Muon Beam Simulation in ICEDUST

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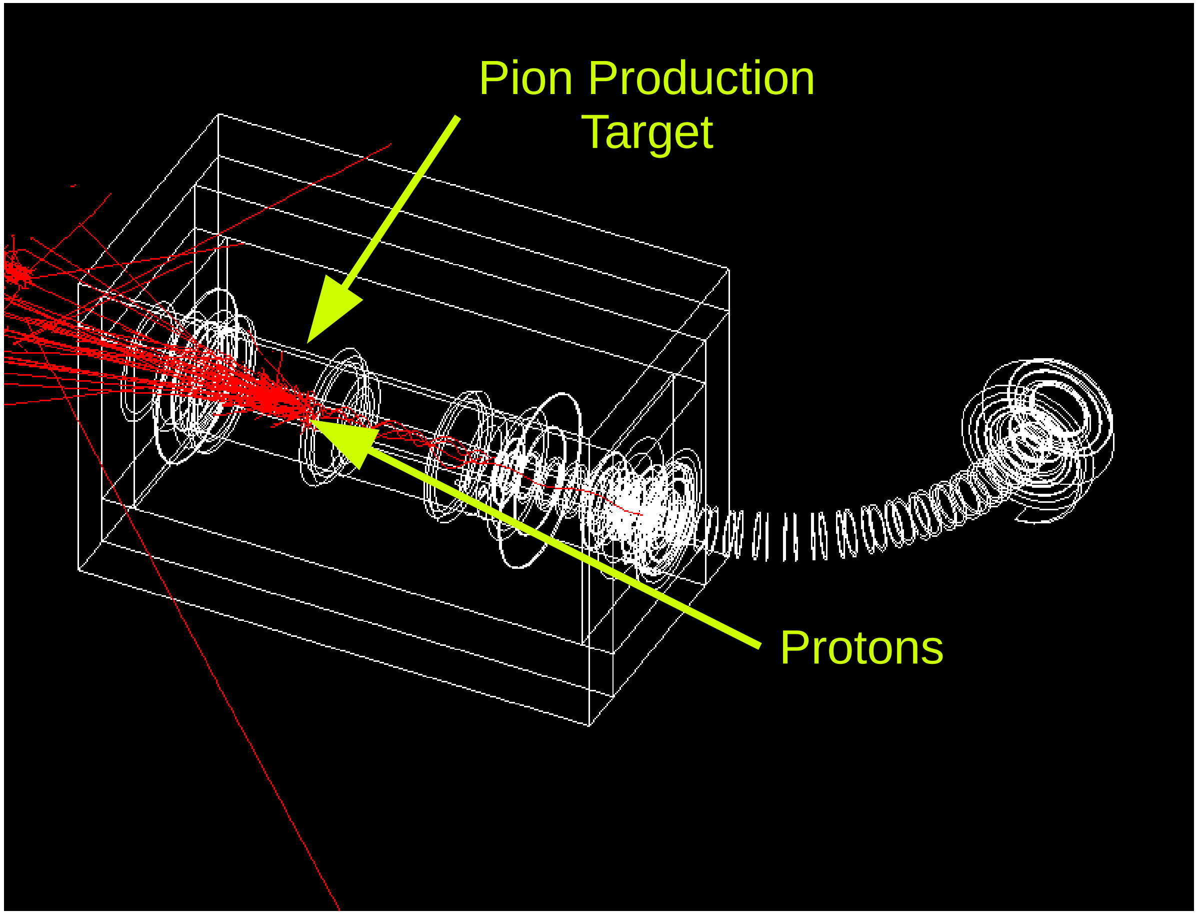
Outline

- Motivation
- Hadron Production Models
- Previous Work
- Present / Future Work

Motivation

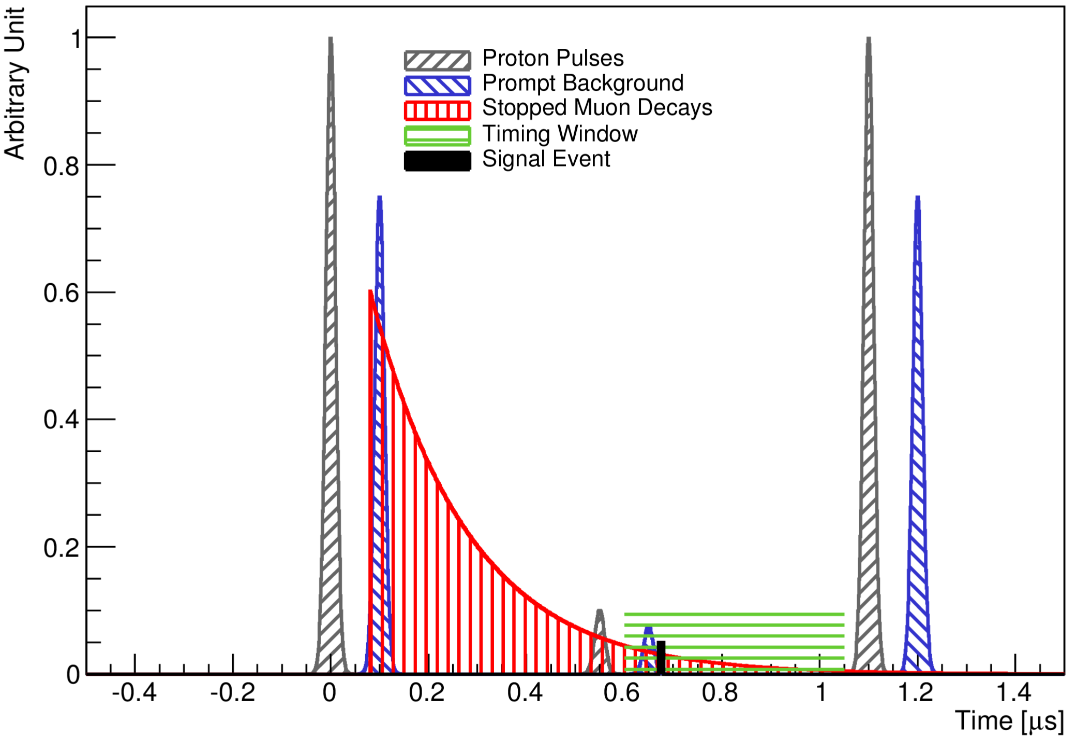
- COMET will be using a novel pion capture system which collects backward travelling pions
- Little experimental data in this region



Visualisation pion production target section and first 90° of COMET (π^- tracks are in red)

