MECO Simulations

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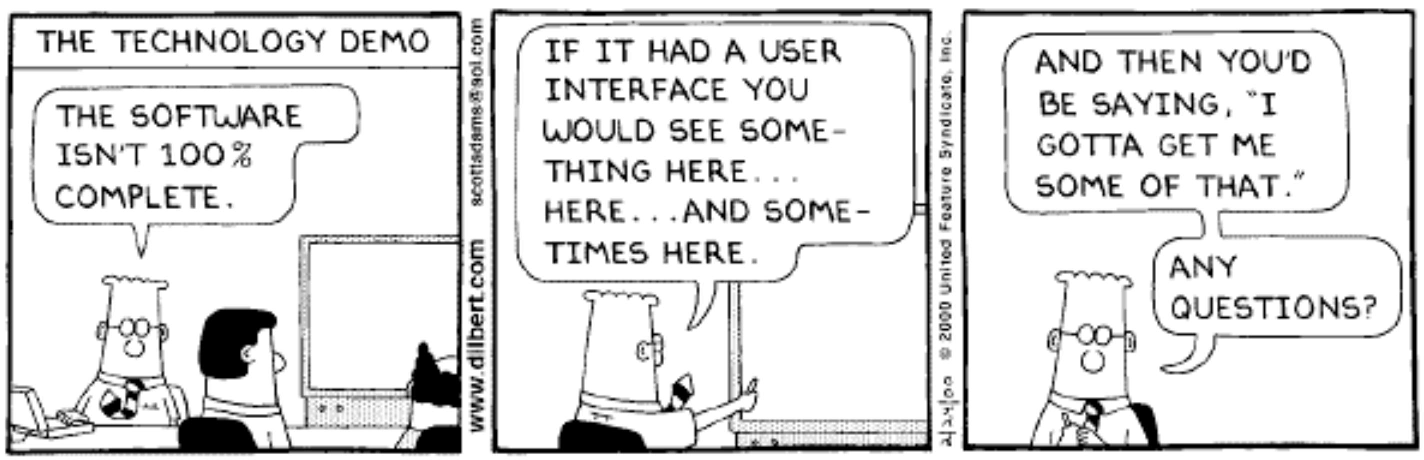
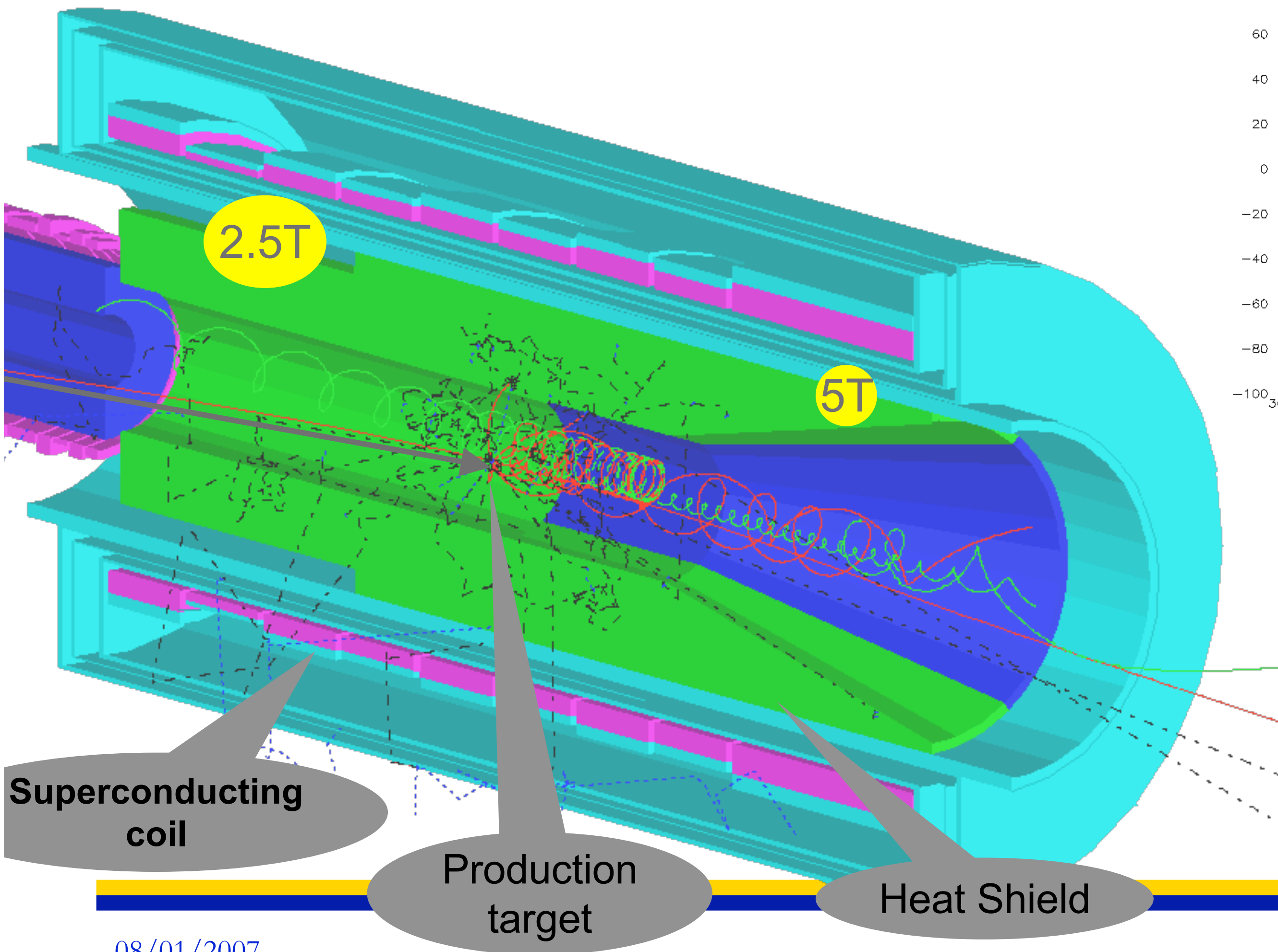
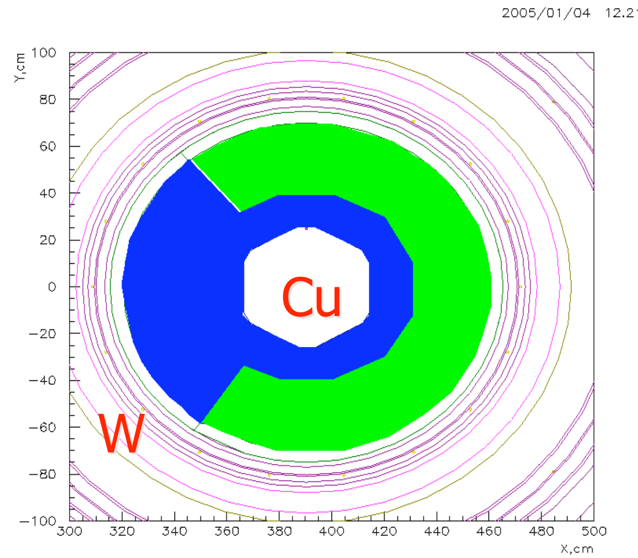


