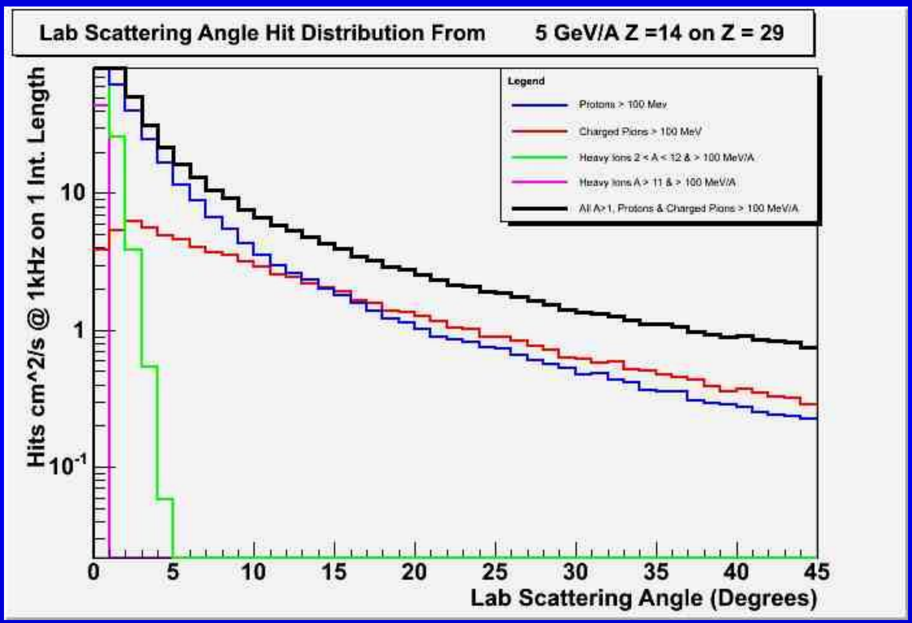
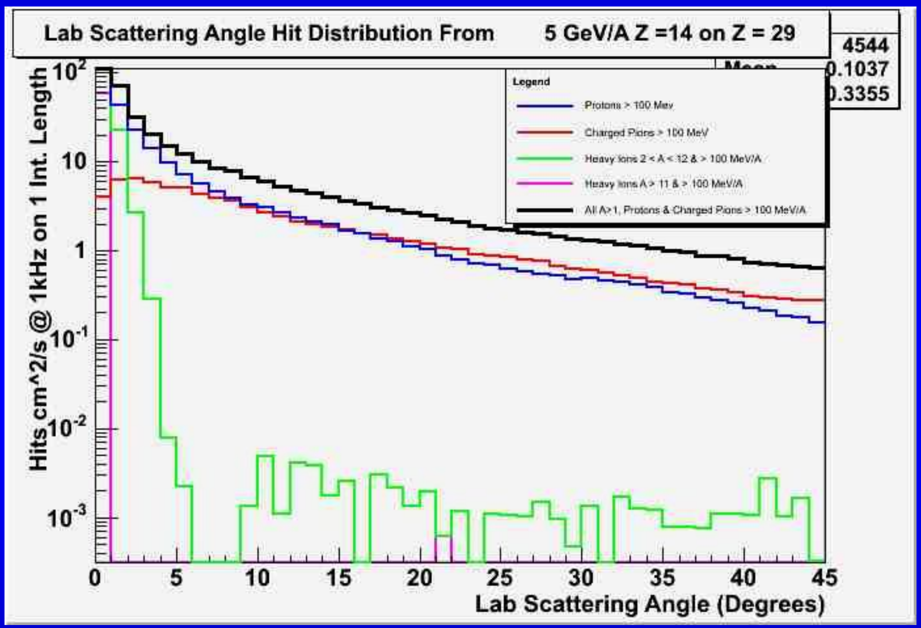
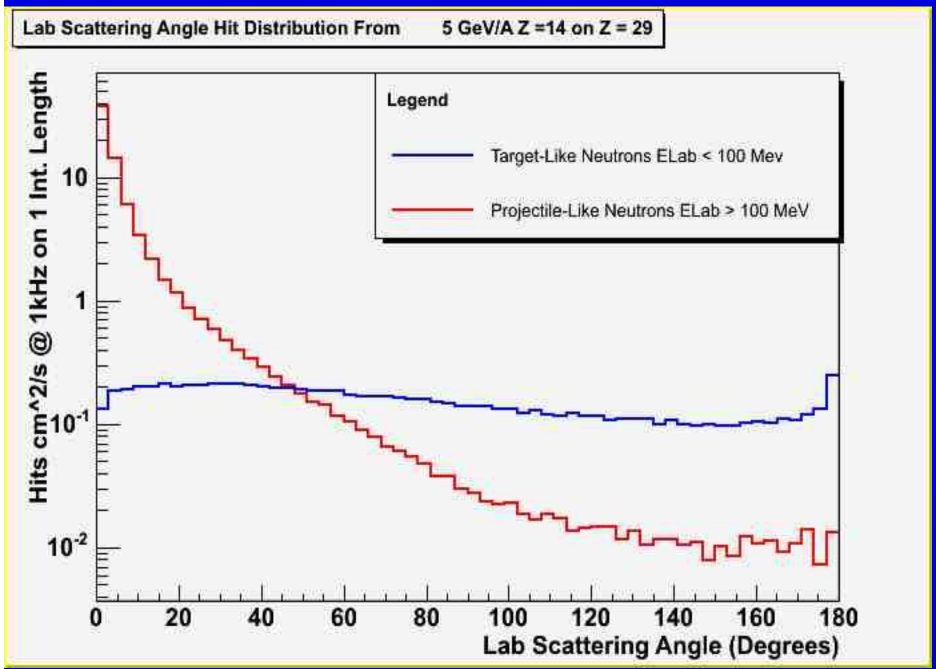
RQMD & DPMJET Laboratory Angular Distributions at 5 GeV/A