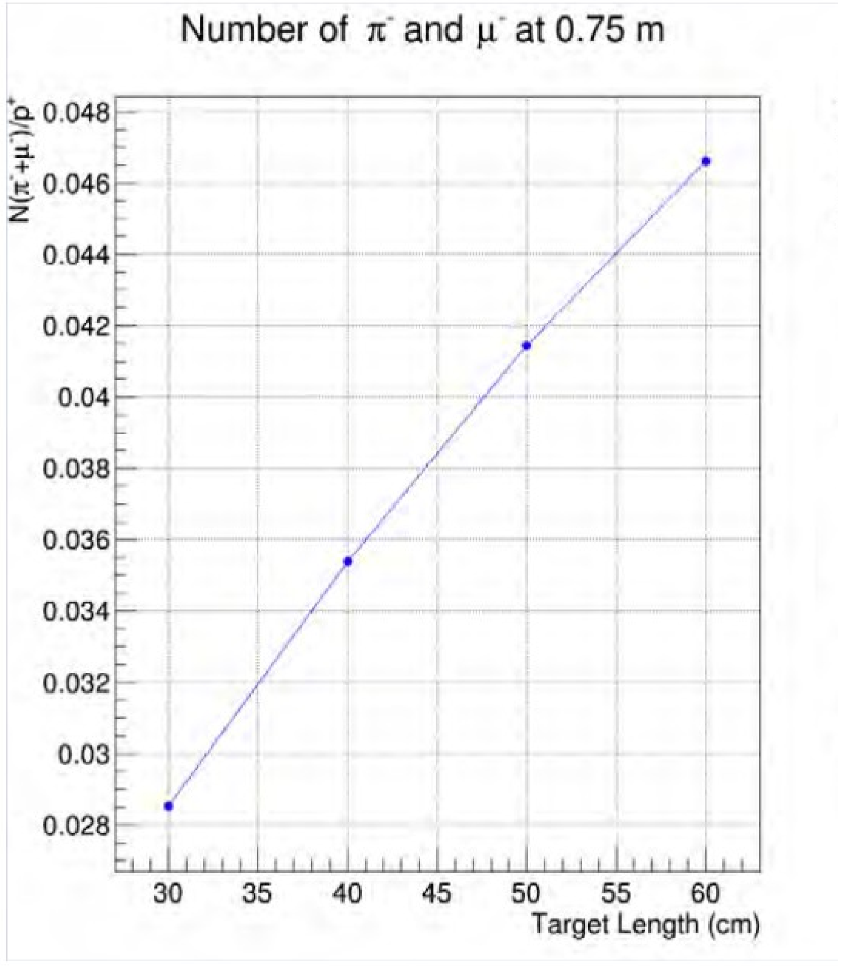
COMET

- Proton Beam
  - 8 GeV
  - Beam Size
  - Timing Structure



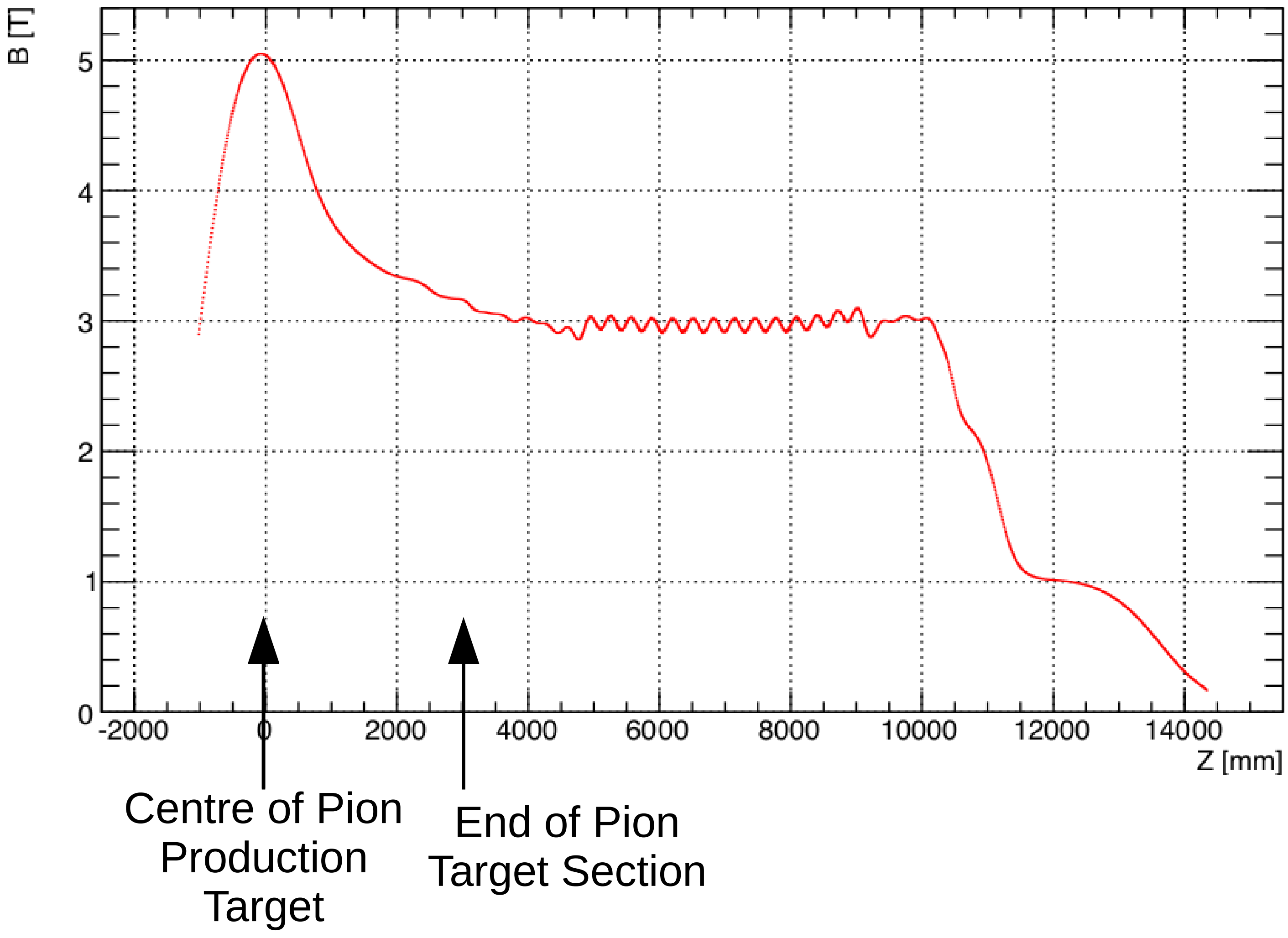
COMET

- Pion Production Target
  - Graphite
  - 60cm length
  - 2cm radius

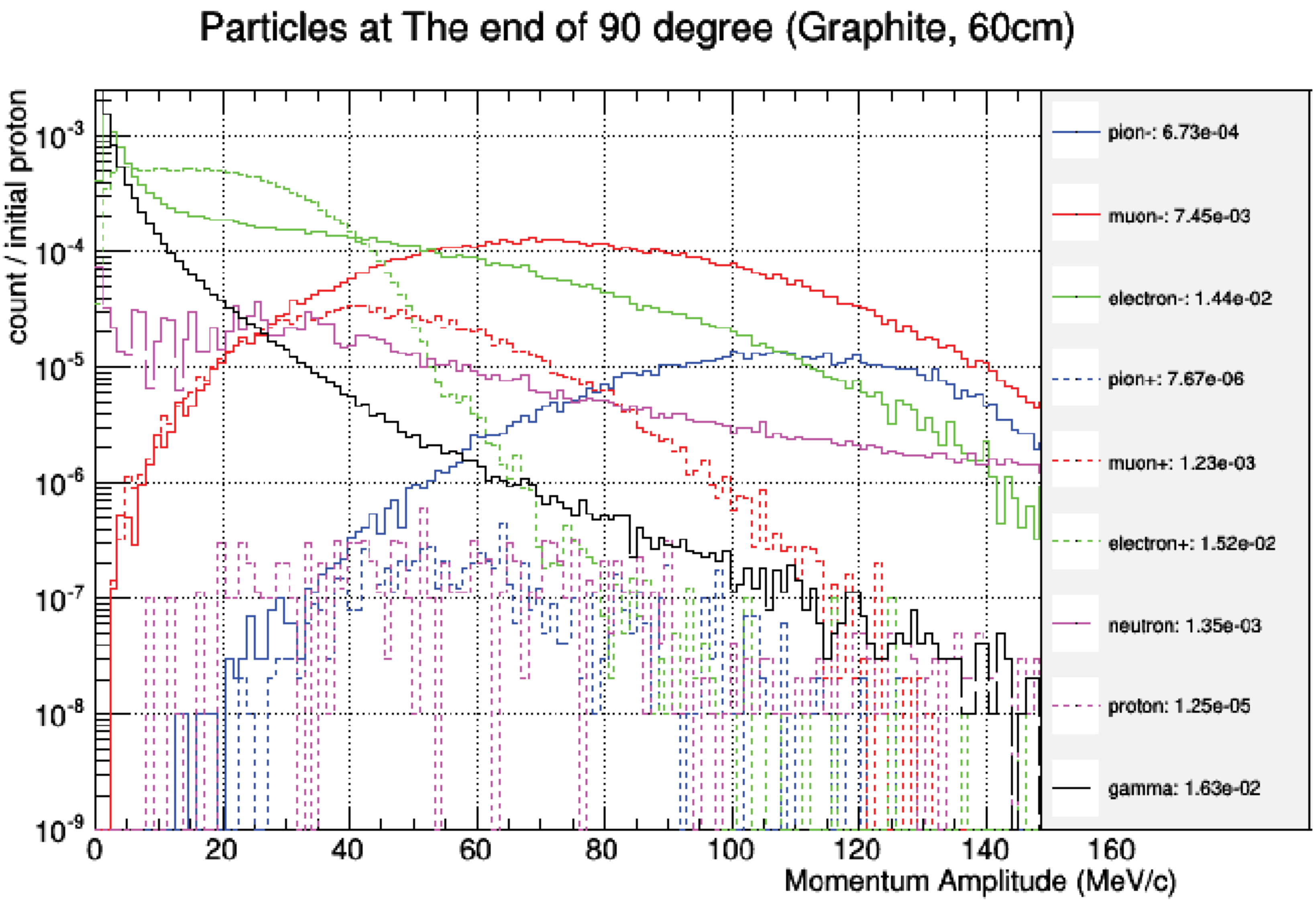


COMET

- Magnetic Field



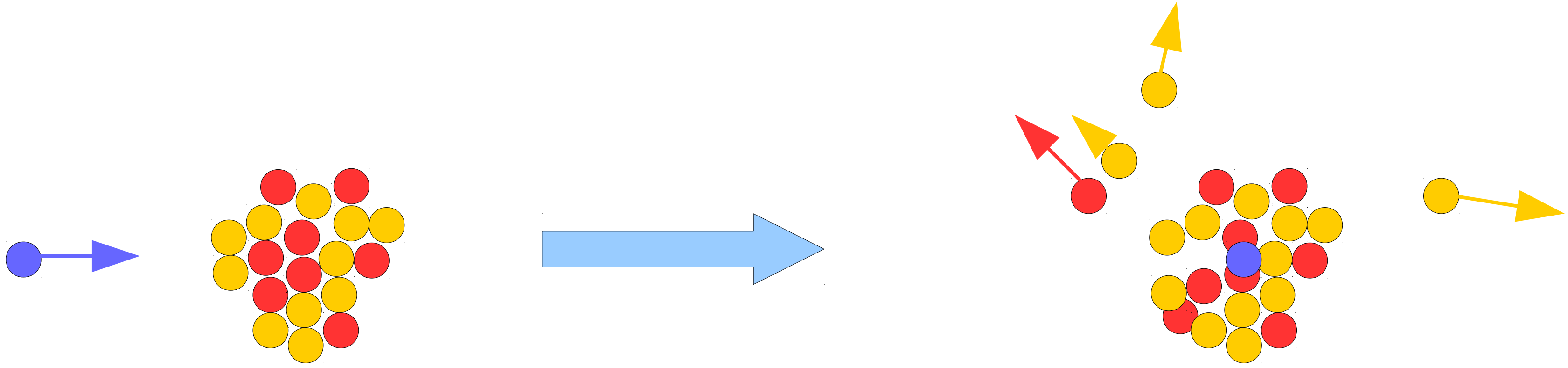
COMET



Particles at The end of 90 degree (Graphite, 60cm)
count / initial proton
10^-3
10^-4
10^-5
10^-6
10^-7
10^-8
10^-9
0
20
40