History

- MECO proposal and technical design developed over about 10 years
  - Accompanied by detailed Monte Carlo analysis of all major subsystems
  - Main focus on beam transport, radiation and background issues in the solenoids, detector performance
    - ☞ 20-30 man-years of effort
    - ☞ Concentrated mostly at UCI and NYU

Example from V. Tumakov: PS Heat Shield





Existing Software Base

- Two simulations packages, based on Geant3 and Geant4
  - GMC (G3): most developed
    - Package based on Geant3, with ascii-driven configuration
    - Detailed geometry, field maps for the entire MECO beamline
    - Beamline simulations, signal and backgrounds
    - Integrated (perhaps too tightly) pattern recognition/tracking
    - Most of the development centered at Irvine
  - Standalone G3
    - NYU effort, including "pure" GMC
  - Some work on Geant4
    - Work by Vladimir Tumakov on porting MECO geometry
    - Comparisons of hadronic codes in G4
- No hardware response (hit digitization, efficiency)
  - Resolution smearing

Reconstruction

- Mostly developed for tracking
  - L-Tracker studies at Irvine
    - PatRec (new C++ code by Paul Huwe) and track fitting (Jim Popp)
    - Tightly coupled to GMC (via common blocks, event structure, makefiles, etc)
    - Used for performance studies (background rates, resolutions)
  - T-Tracker studies at NYU
    - C++-based PatRec and fitting, including Kalman filter
    - Standalone (G4-based makefiles, ascii file inputs from MC for signal and backgrounds)
- Some code was also developed for calorimeter simulations and reco, trigger

Example: Energy Leaving PS Bore

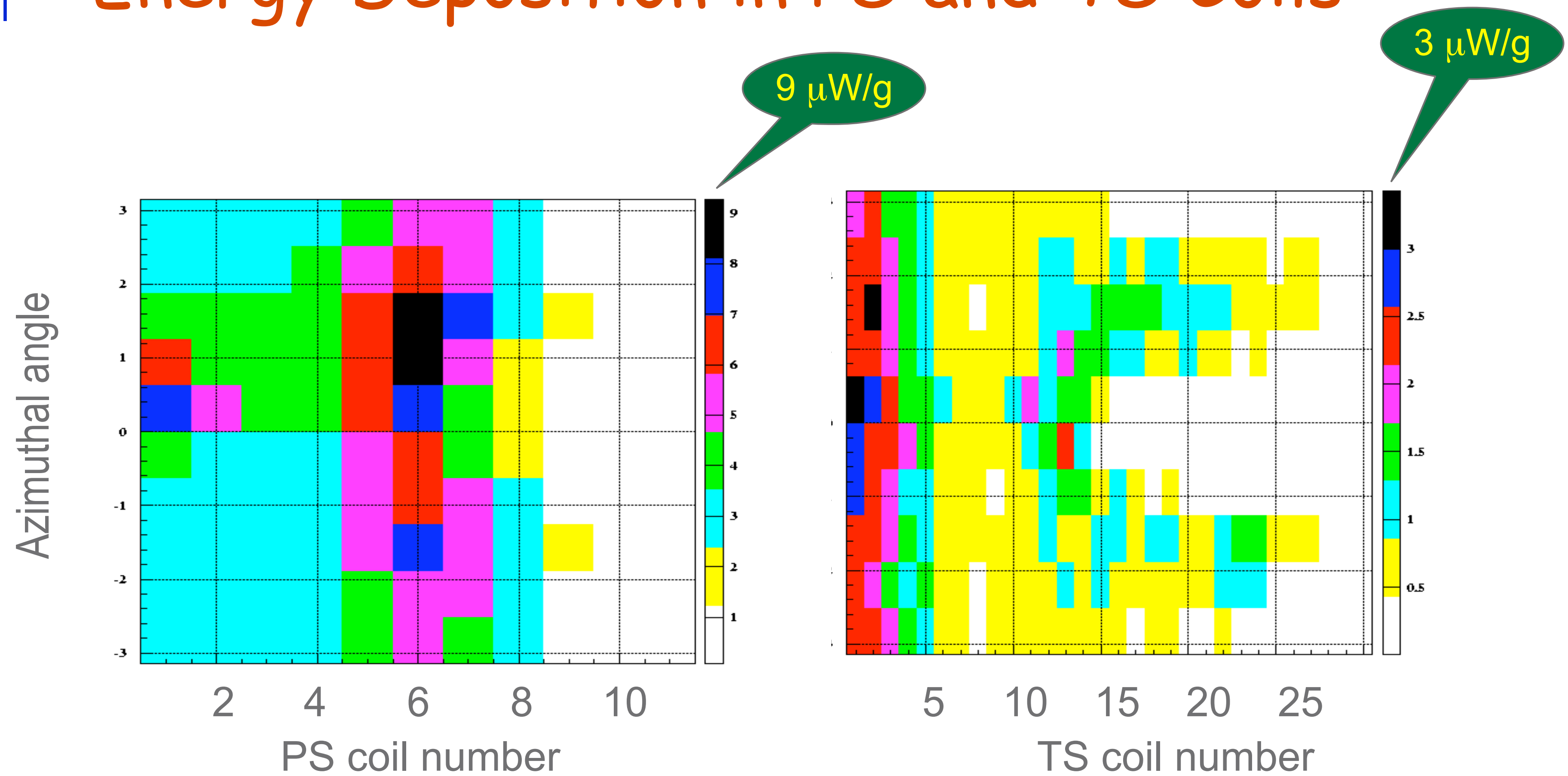
Particle	Radial [W]	Forward [W]	Backward [W]
ν	358	37	20
K	3	52	-
γ	16	461	2
e	4	703	86
μ	1	77	30
π	18	2351	85
n	279	2893	5
p	16	12438	8

Energy deposition in different volumes, [W]	
Target	4186
PS shield	15937
Collimator	179
TS shield	72

- PS heat shield must be water cooled (16 kW)
- TS heat shield may be water cooled
- Thermal management of SM bores is important

- Load on PS cold mass primarily from neutrons
- Backward energy flow requires some TS shield

Energy Deposition in PS and TS Coils



- Cylindrical proton beam pipe R=4cm
- Azimuthal asymmetry due to targeting angle

