Hadron Induced Reactions

Background Calculations with FLUKA

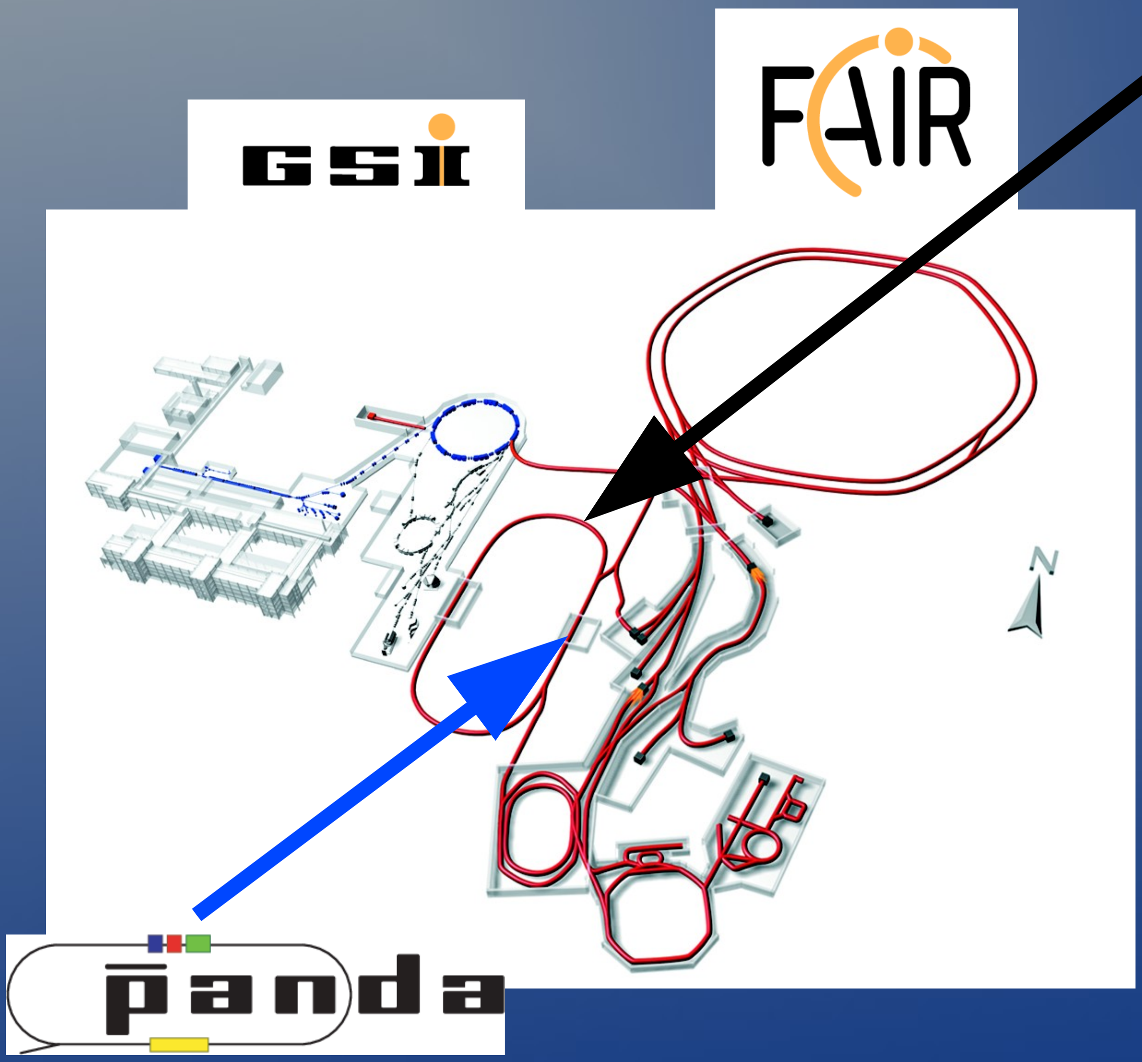
Olaf Hartmann
Stefan-Meyer-Institute for Subatomic Physics
Austrian Academy of Sciences
Vienna, Austria

FLUKA Workshop, Ericeira/Portugal, October 4th-8th, 2010

Overview

- Motivation – Physics Case
  - PANDA@FAIR
- Implementation with FLUKA
  - ROOT output files (FairRoot, PandaRoot)
- Comparison with other event generators
- Discussion, Outlook
  - Porting Geometry
  - Detector Radiation Map