60
80
100
120
140
160
Momentum Amplitude (MeV/c)
pion-: 6.73e-04
muon-: 7.45e-03
electron-: 1.44e-02
pion+: 7.67e-06
muon+: 1.23e-03
electron+: 1.52e-02
neutron: 1.35e-03
proton: 1.25e-05
gamma: 1.63e-02

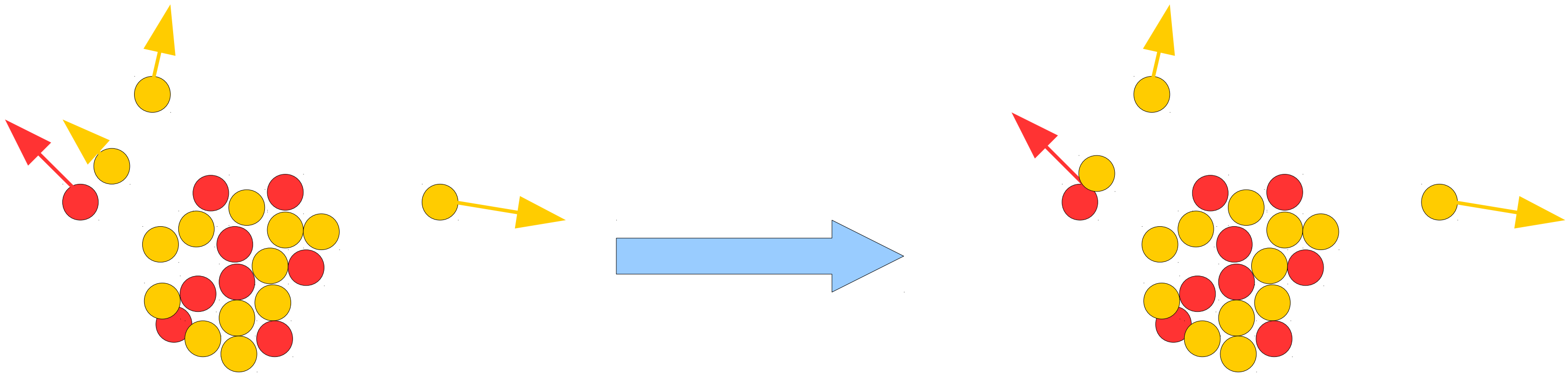
Hadron Production Models

- Three general steps to hadron production models
  - Step 1: Intra Nuclear Cascade
    - Projectile interacts with nucleons and produces secondaries until it escapes or is absorbed by the nucleus