V.Tumakov

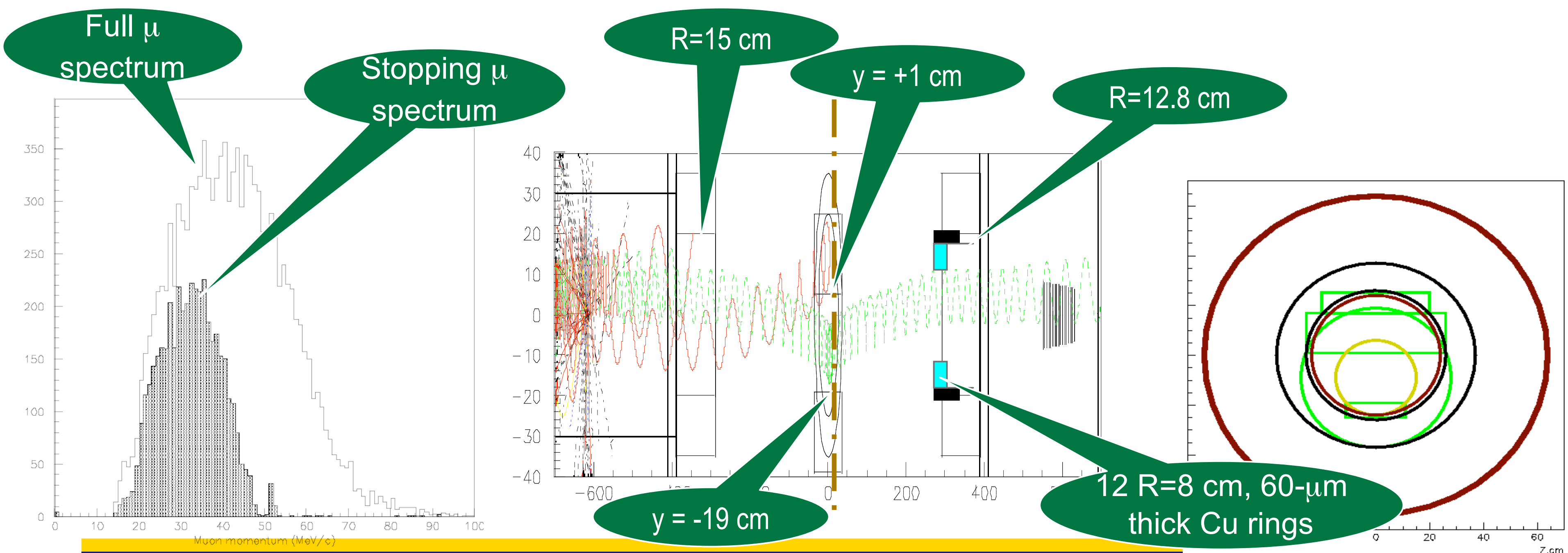
Transport Solenoid

Sign and momentum select in curved solenoid section.

- Curvature eliminates direct photon transport
- Collimators absorb high momentum and positive particles.

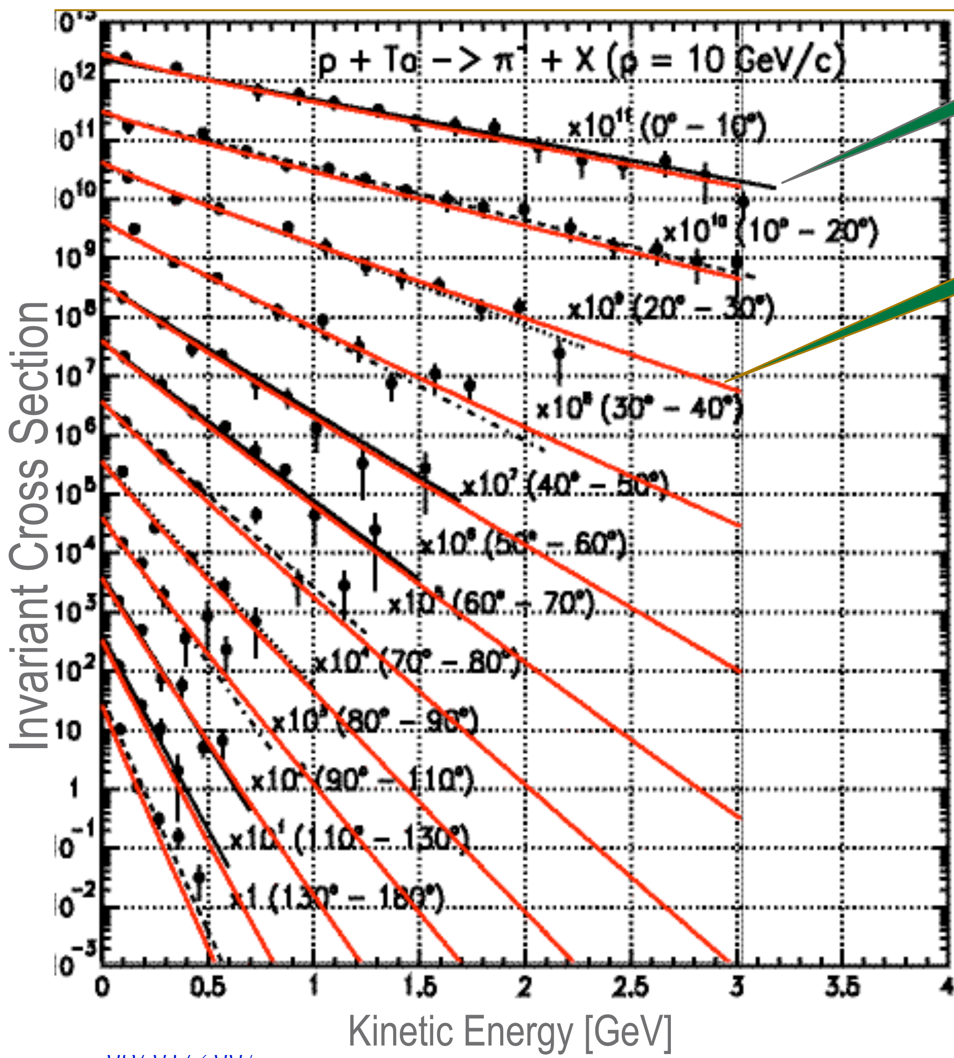
Collimators tuned for specific purposes

- Offset center collimator to reduce positrons (high rates)
- Thin disks at end collimator to absorb very low momentum muons



Calculation of Pion Fluxes

Experimental measurements of π^- production cross section for 10 GeV protons on Ta



C exp(-T/T_0)

C exp(-f(θ)T/T_0)

- Pion production cross sections calculated using experimental invariant cross sections, scaled to MECO beam energy

$$\frac{dN^{\pi}}{N^{p}_{incident}} = I(\Theta,T) * \frac{L\rho}{m_p E} * p * E * 2\pi * d(\cos\Theta) * dT$$

