Benchmarking and Needs for Data

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Fermilab

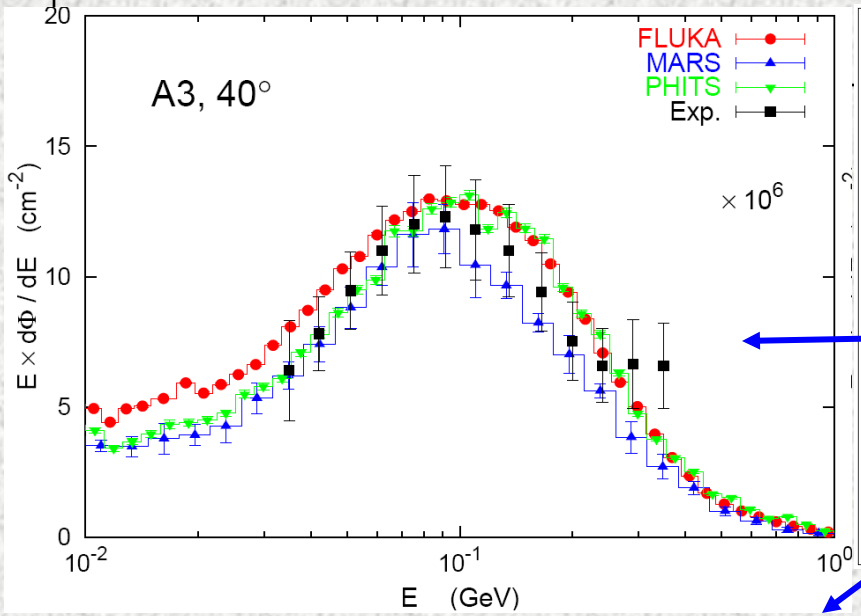
JASMIN Collaboration Meeting
Fermilab
February 16, 2012

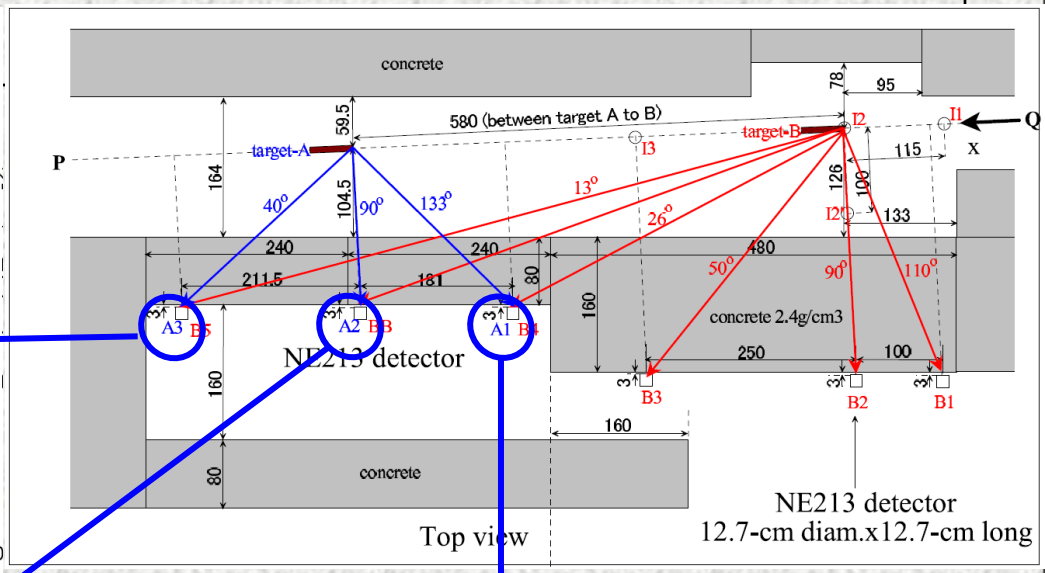
Outline

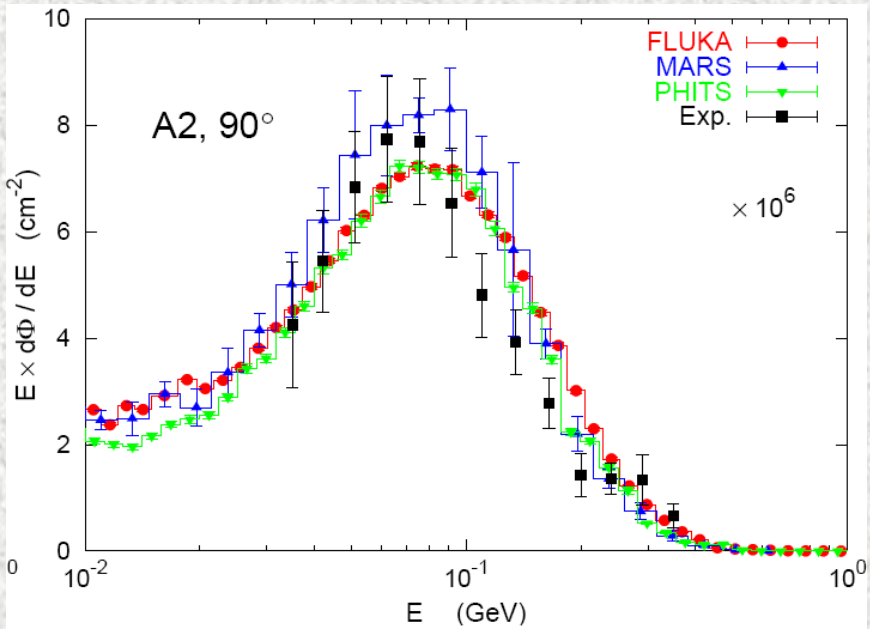
- Benchmarking Activities
- JASMIN
- Issues
- Recent Code Developments
- Data Needs

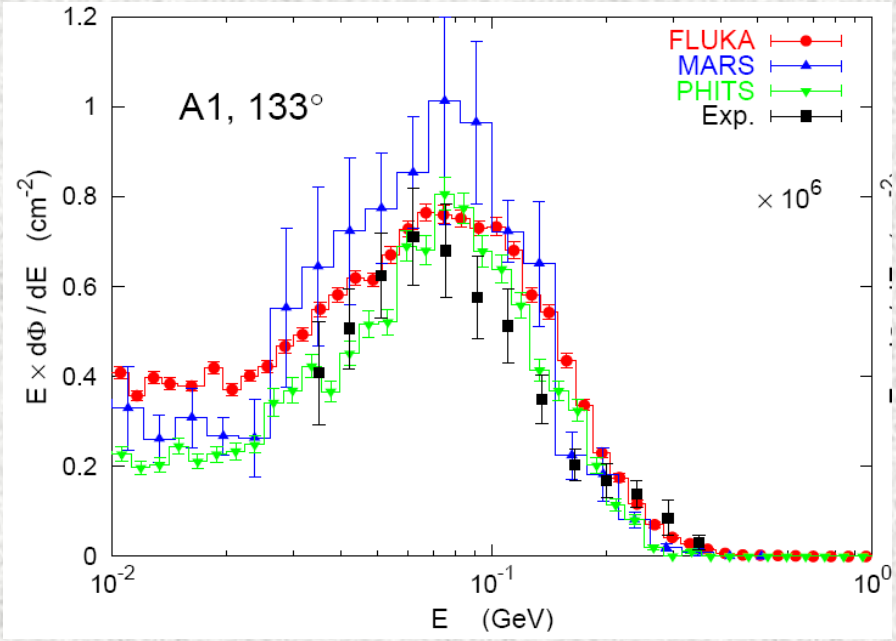
120-GeV p/π on CERF Cu-Target:

Concrete, 80cm





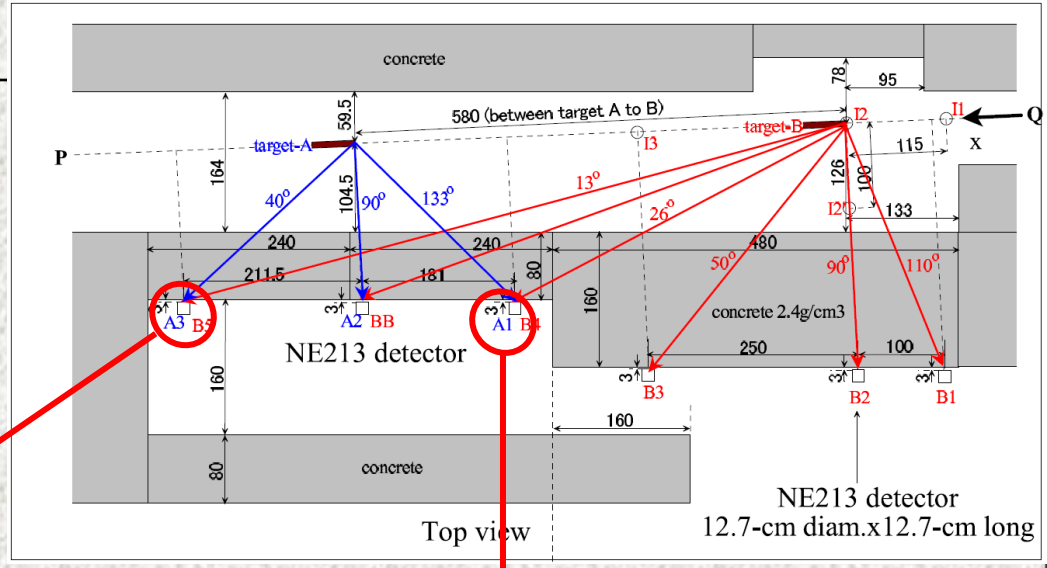


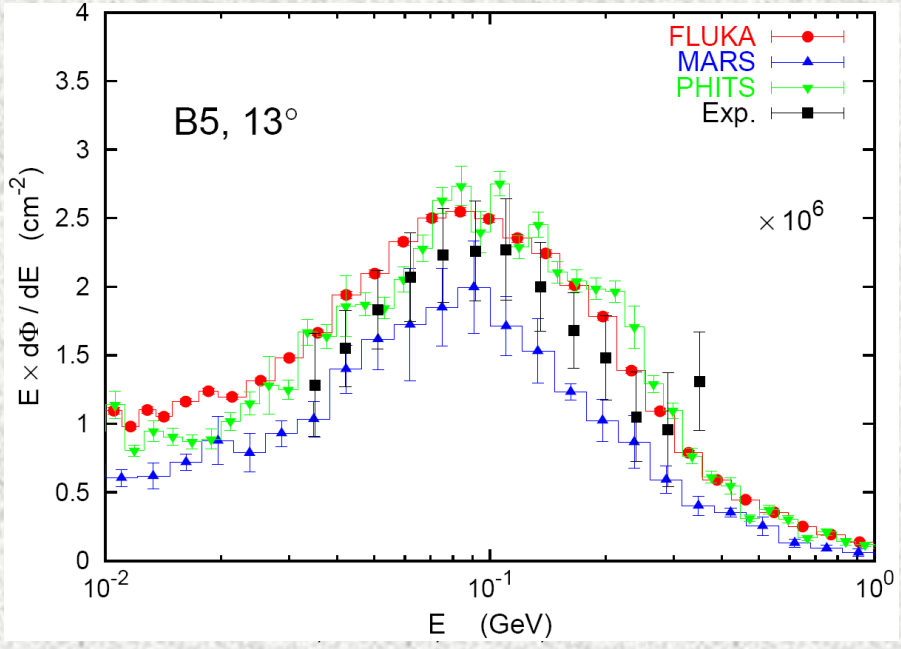


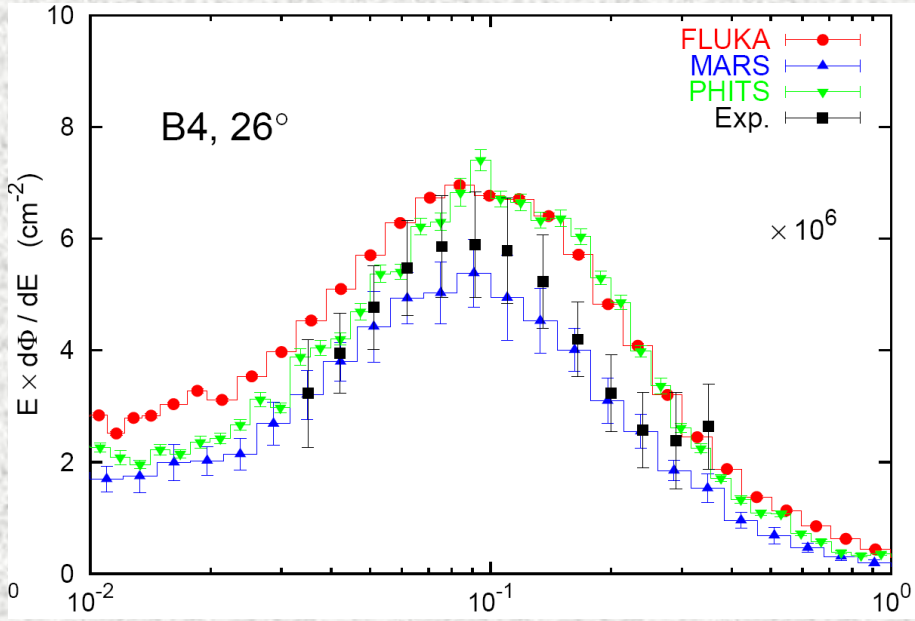
Courtesy S. Roesler & N. Nakao

120-GeV p/π on CERF Cu-Target:

Concrete, 80cm



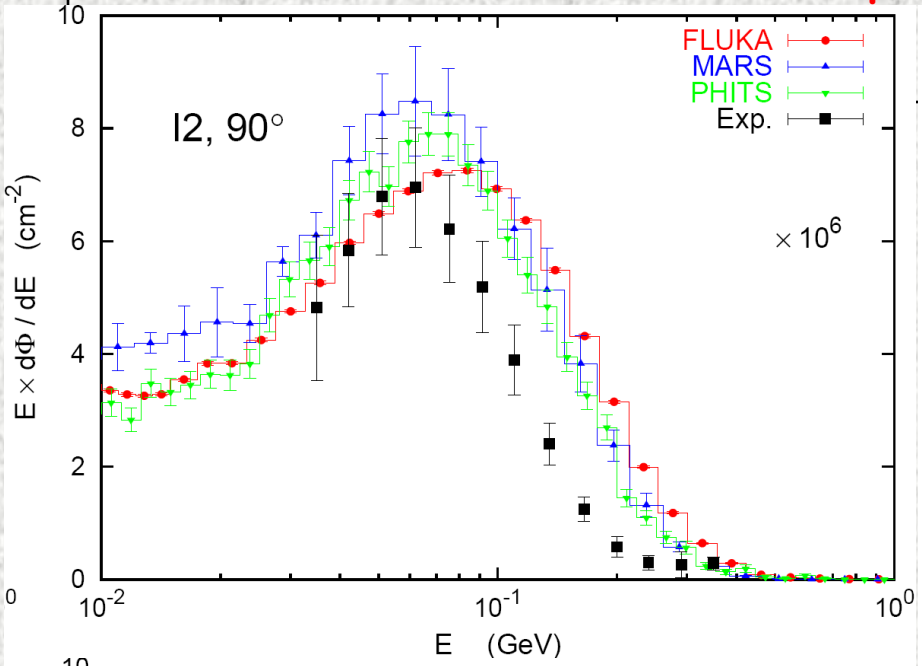


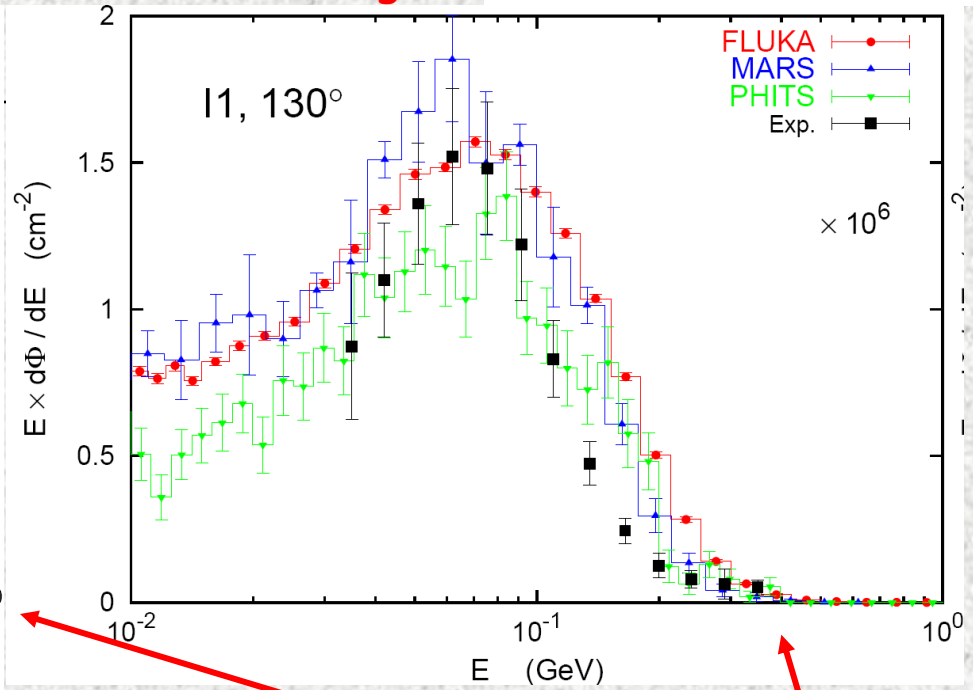


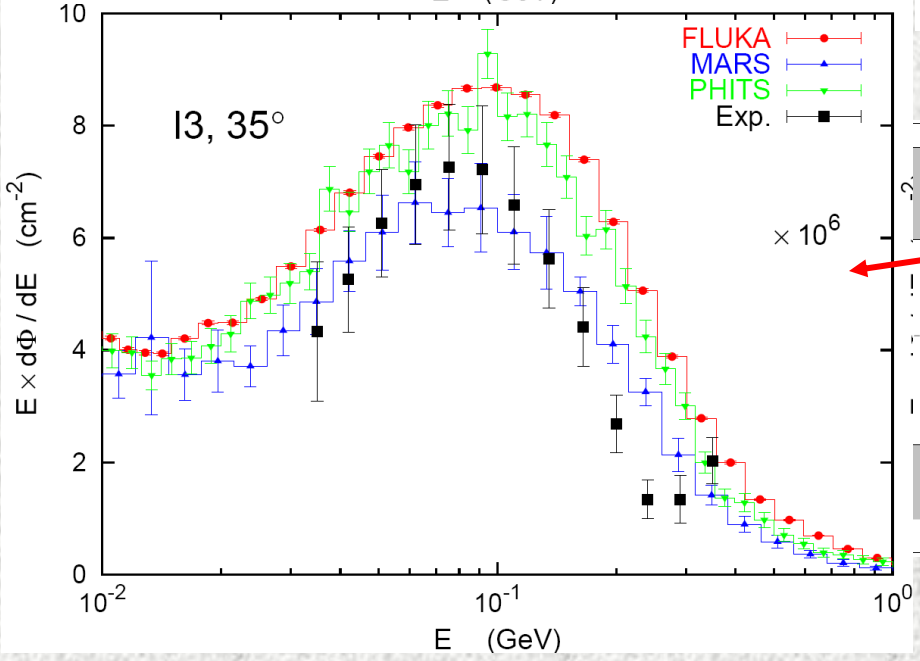
Courtesy: S. Roesler & N. Nakao

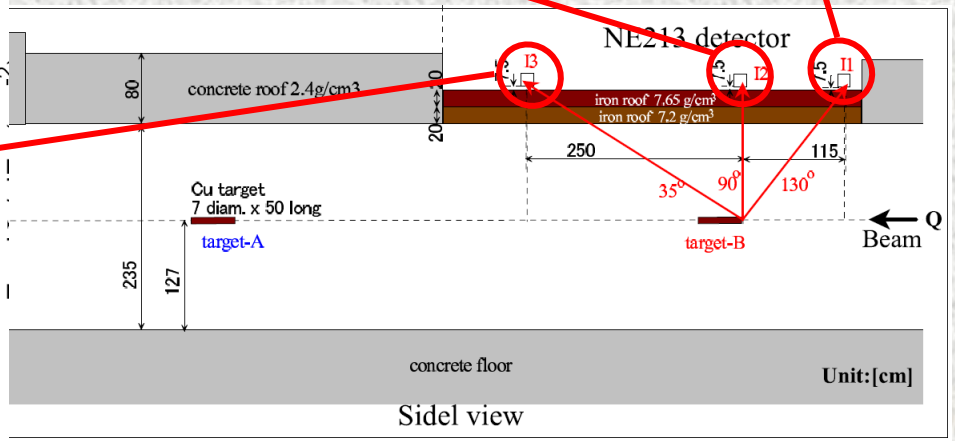
120-GeV p/π on CERF Cu-Target:

Iron, 40cm









Courtesy: S. Roesler & N. Nakao

Measurement and calculation of high-energy neutron spectra behind shielding at the CERF 120 GeV/c hadron beam facility

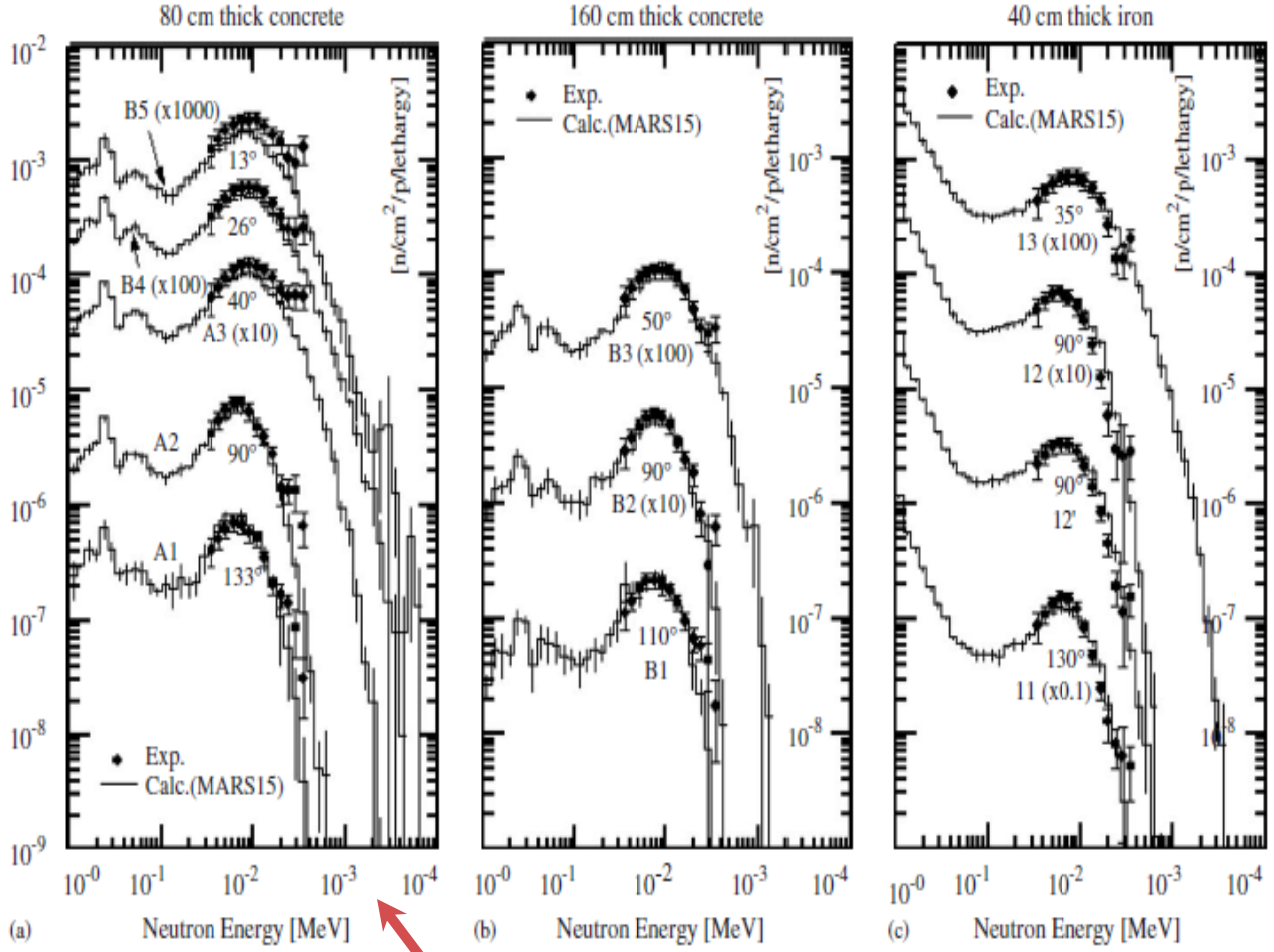
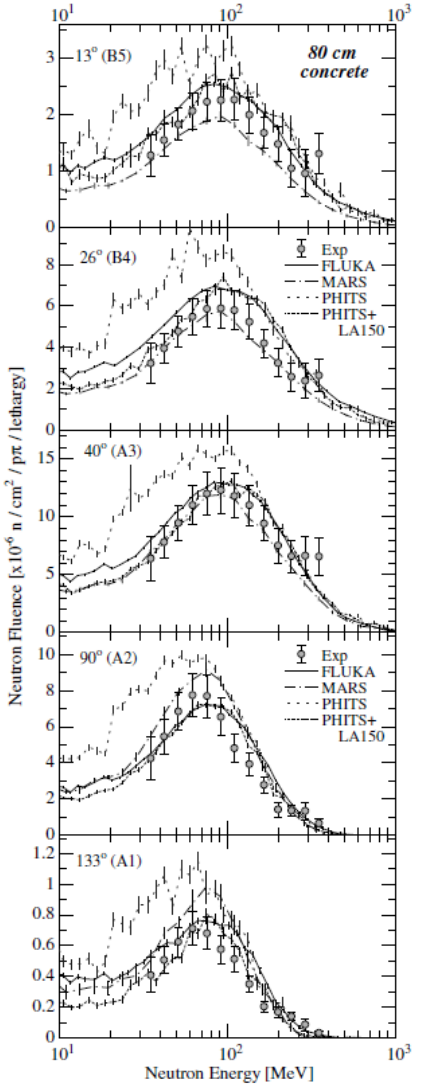


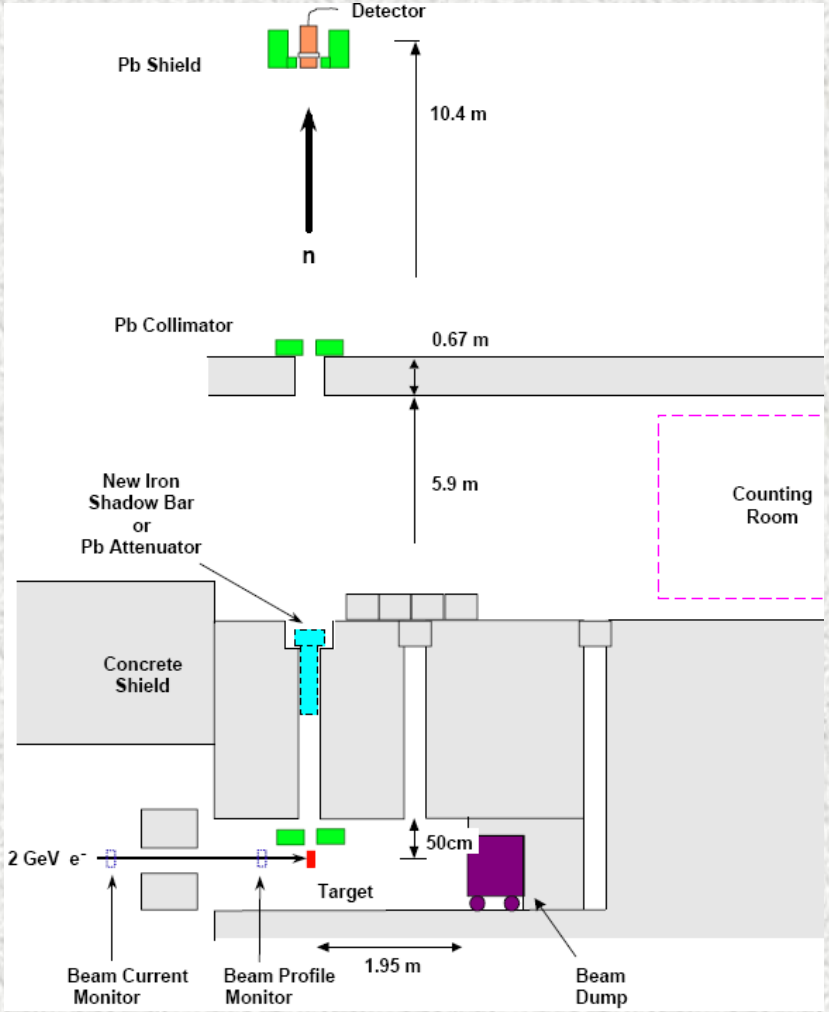
Fig. 3. Experimental neutron energy spectra compared with the MARS15 Monte Carlo calculation results: (a) behind 80-cm thick concrete (b) behind 160-cm thick concrete; and (c) behind 40-cm thick iron.