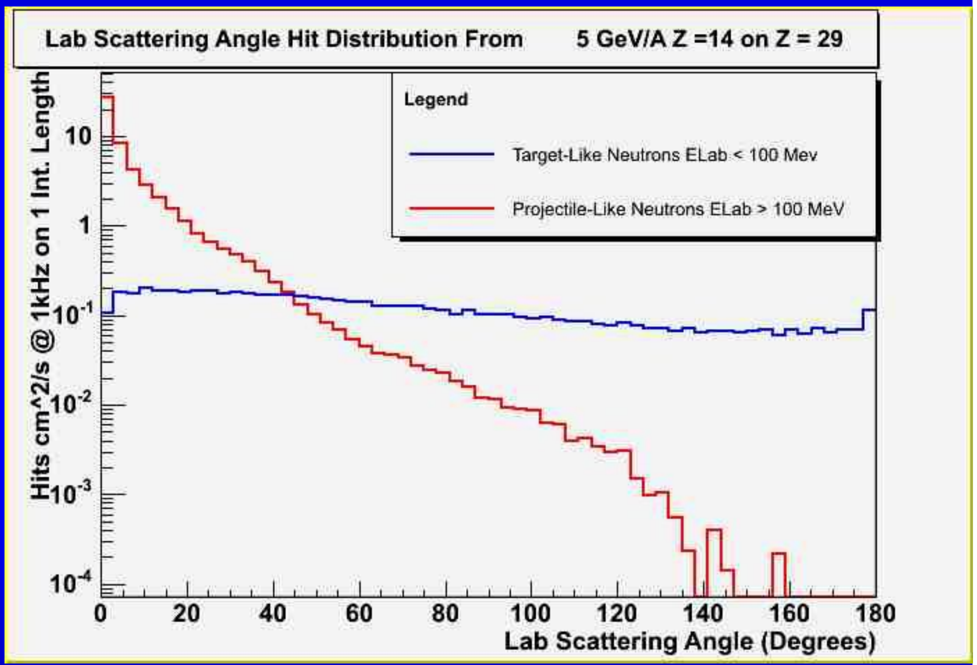




RQMD Si on Cu DPMJET