- Energy and angle dependence compared with various hadronic models

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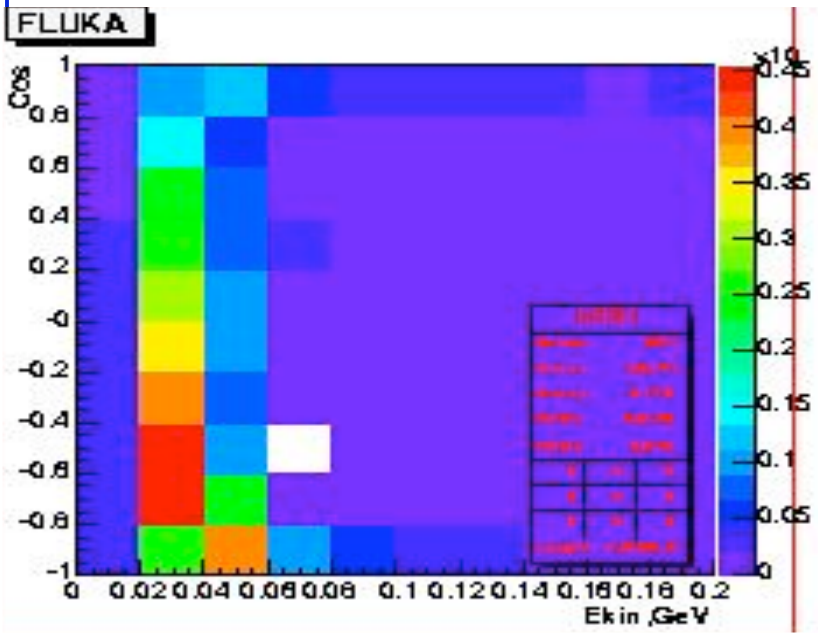
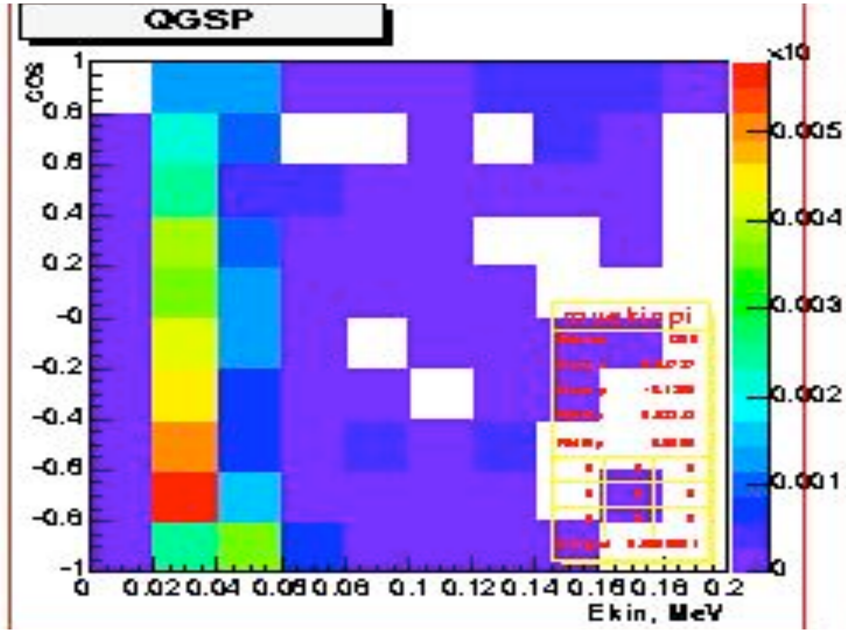
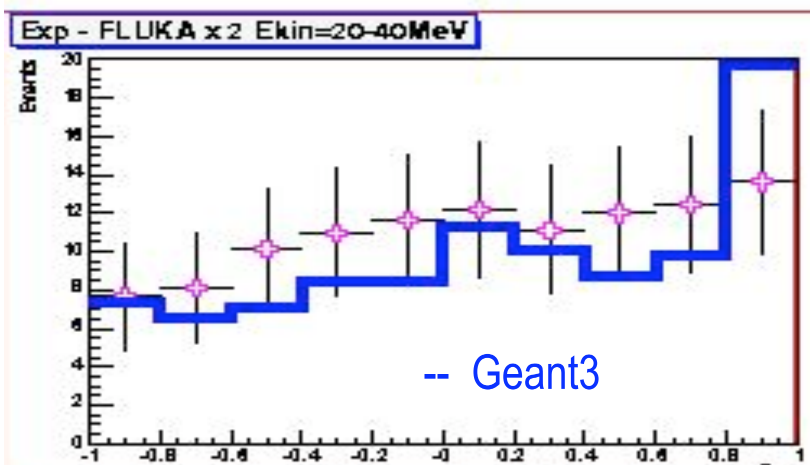
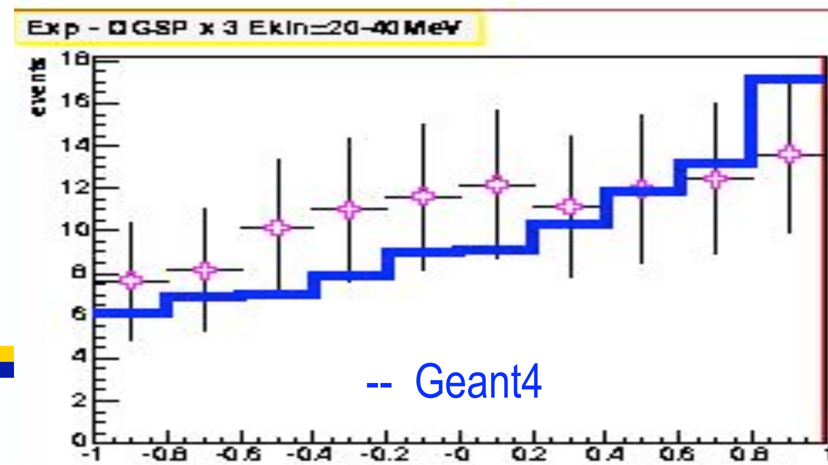
Pions that Produce Stopped Muons