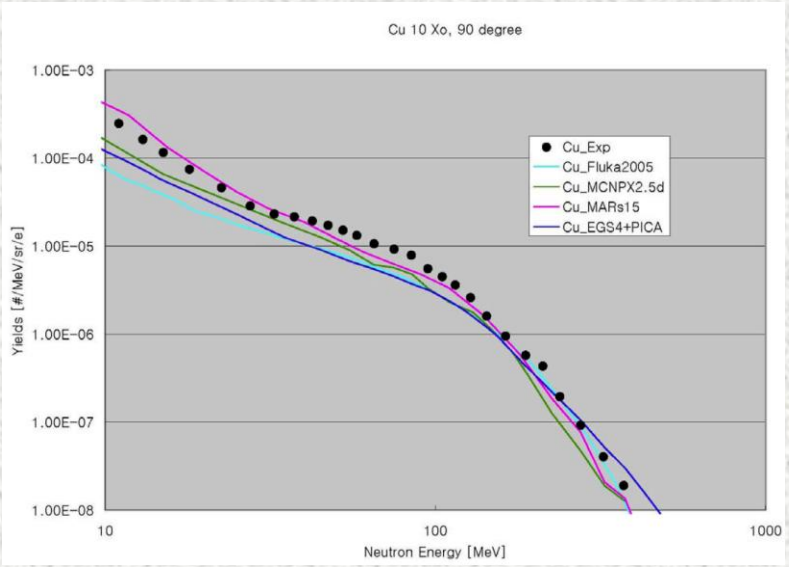


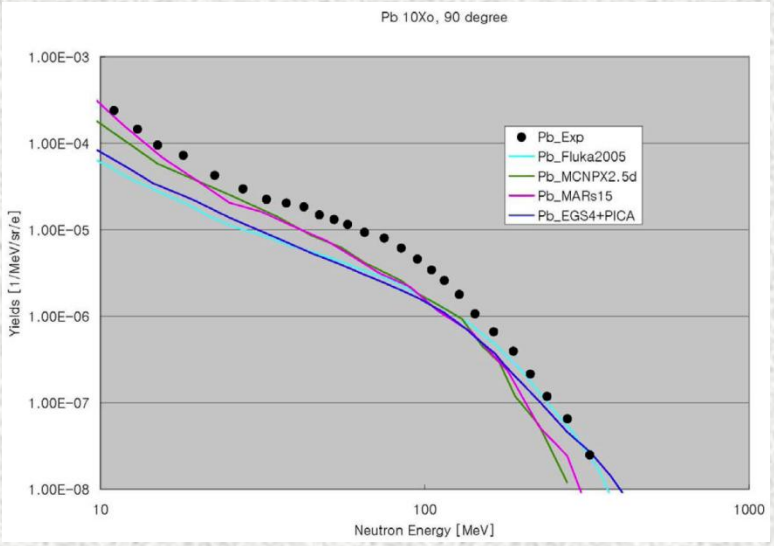
13. Neutron energy spectra behind the 80 cm thick concrete shield, compared between measurement and simulation results.