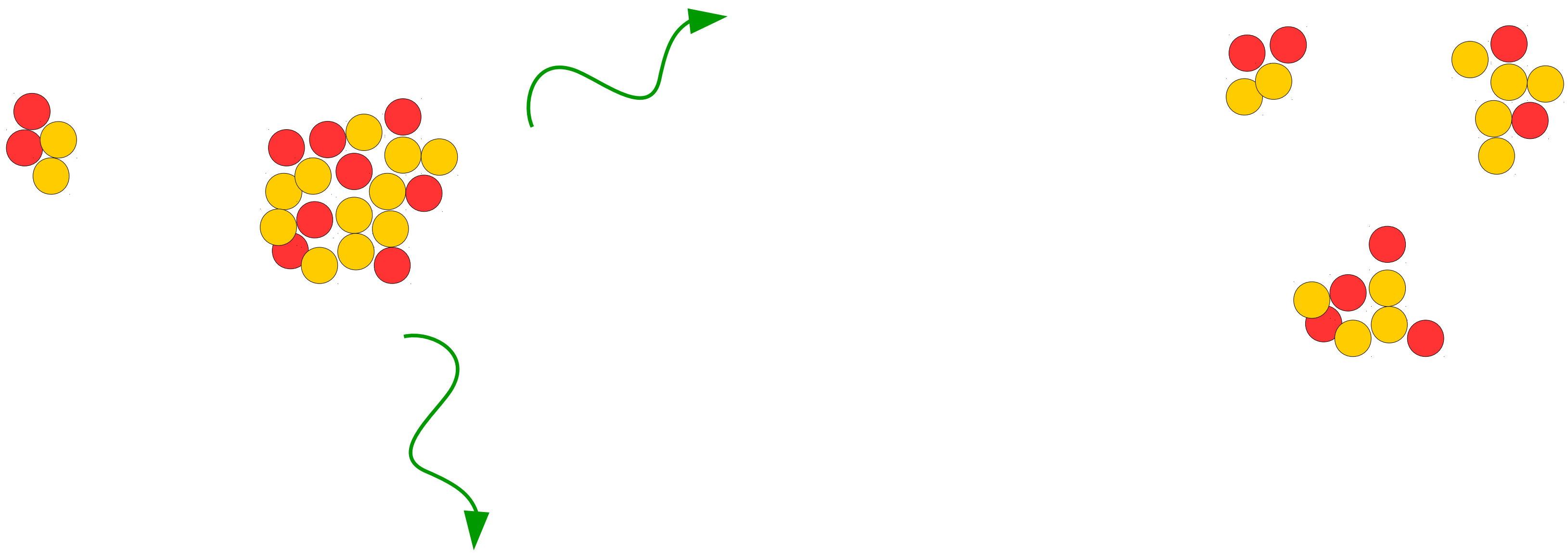
Hadron Production Models

- Step 2: Coalescence
  - The emitted particles are grouped to form higher mass states (d, t, He-3 etc.)



Hadron Production Models

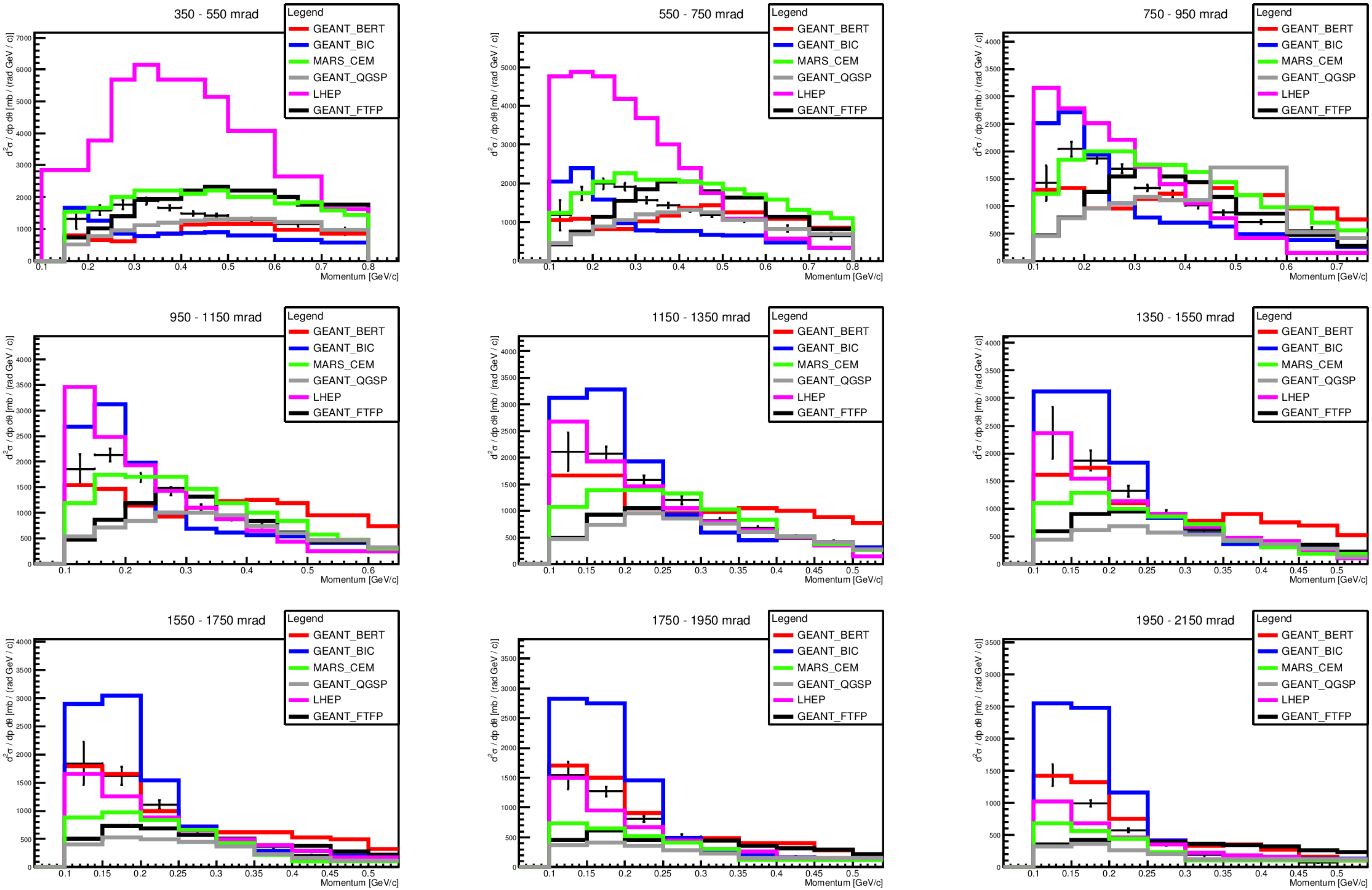
- Step 3: Relaxation/Break-Up
  - The remaining nucleus may be in an unstable state and so will relax back to the ground state
  - Or disintegrate