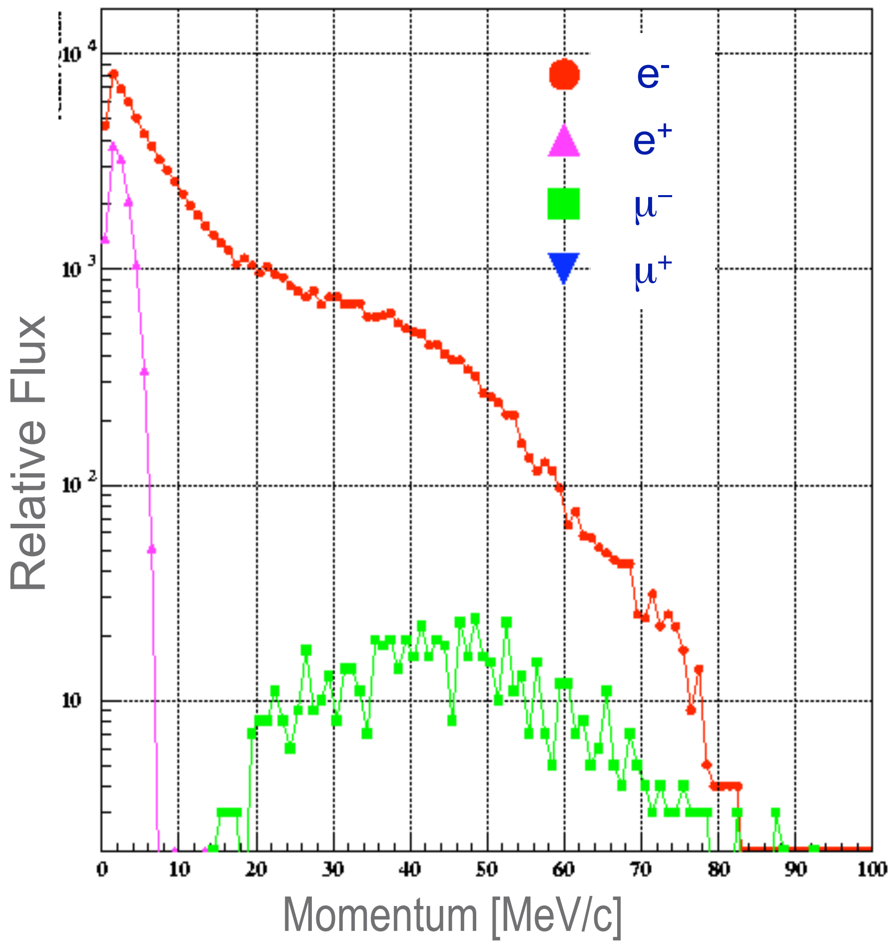


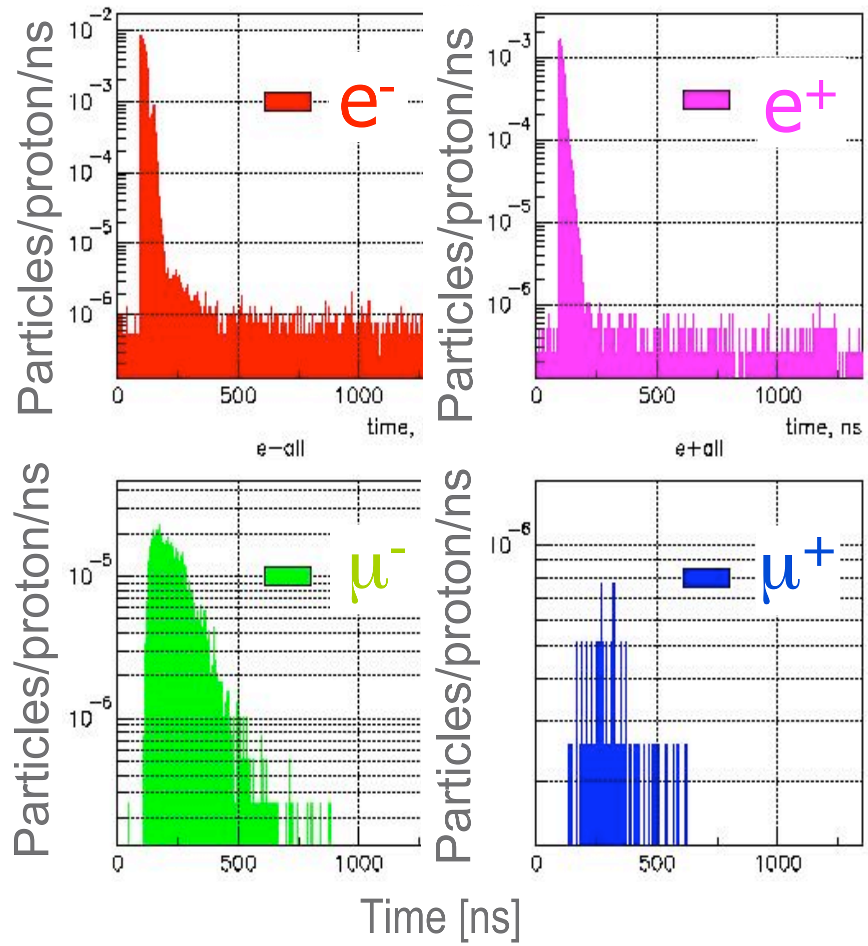
Data and Monte Carlo in 20-40 MeV region agree well in angular distributions after correction of the multiplicity by factor 2 (G3) or 3 (G4)





MECO Muon Beam





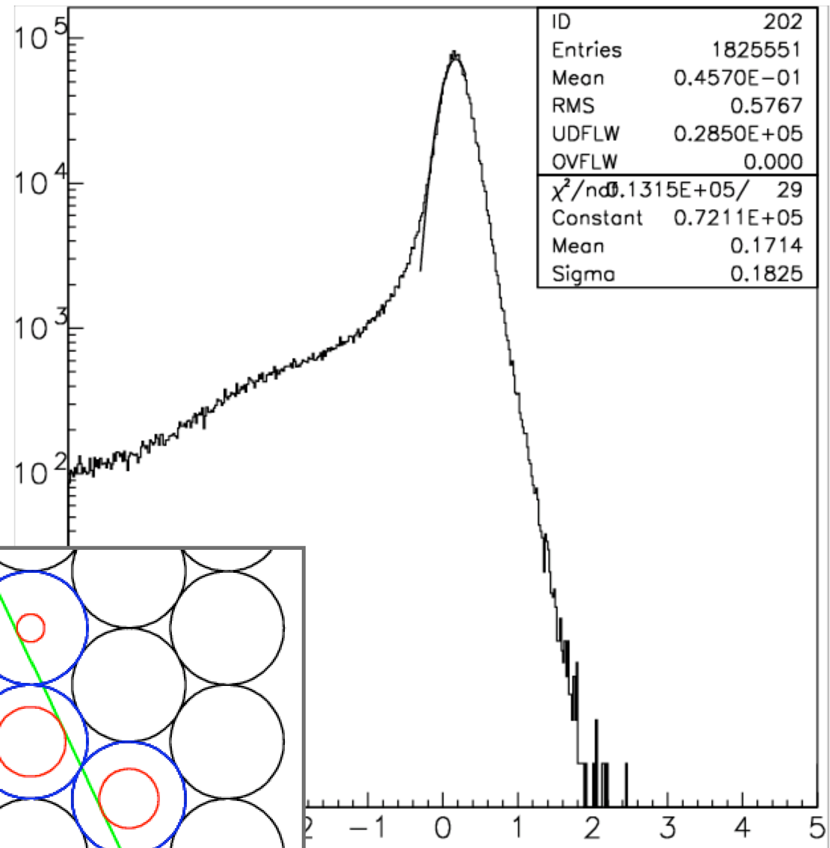
Comments: low energy e^+ suppressed with highly asymmetric central collimator, small μ^- loss