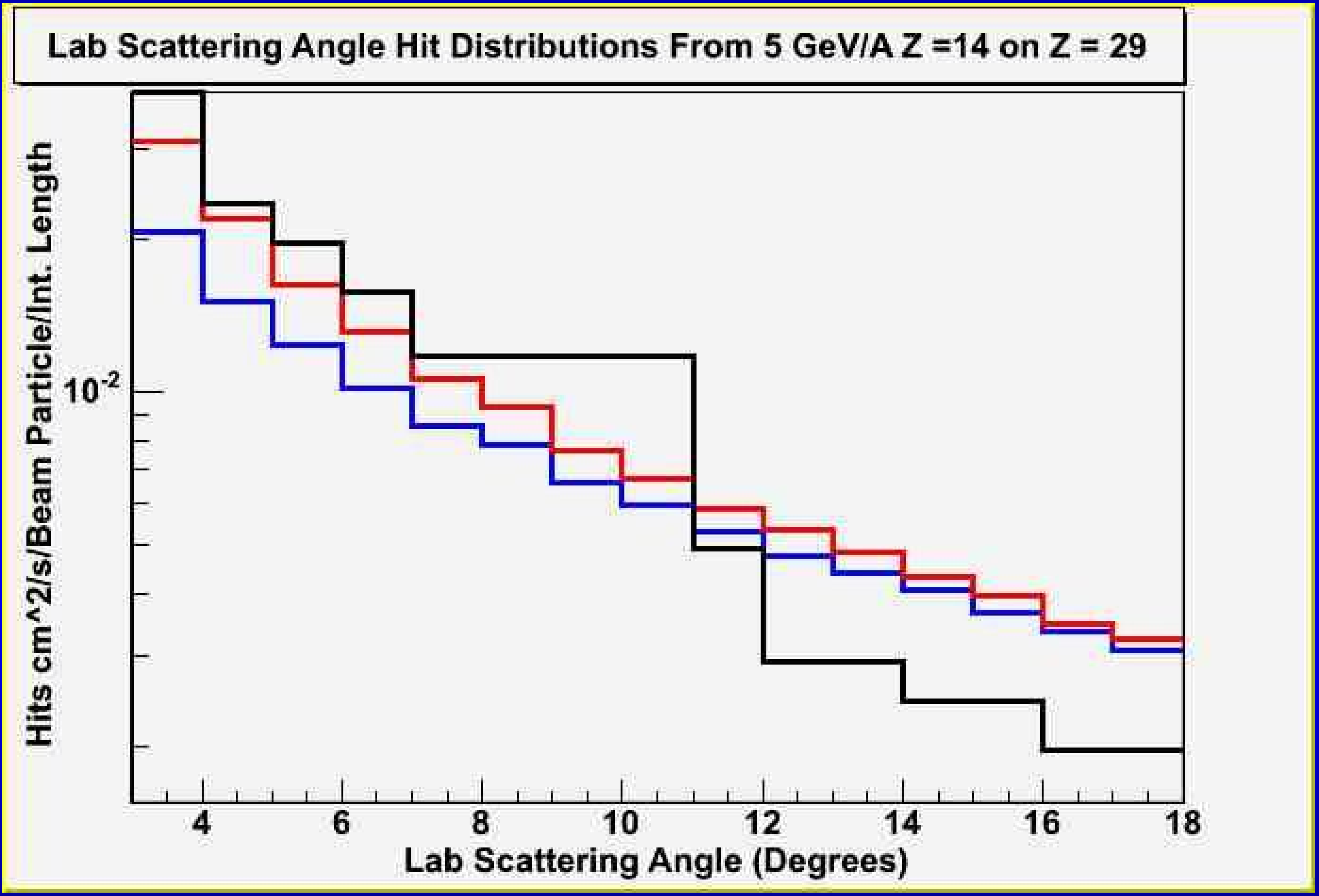
RQMD v. DPMJET Neutron Laboratory Angular Distributions