Hadron Production Models

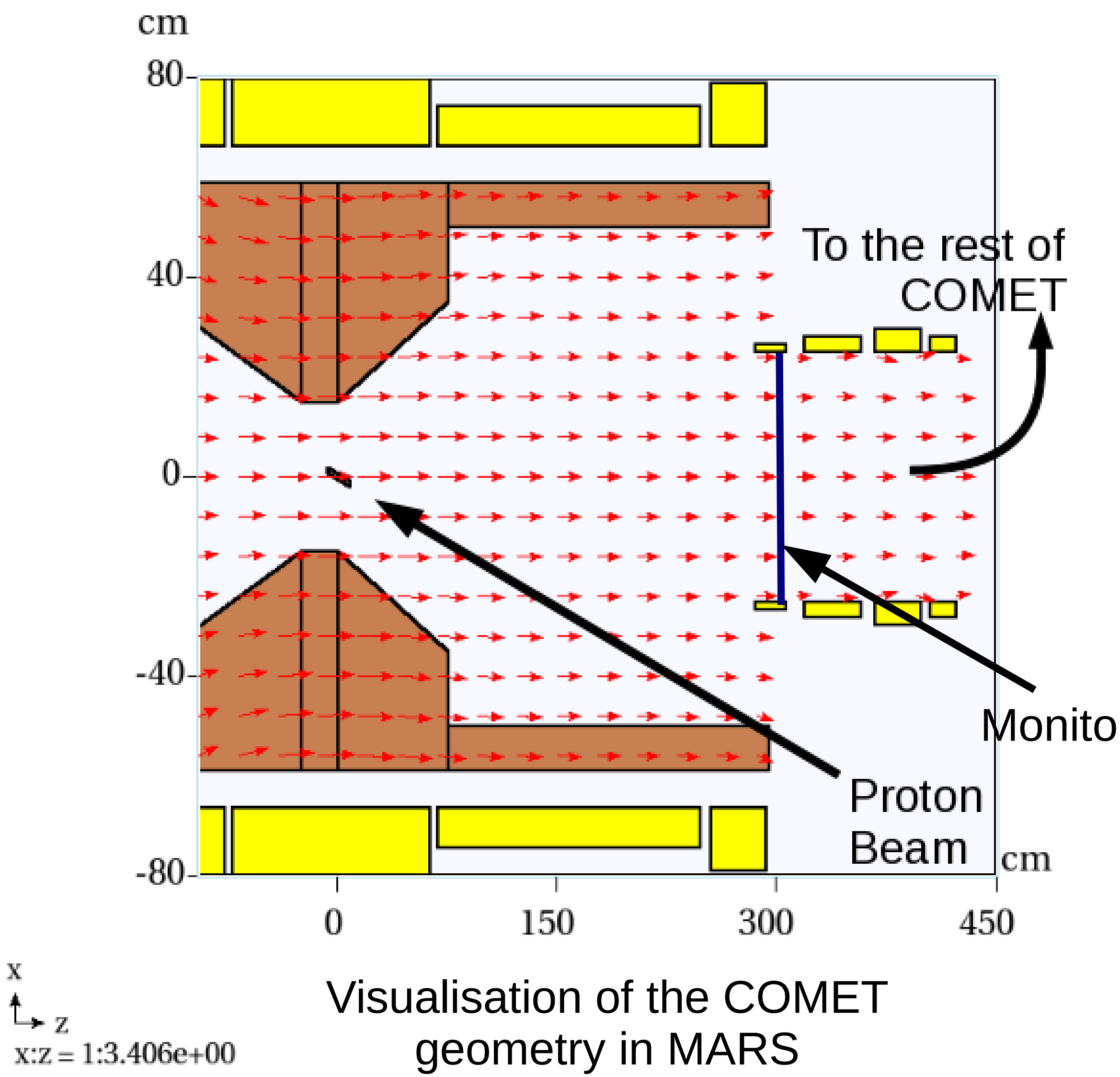
- Various programs with various models
  - GEANT4
    - QGSP_BERT, QGSP_BIC, FTFP_BERT etc.
  - MARS
    - CEM, LAQGSM
  - PHITS
    - INCL, Bertini, JAM

HARP


350 - 550 mrad
550 - 750 mrad
750 - 950 mrad
950 - 1150 mrad
1150 - 1350 mrad
1350 - 1550 mrad
1550 - 1750 mrad
1750 - 1950 mrad
1950 - 2150 mrad
Legend
GEANT_BERT
GEANT_BIC
MARS_CEM
GEANT_QGSP
LHEP
GEANT_FTFP
d²σ / dp dθ [mb / (rad GeV / c)]
Momentum [GeV/c]