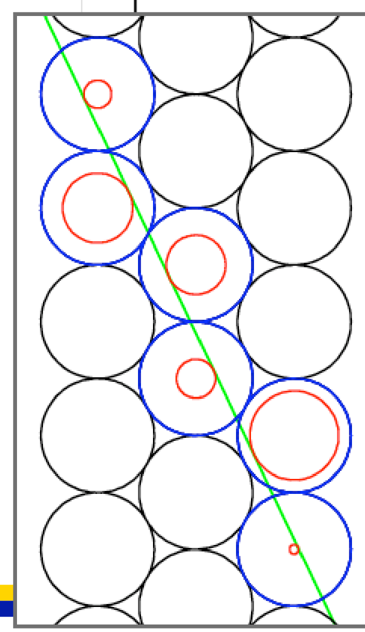
late e^- from stopped muon decay – μ^- capture implemented in GEANT3

flash of prompt e^+, e^- primarily from γ conversions in production target

L Tracker Simulations

- 5×10^6 reconstructed conversion events using the "average material" tracker and detailed CDR field map
- The intrinsic resolution is 180 keV
- The acceptance is 19% for $N_{Back} / N_{signal} = 0.05$



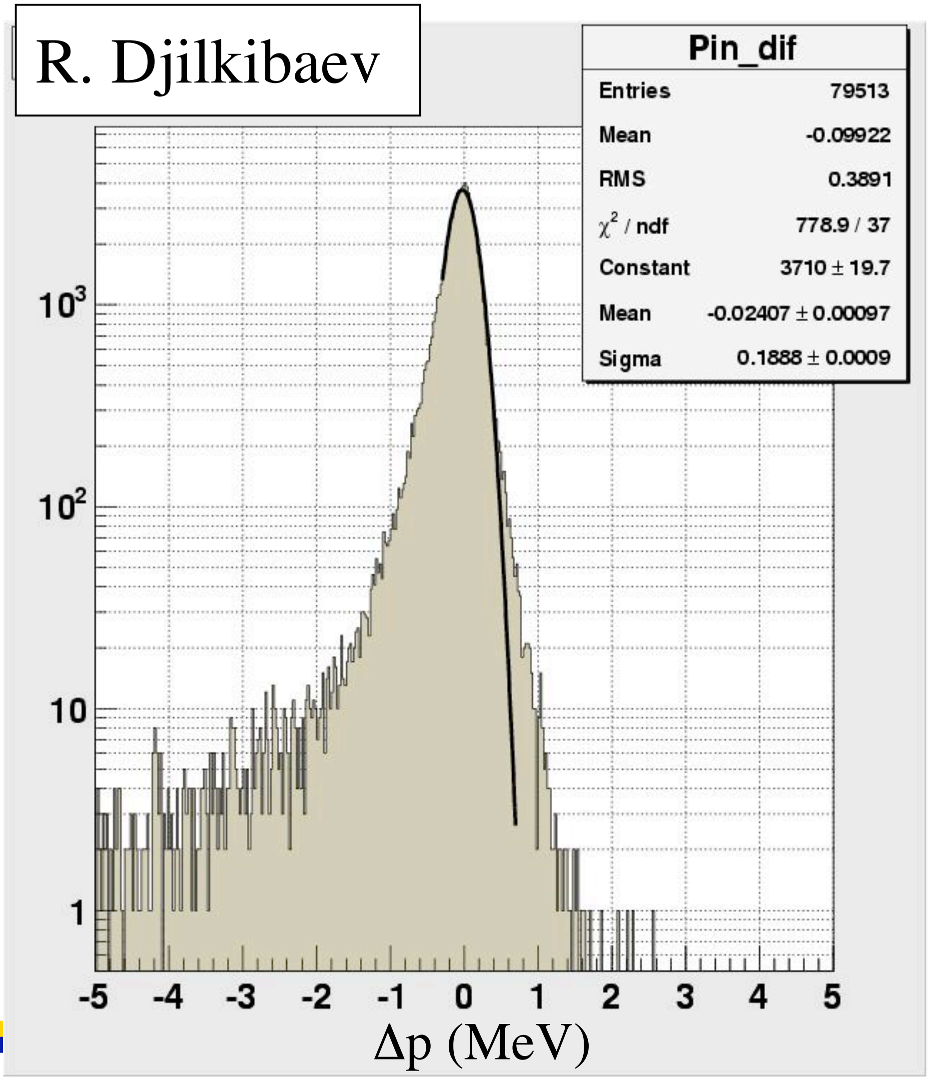


T-Tracker Resolution with Background

- Nominal background and 25 μm
- Delta-ray and straw inefficiency
- Kalman filter reconstruction
- Tracker Resolution
  $\sigma = 0.19$ MeV/c
- Plot is the Difference between reconstructed input momentum and actual input momentum

Average straw rate 550 kHz

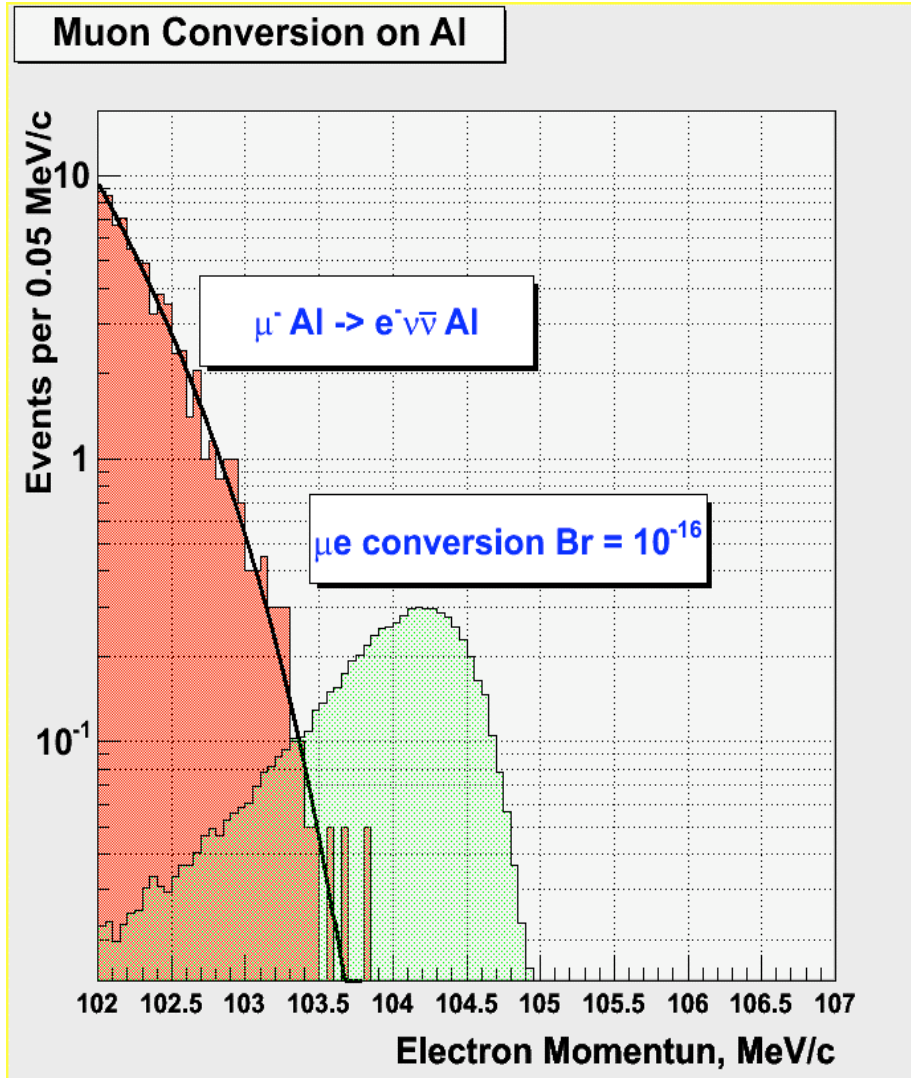
Straw eff.	Overall acceptance
100%	19.2 %
97%	18.7 %