Scale should be 10^{0} to 10^{4} MeV, not 10^{-0} to 10^{-4} as in NIM_A562_2006

Photo-Neutron Yields from Thick Targets for 2-GeV e-

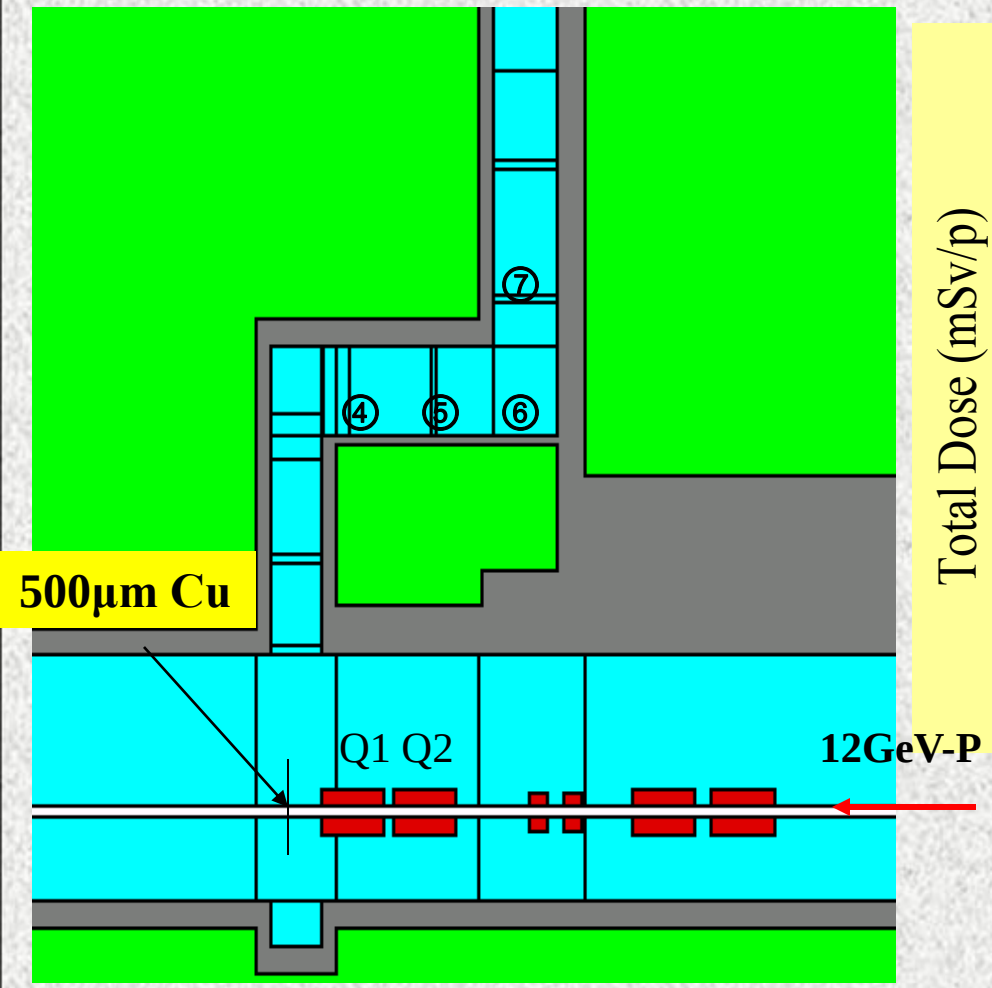


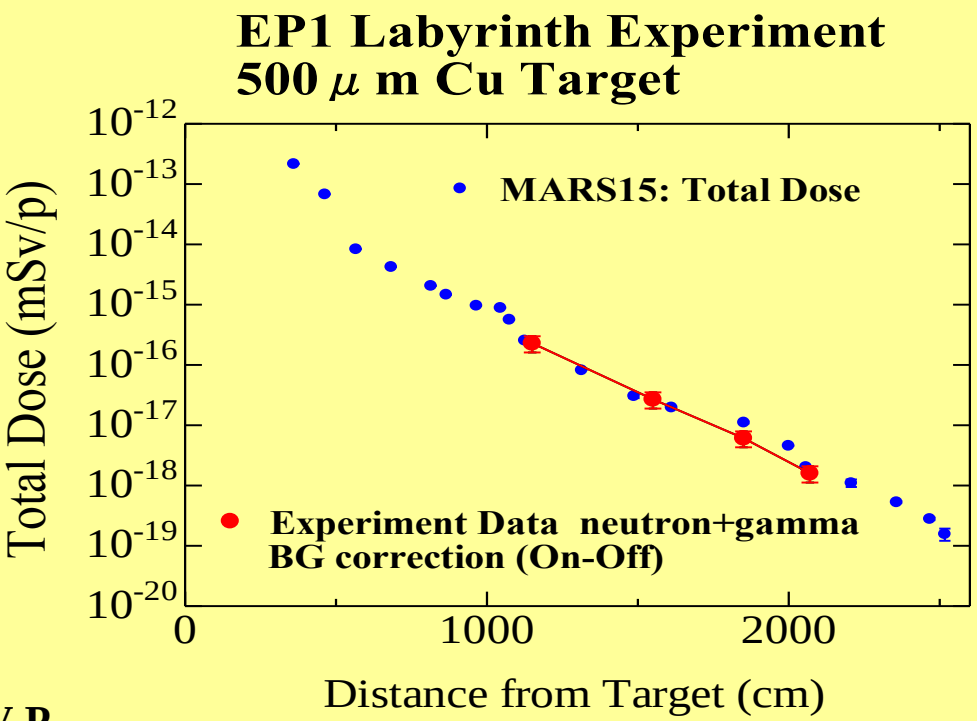




Courtesy H.S. Lee & T. Sanami

BENCHMARKING AT KEK: EP1 LABYRINTH

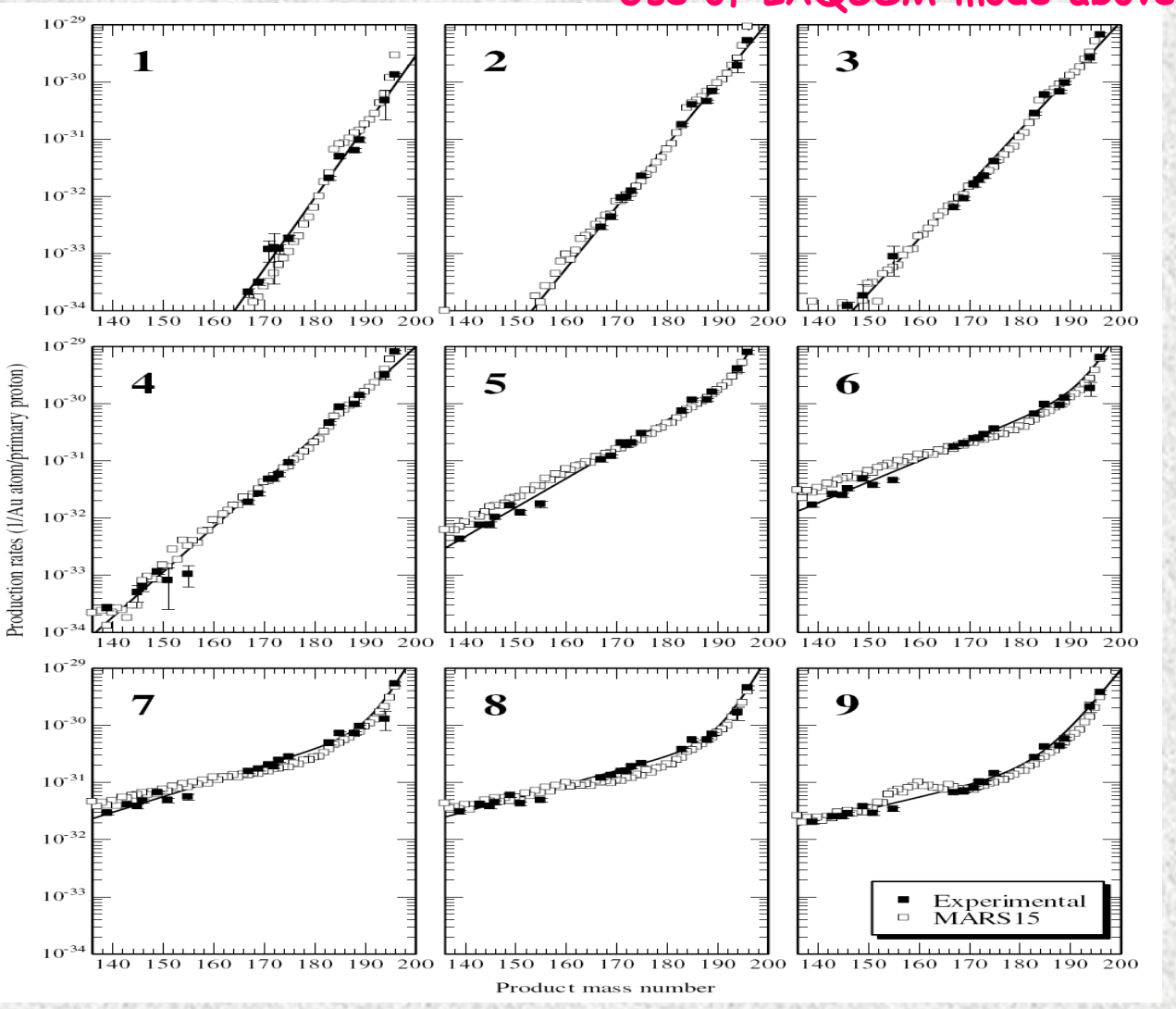


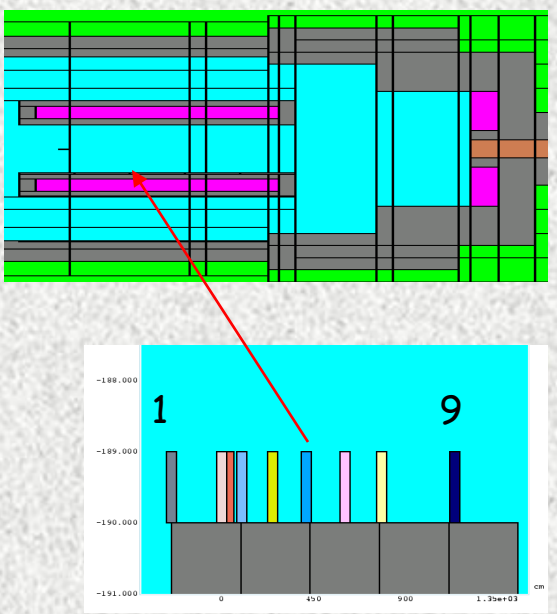


Courtesy: Takenori Suzuki

12-GeV K2K TARGET STATION

Use of LAQGSM mode above 3 GeV



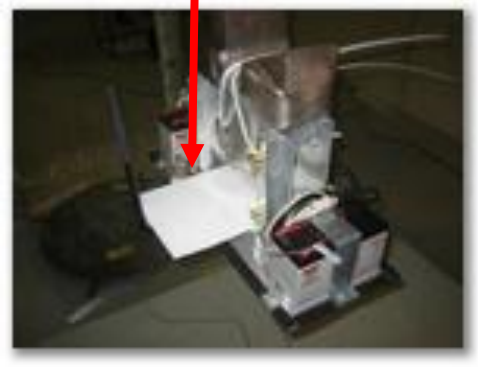


Nine gold foil samples over 12 meters

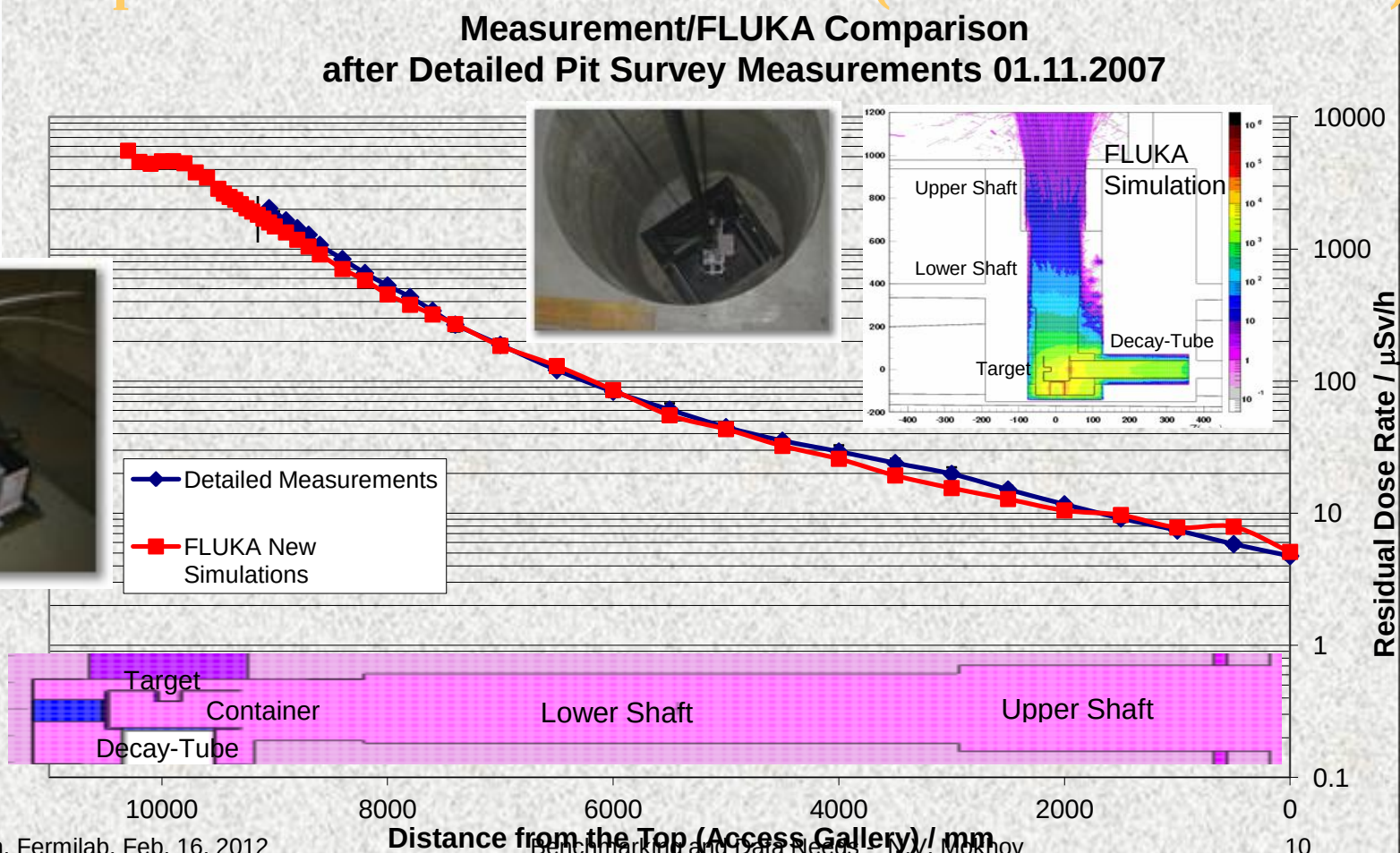
Courtesy: T. Suzuki and H. Matsumura

Activation: Benchmarks, benchmarks, benchmarks

Elias Lebbos for CERN nToF



Inside the pit: using a laser attached to the crane to contr
the position of the remote detector (attached to the hook)