Previous Work

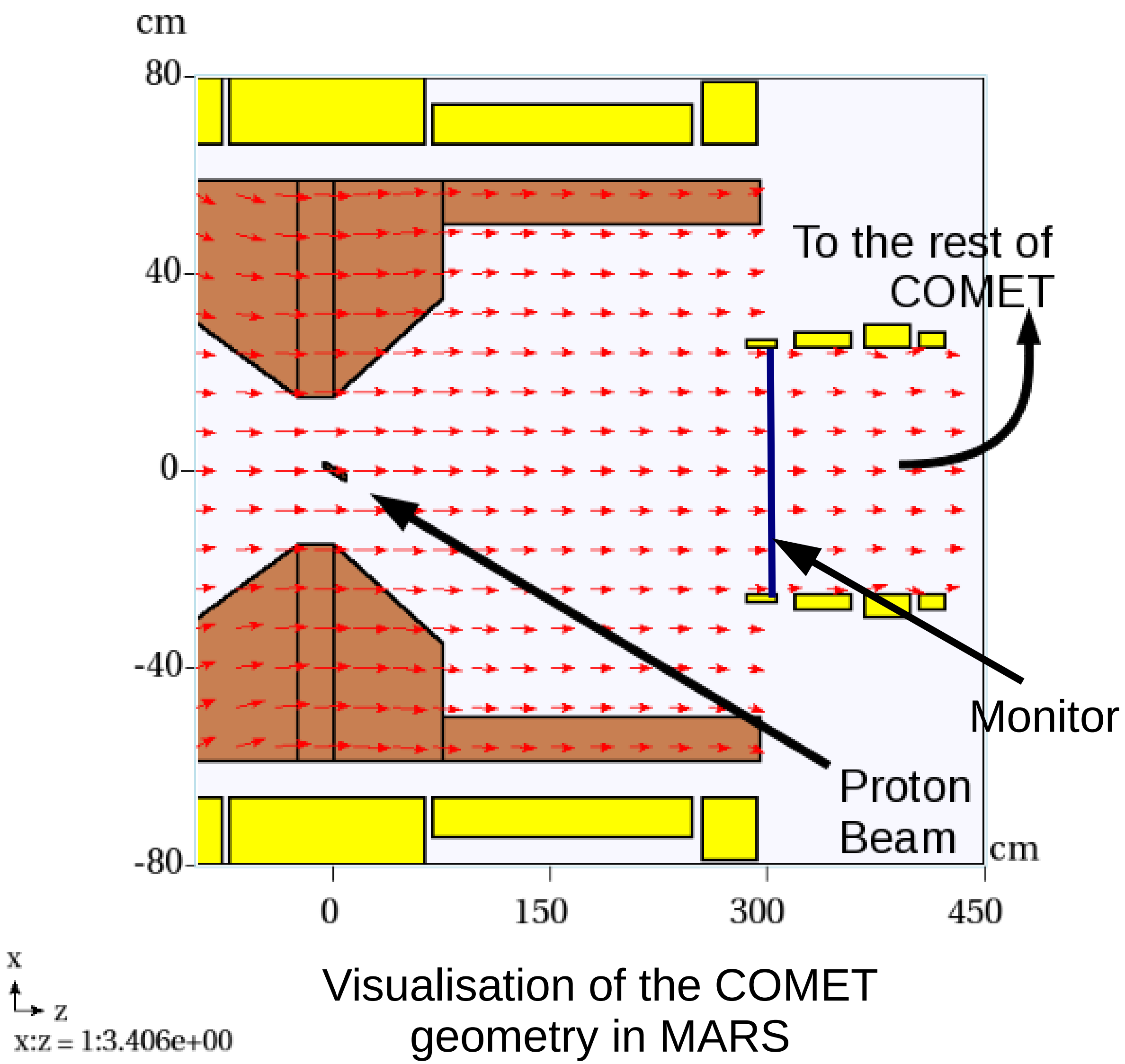
- Previously looked at hadron production uncertainty
- Used two MC programs
  - GEANT4
  - MARS
- And three modes from each have been simulated



Visualisation of the COMET geometry in MARS

Previous Work

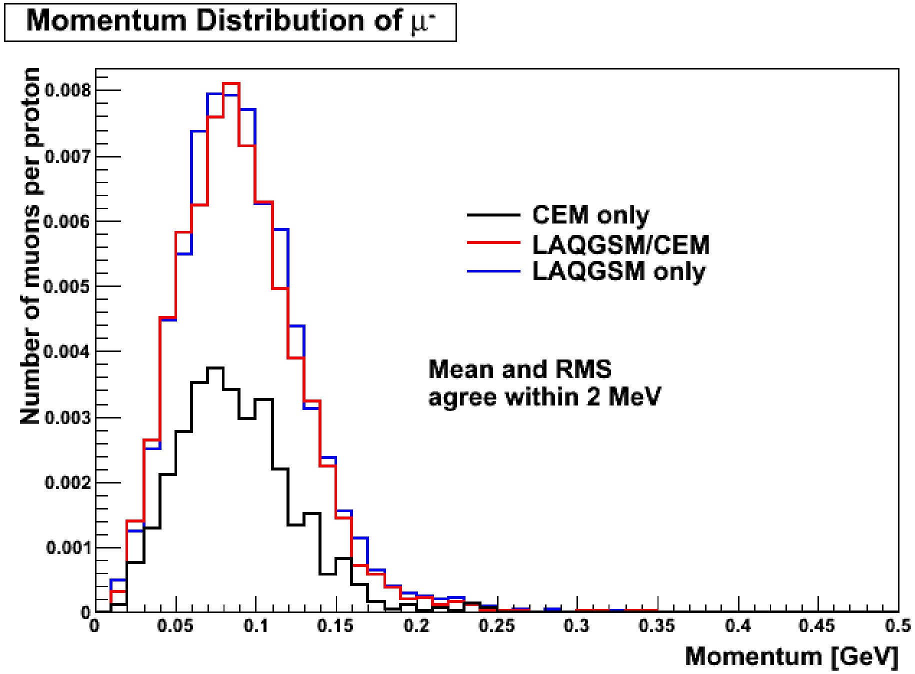
- Proton Beam
  - 8 GeV
  - 2mm x 2mm
- Target
  - Tungsten
  - 16cm long
- Magnetic Field
  - Calculated by Toshiba