DIO Reconstruction with Background

- 1M DIO events (> 100 MeV/c)
  → 20 times more than expected
  Fit by Norm x $(E_{max} - E)^5$
- 3 event found
  in search range > 103.5 MeV
  Background → 3 / 20 = 0.2 event

Muon Conversion Signal →
5.5 events expected
for Br = 10^{-16}
Background/Signal Ratio = 0.03



R. Djilkibaev

Code Base

- Originals in CVS repository at UCI
- Geant3-based GMC was the standard at MECO
  - I have a copy at Berkeley; last run 2 years ago
    - ☞ Includes proton beamline, production target, PS, TS, detector, L-tracker, calorimeter
  - Also start-up G4 code from Vladimir
- Reconstruction
  - Integrated into GMC: was in a messy state last time I checked
  - PatRec converted to C++ for both trackers
    - ☞ Fitter for the L-tracker still in Fortran (Jim Popp)
- Would take some effort to get it back running again, but this is doable
  - Ultimately, need to migrate all this to maintainable code base (G4)
  - Need manpower

Documentation

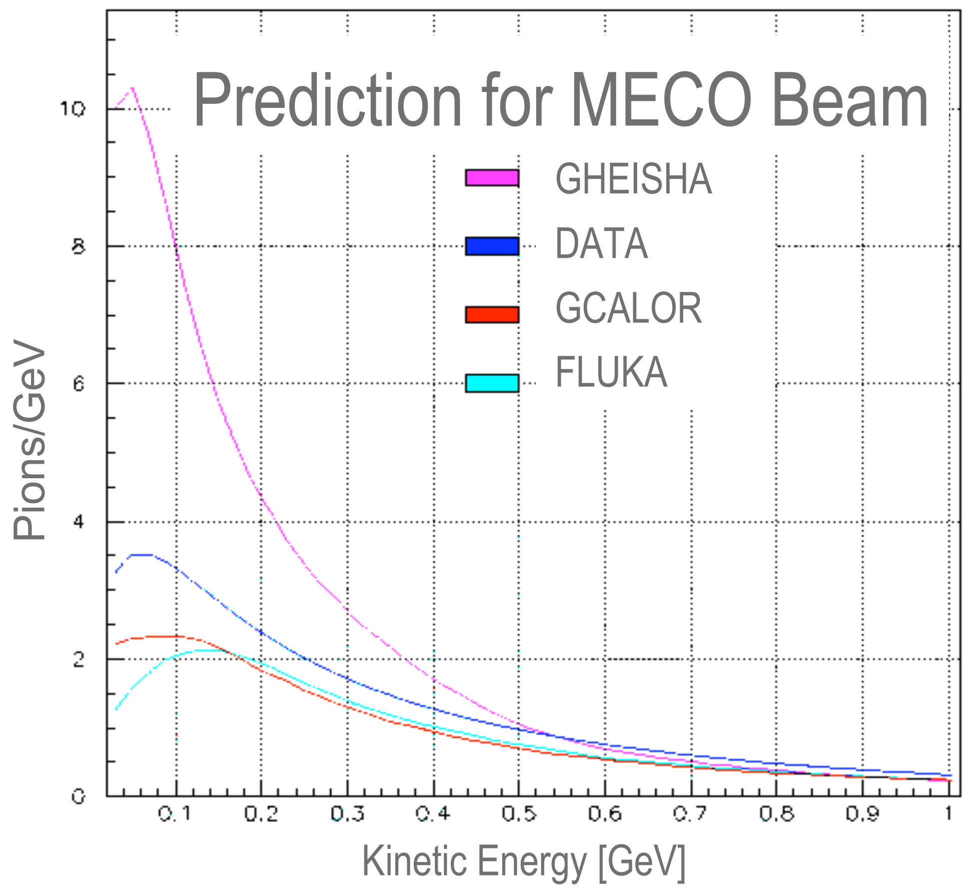
- MECO internal document repository still alive

http://meco.ps.uci.edu/internal/meco_internal_memos.html

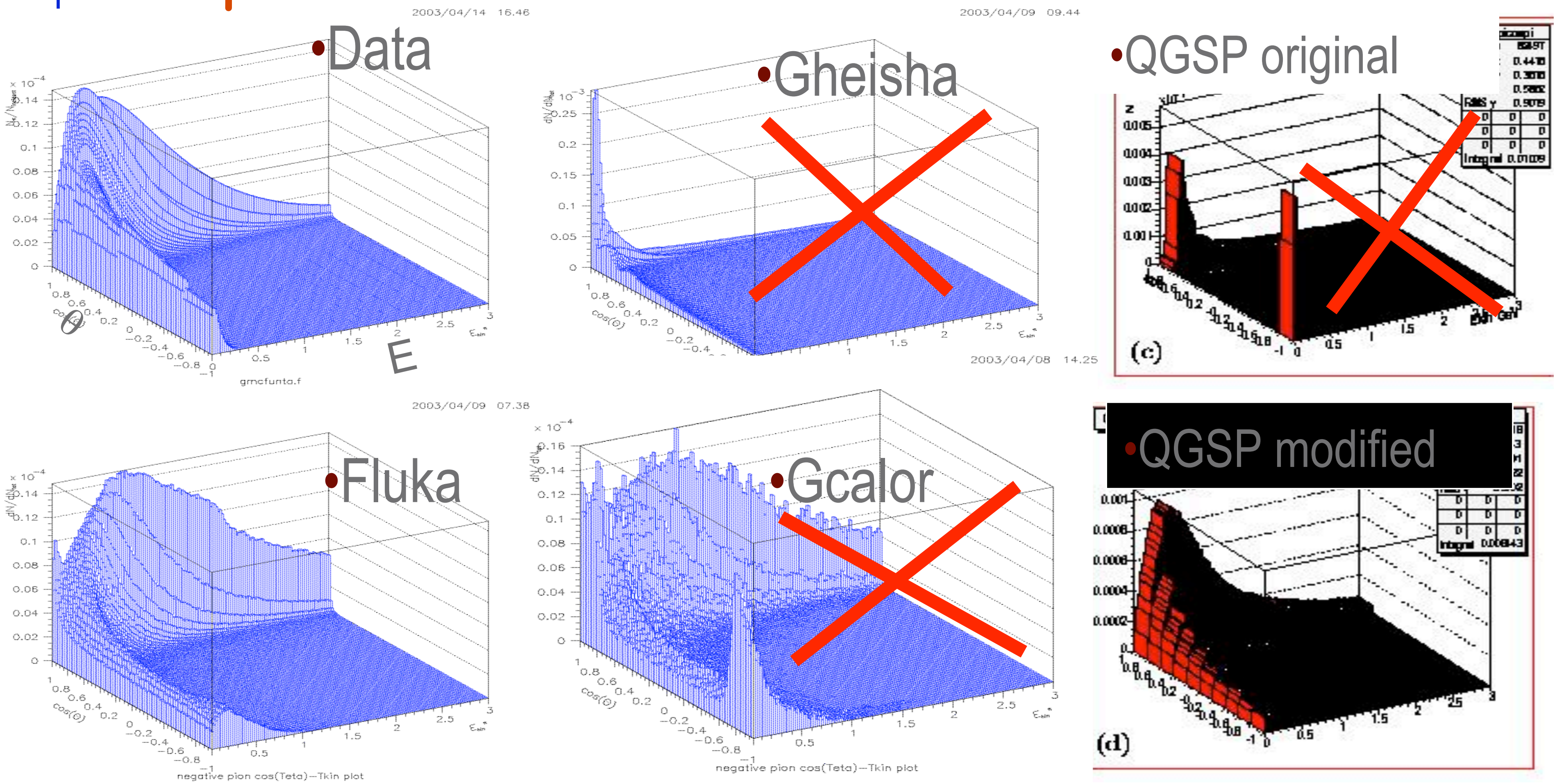
  - (links broken but URLs work)
- Also brief README in GMC package
- Experts also still accessible
  - Vladimir Tumakov (UCI)
  - Rashid Djilkibaev (NYU, INR)
  - Jim Popp (ISU)