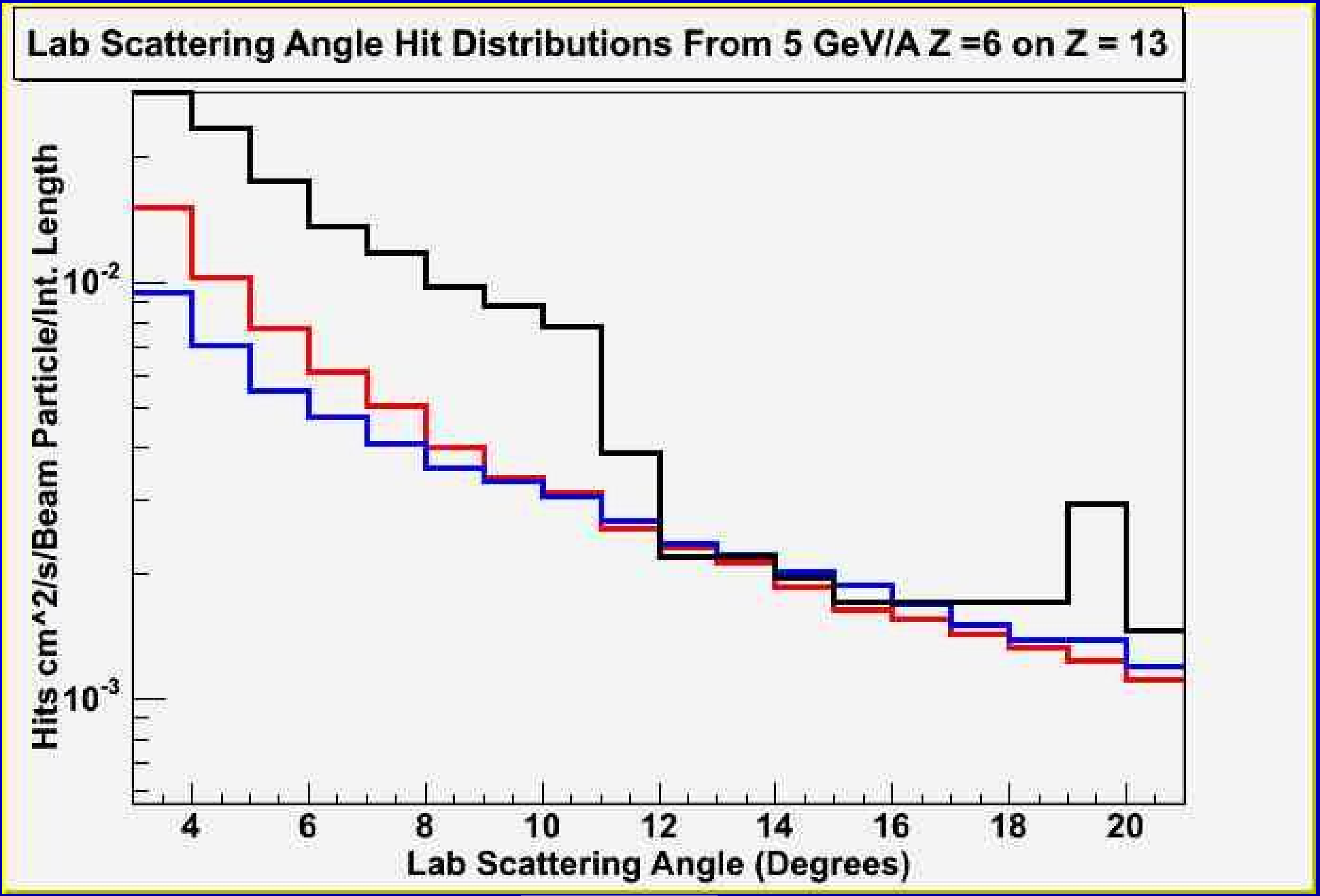


RQMD Si on Cu DPMJET

PRELIMINARY



PRELIMINARY



Data Was Taken For:

- Beams: C, Si & Fe
- Energies: ~3, 5 and 10 GeV/A
- Targets: C, Al, Fe & Cu
  + Several Thick Targets

To Be Continued
?????

AGS Analysis…

Space Radiation Shielding Consortium…

ISS…