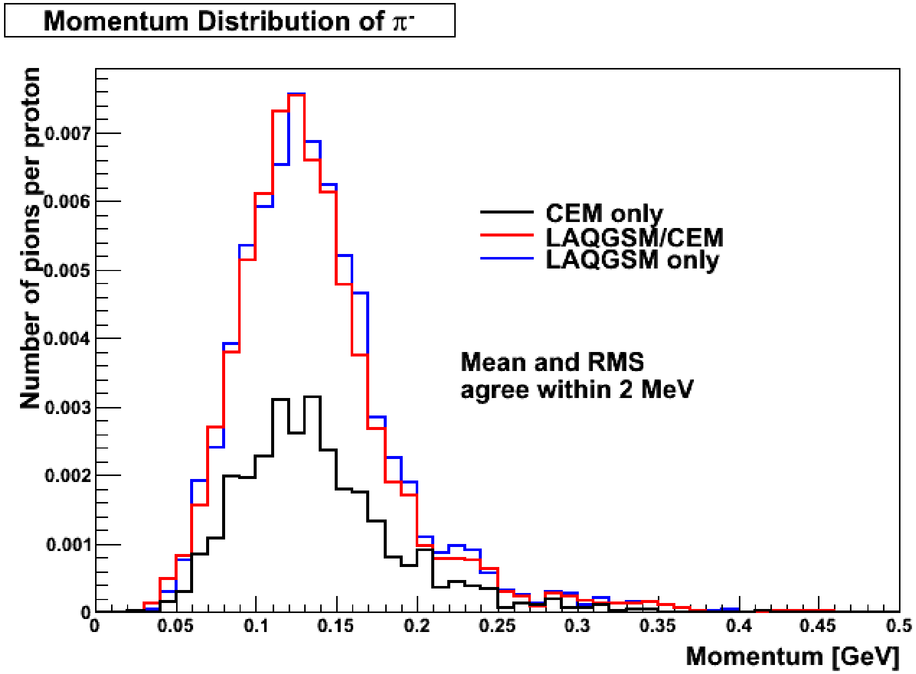


Visualisation of the COMET geometry in MARS

MARS Simulations

- Have simulated the pion production with the three different MARS models

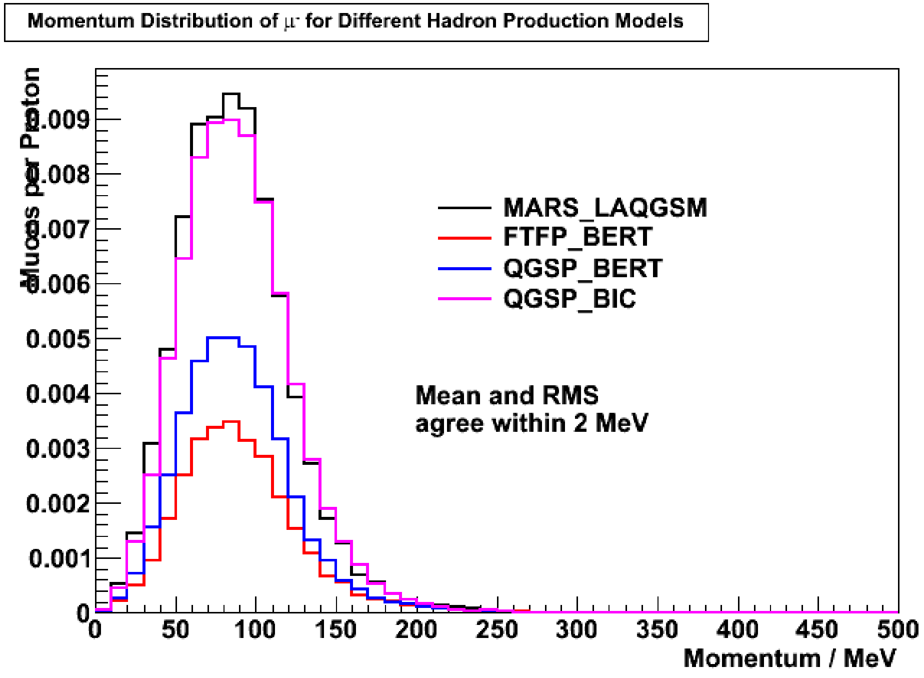


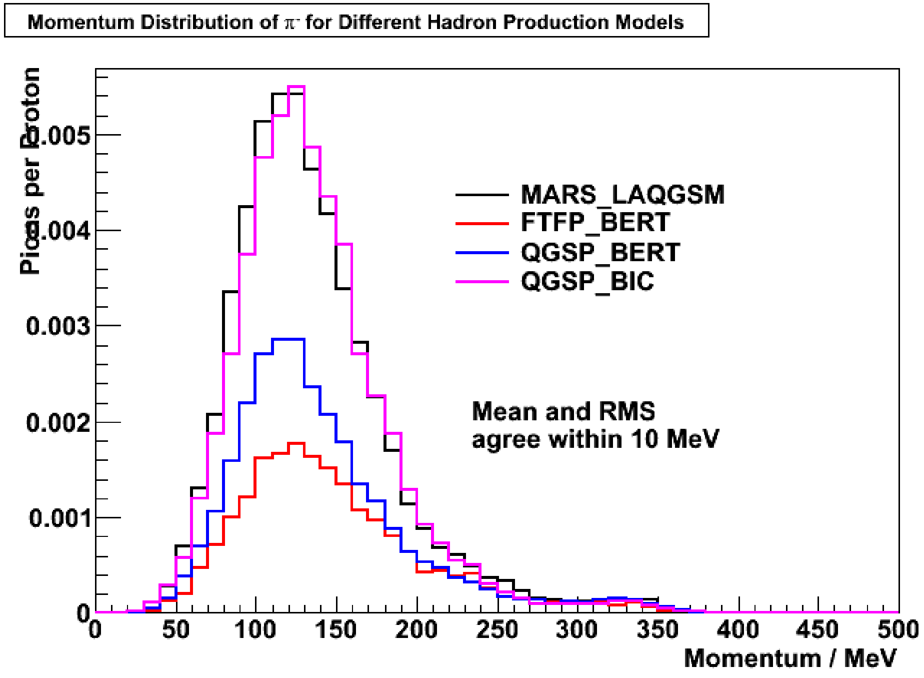


MARS(1510) Model	N(π- + μ-)/p
CEM only	0.061 ± 0.001
CEM/LAQGSM	0.138 ± 0.001
LAQGSM only	0.144 ± 0.001

GEANT4 Simulations

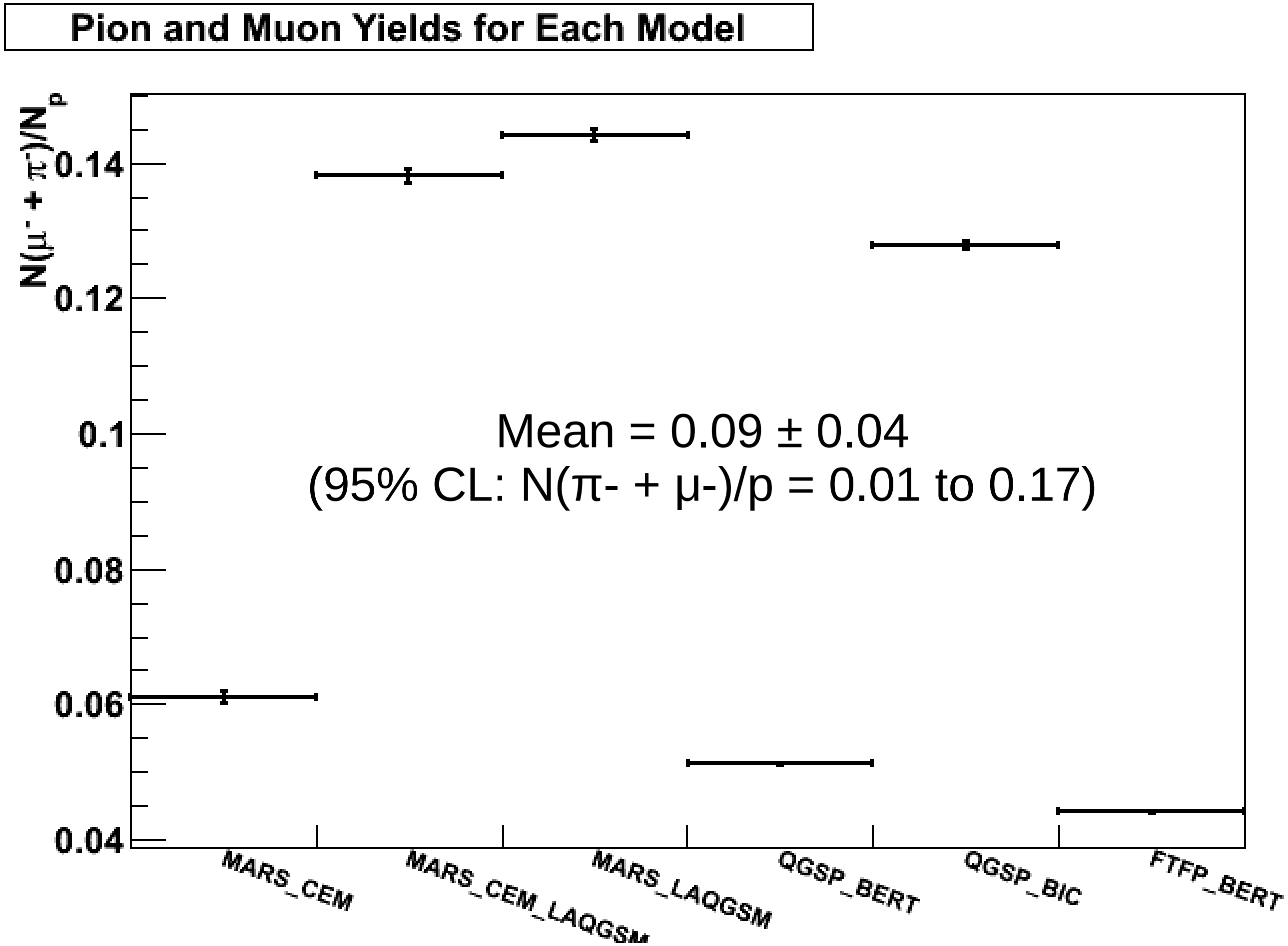
- Have also simulated with three different GEANT4 models