Backup

Number of π^- per Interaction

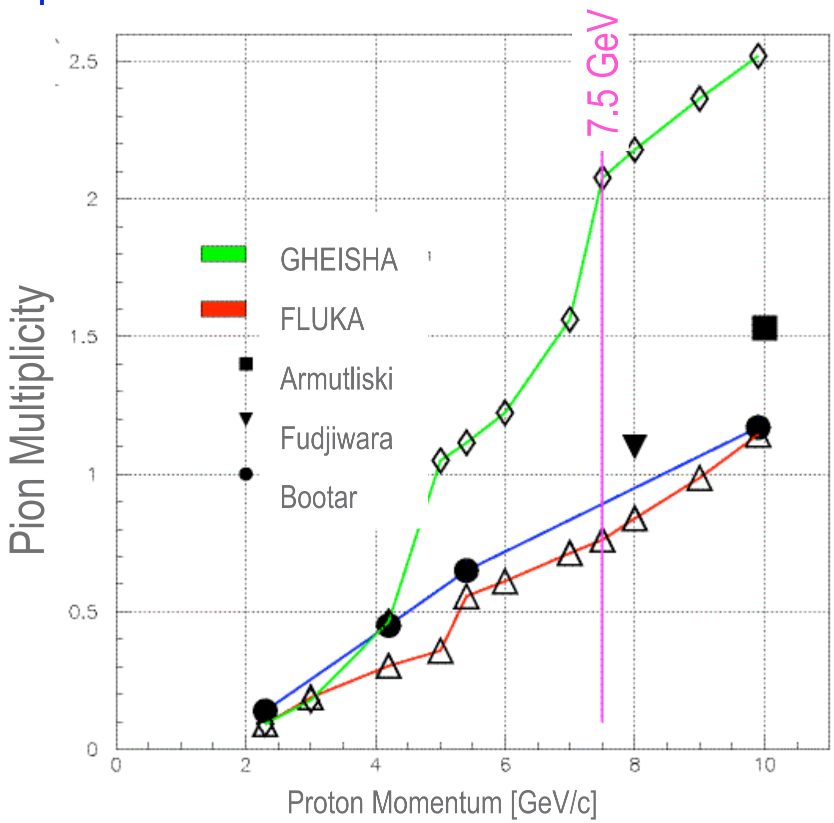


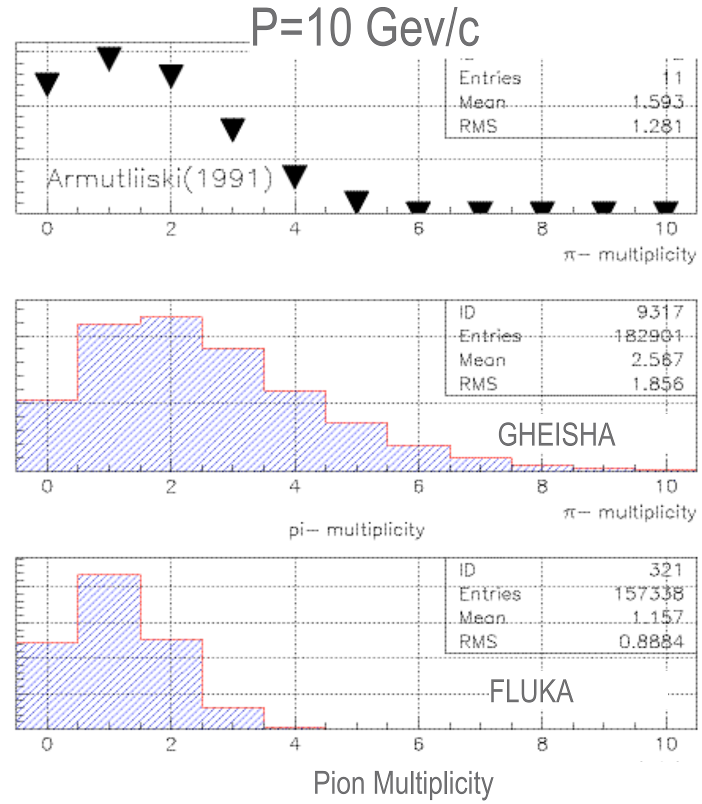
Comparison of π^- Production Distributions



Only Geant3 FLUKA and modified Geant4 QGSP give pion spectrum close to experiment

Additional Measurements of π^- Multiplicity





	Cross section [barn]	Multiplicity per interaction	Multiplicity per proton
experiment	1.56	1.53	0.0133
FLUKA GEANT3	1.69	1.16	0.0109
QGSP GEANT4	1.75	0.95	0.0092

Comparison of GEANT simulations with thin-target experimental data

Particle Fluxes in FLUKA and QGSP Simulations

- Particle fluxes per proton calculated without any corrections
- Good agreement between GEANT3 and GEANT4 simulations

	μ^-	μ^+	All e^-	Late e^-	All e^+	Late e+	π^-
FLUKA	1.8×10^{-2}	8.2×10^{-6}	0.226	4.6×10^{-4}	0.0324	7.4×10^{-5}	2.7×10^{-6}
QGSP	2.0×10^{-2}	6.1×10^{-6}	0.182	6.3×10^{-4}	0.0185	12.4×10^{-5}	4.1×10^{-6}