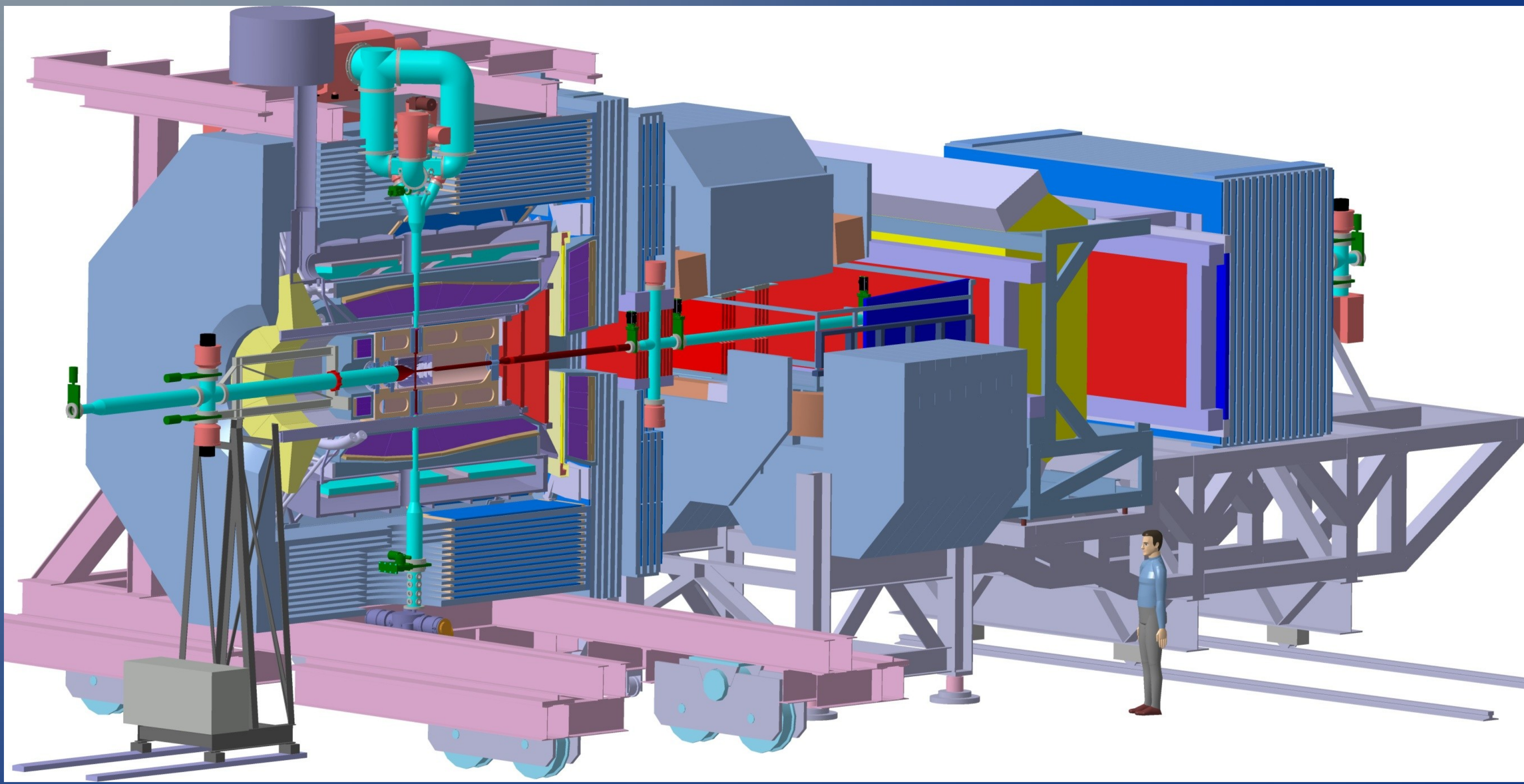
Antiprotons at FAIR-HESR



- Antiproton ring HESR
- Injection at 3.5 GeV/c
- 1.5 – 15 GeV/c (0.83 – 14 GeV)
- 10^{10} to 10^{11} stored particles
- bunched beam
- high resolution mode
  - $2 \cdot 10^{31} cm^{-2} s^{-1}$ (10^{10} pbar)
  - $\sigma_p/p \leq 2 \cdot 10^{-5}$
  - $p \leq 9$ GeV/c, e^- cooling
- high luminosity mode
  - $2 \cdot 10^{32} cm^{-2} s^{-1}$ (10^{11} pbar)
  - $\sigma_p/p \sim 10^{-4}$
  - $p \leq 15$ GeV/c, stochastic cooling

FAIR officially started on monday this week!

www-panda.gsi.de



Internal Target (Pellets, Cluster Jet, ...)