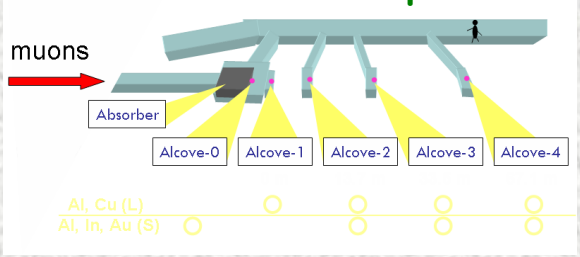


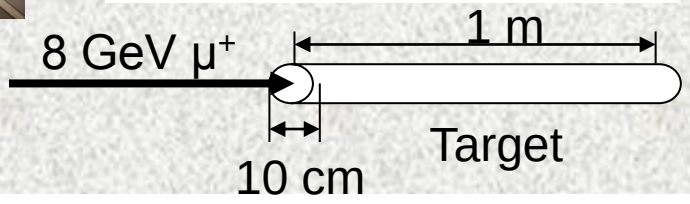
SHIELDING AND RADIATION EFFECT EXPERIMENT

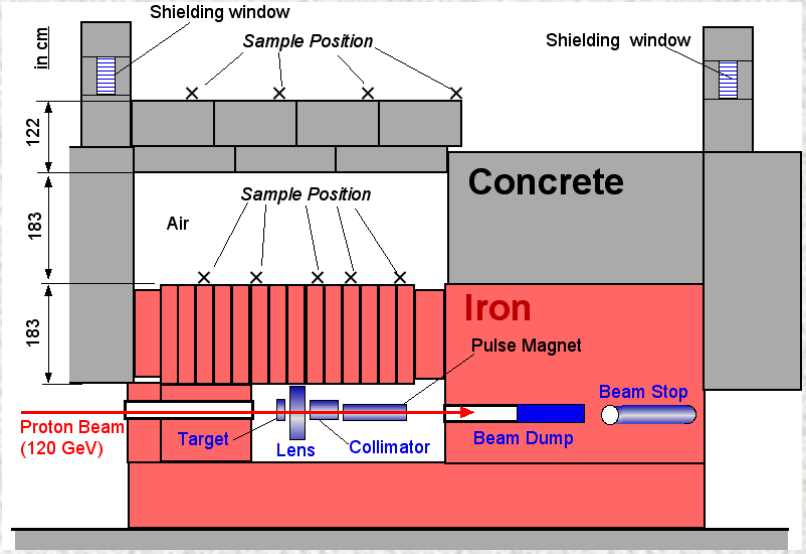
JASMIN Japan-FNAL Collaboration:
Shielding and Radiation Effect Experiments at FNAL
T-972 (2007-2009)
T-993 and T-994 (2009-2012)

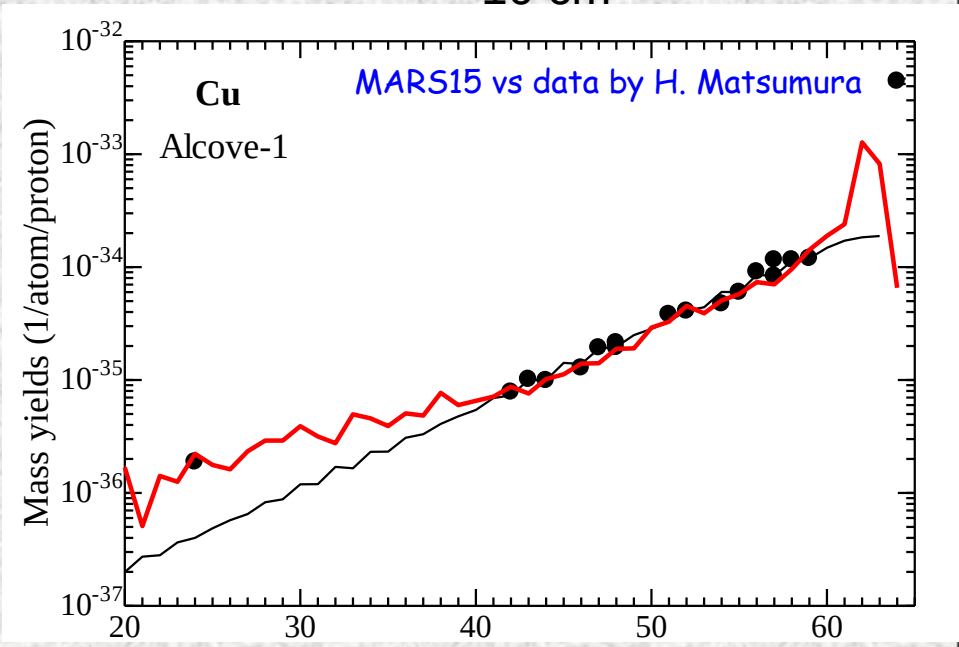
Shielding data and code benchmarking; targets, collimators and thick shields; radiation effects on instruments and materials

Example: Muon-induced nuclide production









JASMIN: MARS15 vs NuMI Data

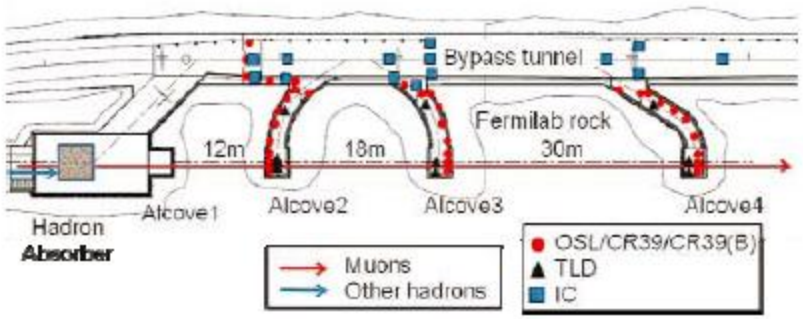


Fig. 2 Locations of dosimeters and detectors to measure muons and secondary particles. The thicknesses of rock between the alcoves are also shown in this figure.

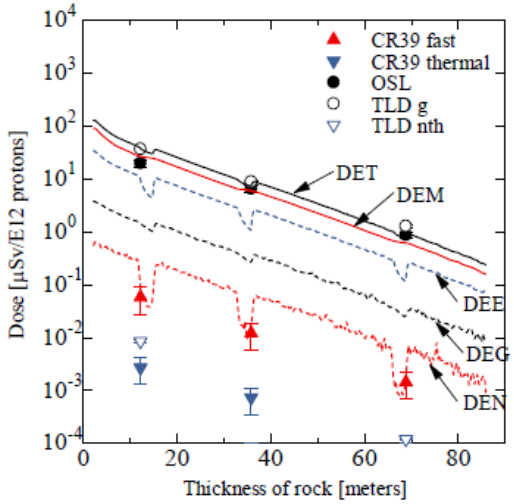


Fig. 5 Experimental and calculation results for attenuation of dose on the beam line as a function of rock thickness.

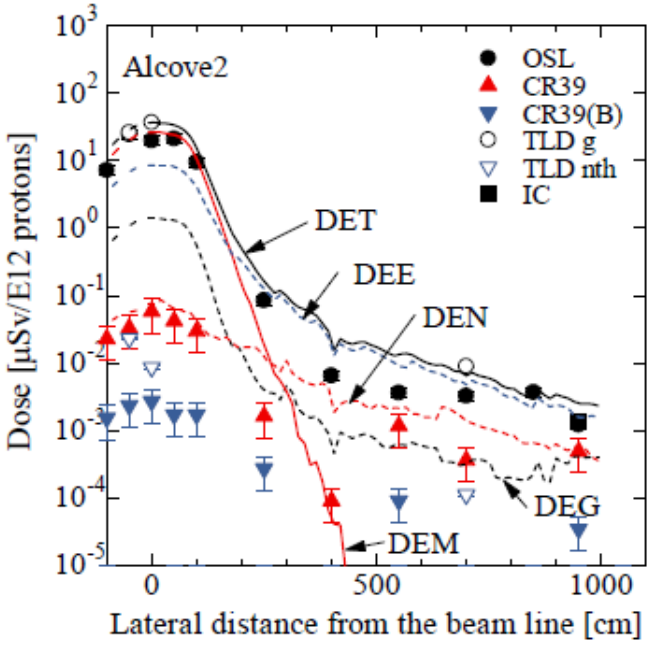
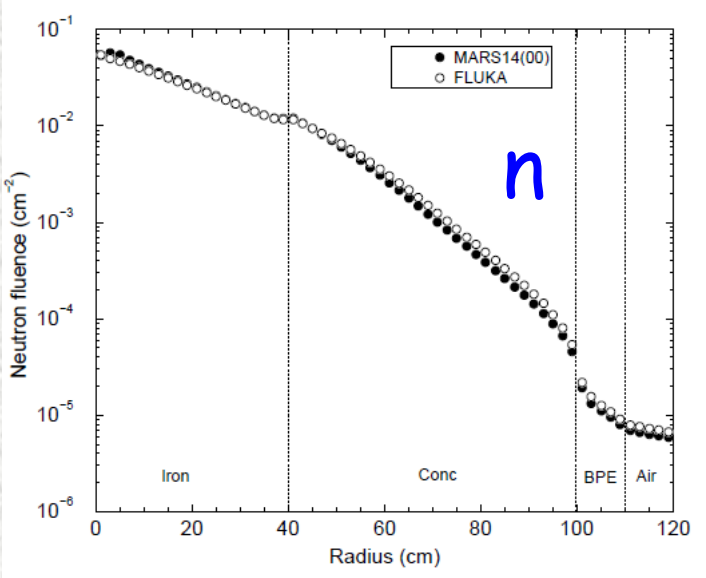