Geant4 Model	N(π- + μ-)/p
QGSP_BERT	0.0511 ± 0.0002
QGSP_BIC	0.1278 ± 0.0005
FTFP_BERT	0.0440 ± 0.0002

Pion and Muon Yields

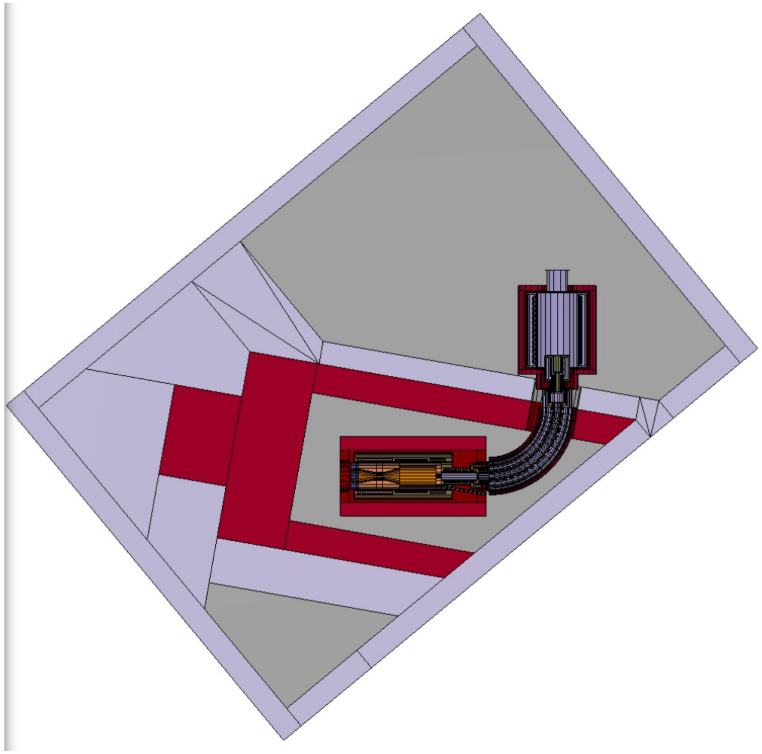


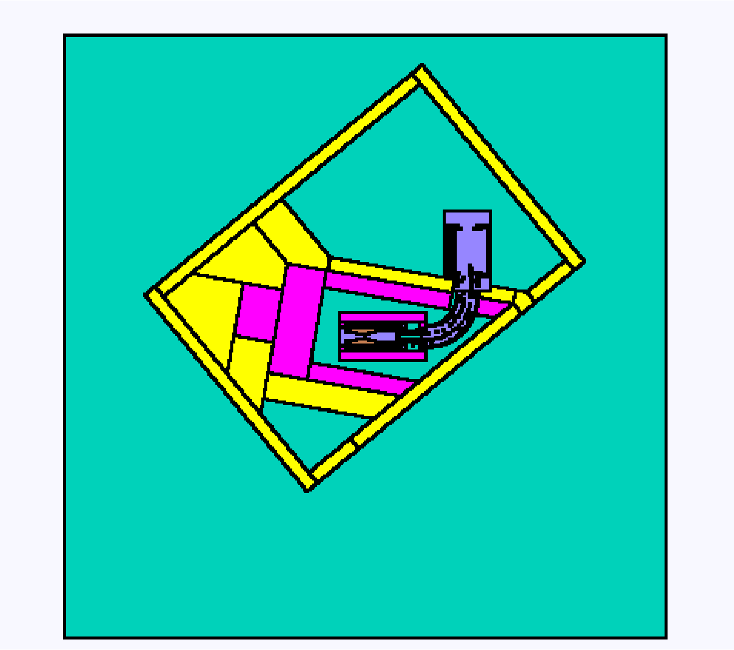
Current / Future Work

- Difficult to maintain consistency of geometry/magnetic field etc. between programs
- Solution: ICEDUST
  - Create geometry once and use everywhere
  - Unify output formats to read out and in to any program
  - Use the same magnetic fieldmaps
- Packages
  - SimG4, SimMARS, SimPHITS

ICEDUST Geometry

- Create in SimG4
  - Can be used in SimMARS directly
  - Planning a converter for SimPHITS





RooTracker

- Heavily based on ND280
  - Removed some neutrino-specific fields
- Readout performed at planes
  - By default in SimMARS
  - Currently in development for SimG4
  - A converter script for SimPHITS

```
static TBits*       brEvtFlags = 0; // Generator-specific eve
static TObjString* brEvtCode  = 0; // Generator-specific eve
static int          brEvtNum;        // Event number
static double       brEvtXSec;       // Cross section for sele
static double       brEvtDXSec;      // Cross section for sele
static double       brEvtWght;       // Weight of the event
static double       brEvtProb;       // Probability for that e
static double       brEvtVtx[4];     // Event vertex position
static int          brStdHepN;       // Number of particles in
// std-hep like particle array
static int          brStdHepPdg    [kNPmax];       // Pdg codes
static int          brStdHepStatus[kNPmax];       // Generator-
static int          brStdHepRescat[kNPmax];       // Hadron tra
static double       brStdHepX4     [kNPmax][4];   // 4-x (x, y,
static double       brStdHepP4     [kNPmax][4];   // 4-p (px,py
static double       brStdHepPolz   [kNPmax][3];   // Polarizati
static int          brStdHepFd     [kNPmax];       // First daug
static int          brStdHepLd     [kNPmax];       // Last  daug
static int          brStdHepFm     [kNPmax];       // First moth
static int          brStdHepLm     [kNPmax];       // Last  moth

// Added for COMET
static double       brWeight       [kNPmax];       // weight of
static TObjArray*  brMonitorName = new TObjArray();     // t
```

Fieldmaps

- All packages use the same fieldmaps
  - The same code is available for SimMARS and SimPHITS
  - There is also the oaEMField package which we will migrate to

Conclusion

- Simulation of the muon beam is very important
- The characteristics of the beam can depend on the production model used
- Work is ongoing to try and unify as many of these models as possible

Thanks for Listening
Any Questions?