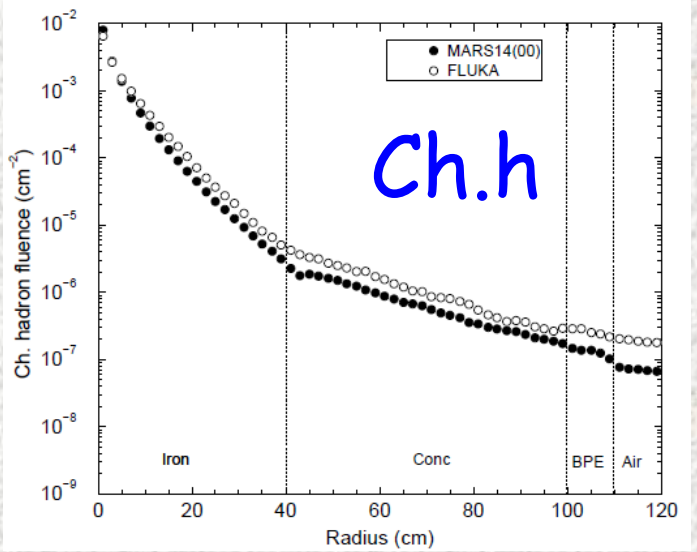
Fig. 4 Experimental and calculation results for dose along alcove 2. DET, DEG, DEM, DEN and DEE stand for dose rate total, photon, muon, neutron and electron, respectively

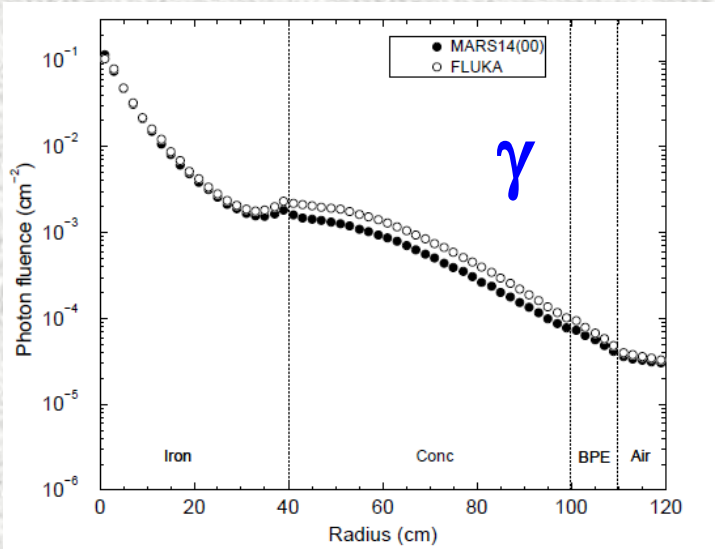
MARS vs FLUKA for 10 GeV/c p on Beam Dump

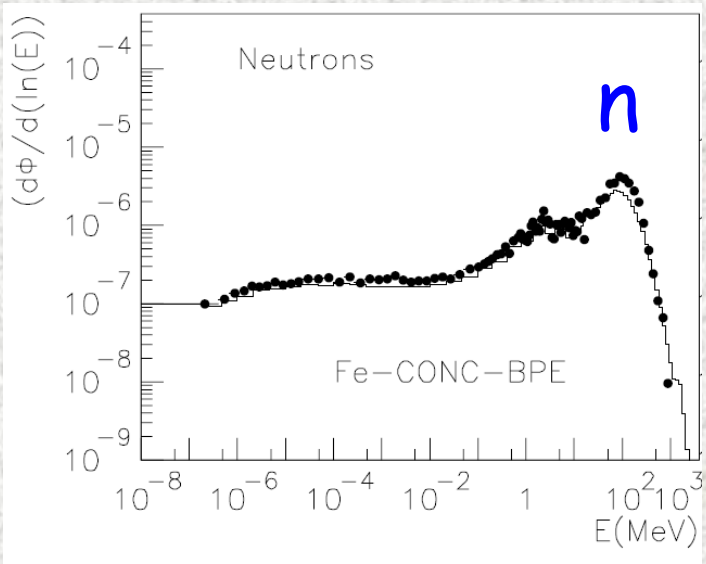


2-m long radial sandwich cylinder

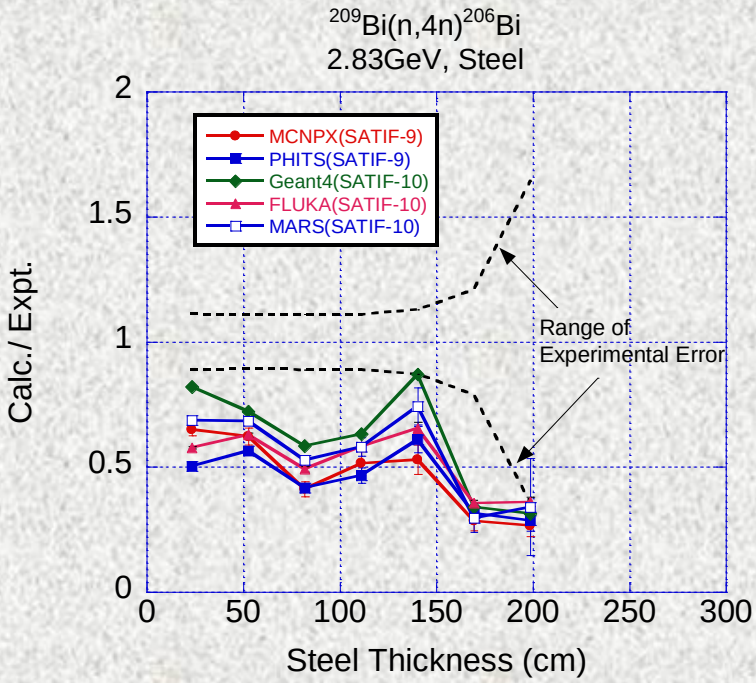
50 < z < 100 cm

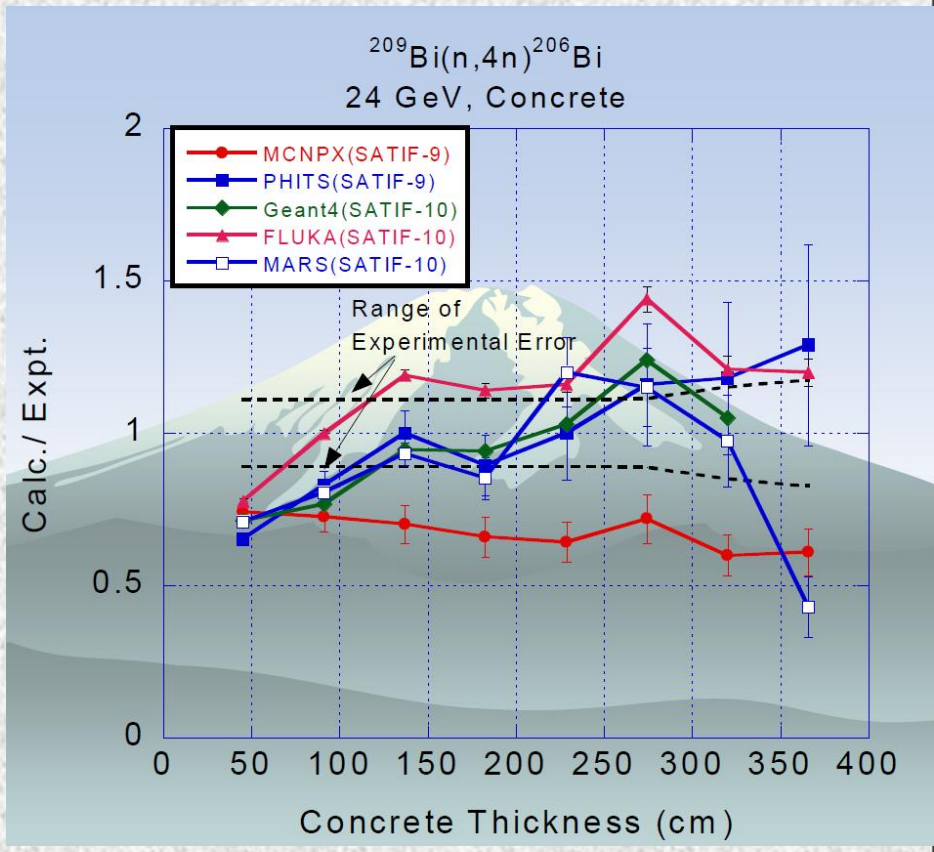






Deep penetration





Agreement within a factor of 2,
but systematic deviation to be resolved

Code Benchmarking: Hadrons

Neutron production and propagation: reasonably well understood by most codes (with some caveats)

Deep penetration: in general well predicted, further benchmarks welcome

Residual nuclei predictions: huge steps forward in the last 10+ years, still a lot of work… new data/comparisons welcome for both thin and thick targets. Special cases (eg production of rare isotopes through (α,x) reactions by secondary α's) sometimes interesting/critical $\rightarrow$ data welcome

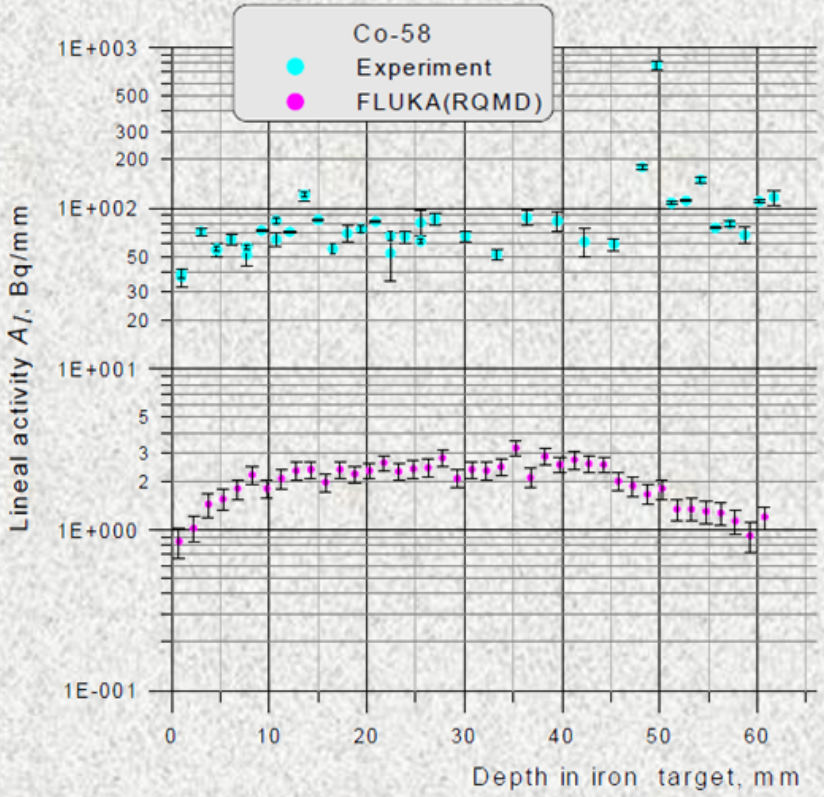
Light (composite) charged particle production: a big challenge, it could be relevant also for radioprotection purposes

Photonuclear reactions/data: Not too much data available at medium/high energies… new data welcome

Code Benchmarking: (α/d/t,x) Reactions

400 MeV/u carbon ions on iron at HIMAC by T. Ogawa

- Low E light ion (α, t, etc) induced reactions?



Code Benchmarking: Heavy Ions

Neutron production: many experiments (mostly by Japanese groups), significant room for improvements in codes (eg forward angles), almost no data available above 1 GeV/n

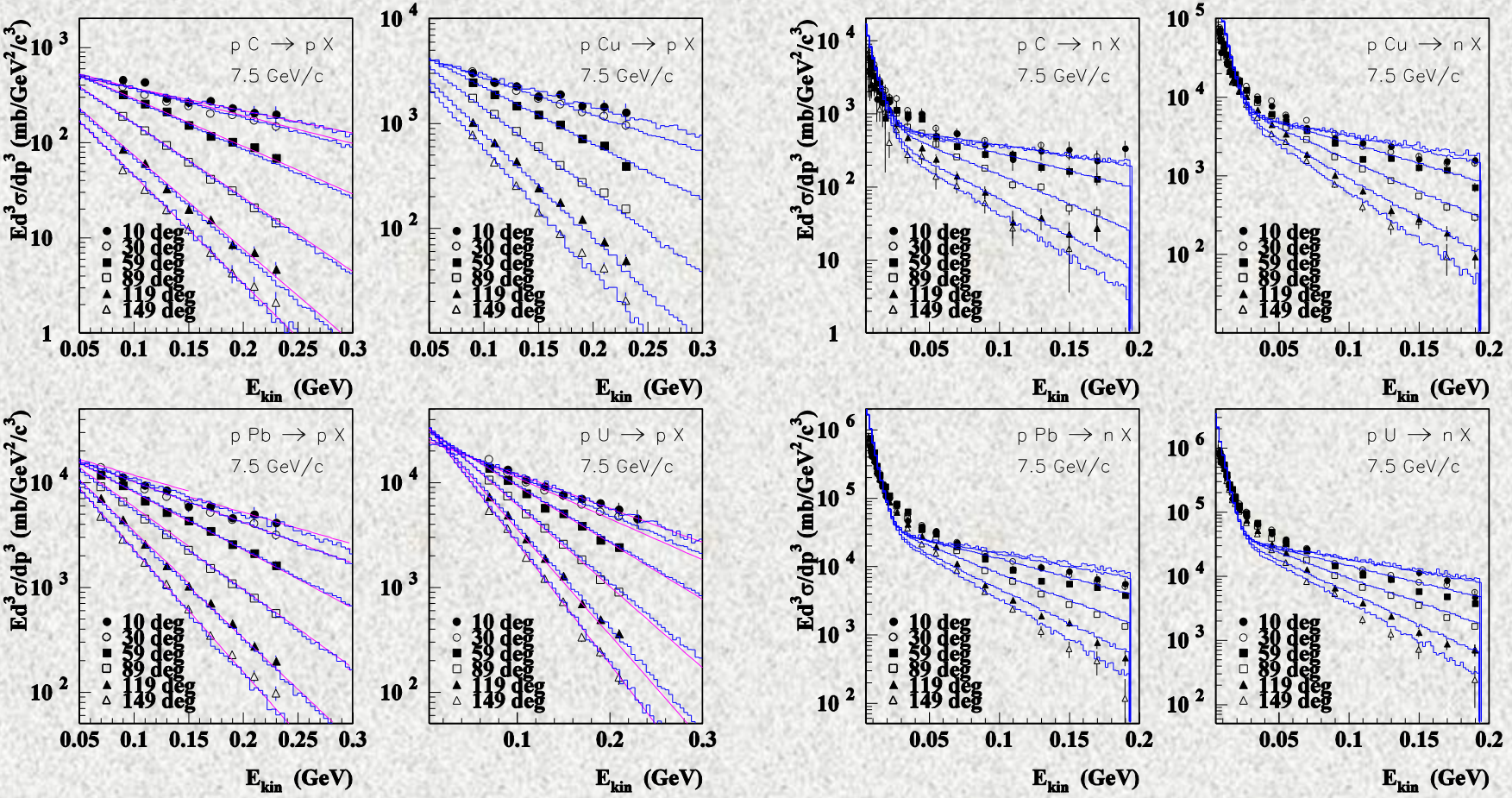
Projectile fragmentation: very important for therapy and not only. All data/benchmarking welcome (the FIRST experiment at GSI should provide data in the next future)

A lot of interesting data from GSI/FAIR, with also some unexpected challenges (ranges…). Radionuclide production distributions of great interest

In general all sort of data for heavy ions are welcome

Low-Energy Nucleon Production in MARS15

7.5 GeV/c protons on C, Cu, Pb and U



Code Status and Developments (1)

- Current FLUKA, MARS and PHITS agree with each other and data within a factor of 2 for most radiation values, **IF** all details of geometry, materials composition and source term are taken into account. Note, PHITS disagrees with newest JASMIN neutron data by up to a factor of 6: need to understand; add MARS to this benchmarking!
- Developments in the intermediate beam energy region $1 < E_p < 8$ GeV (crucial for **ALL** intensity frontier applications), as well as at E_p=1-30 MeV. Further intensification of variance reduction technique use, especially for thick shielding ("deep penetration problem"), growing computation power is not a panacea.

Code Status and Developments (2)

- Codes described are under continuous development, driven by application needs and discrepancies revealed in benchmarking
- Recently in PHITS: improved DPA model
- Recently in MARS15: stopped nuclides followed by decay and transmutation; **ALL** particles, photons and nuclei can be transported down to 1 keV (0.001 eV for neutrons), with improved modeling of dE/dx and DPA in mixtures; enhanced geometry and visualization; substantially extended scoring; work in progress on event generators at intermediate energies

Needs for Data

- High-Intensity Frontier challenges
- Problems revealed in code benchmarking
- Unique capabilities of JASMIN

Needs for Data

1. Energy spectra of neutrons (down to thermal), protons and pions
2. Thick shielding ("Deep penetration problem")
3. Particle yields from thick targets (TTY), especially at E_p = 2 – 8 GeV
4. Nuclide production, including muon-induced
5. Spatial distribution of residual dose rates
6. Radiation damage: targets, insulation, superconducting and structural materials, electronics
7. All of the above for heavy ion beams