Solenoid
Dipole

PANDA Physics Program

- Hadron Spectroscopy
  - Charmonium states, Open Charm
  - Exotics (Glueballs, Hybrids)
  - Baryon-Antibaryon
- Nucleon Structure ($\gamma\gamma$)

pbar - p

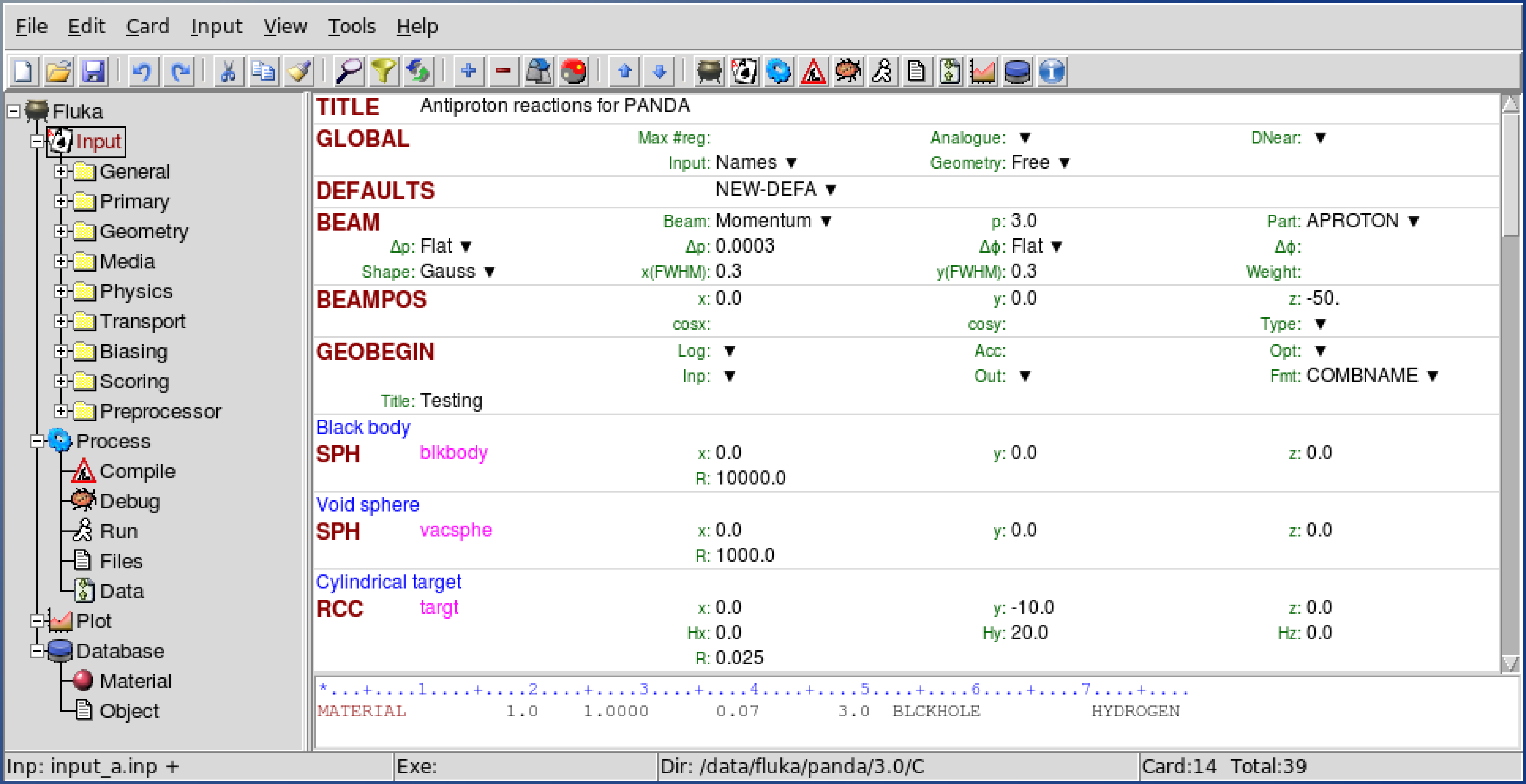
- In-Medium Effects
- S=-1, S=-2 Hypernuclei
  - keV γ spectroscopy

pbar - A

Implementation

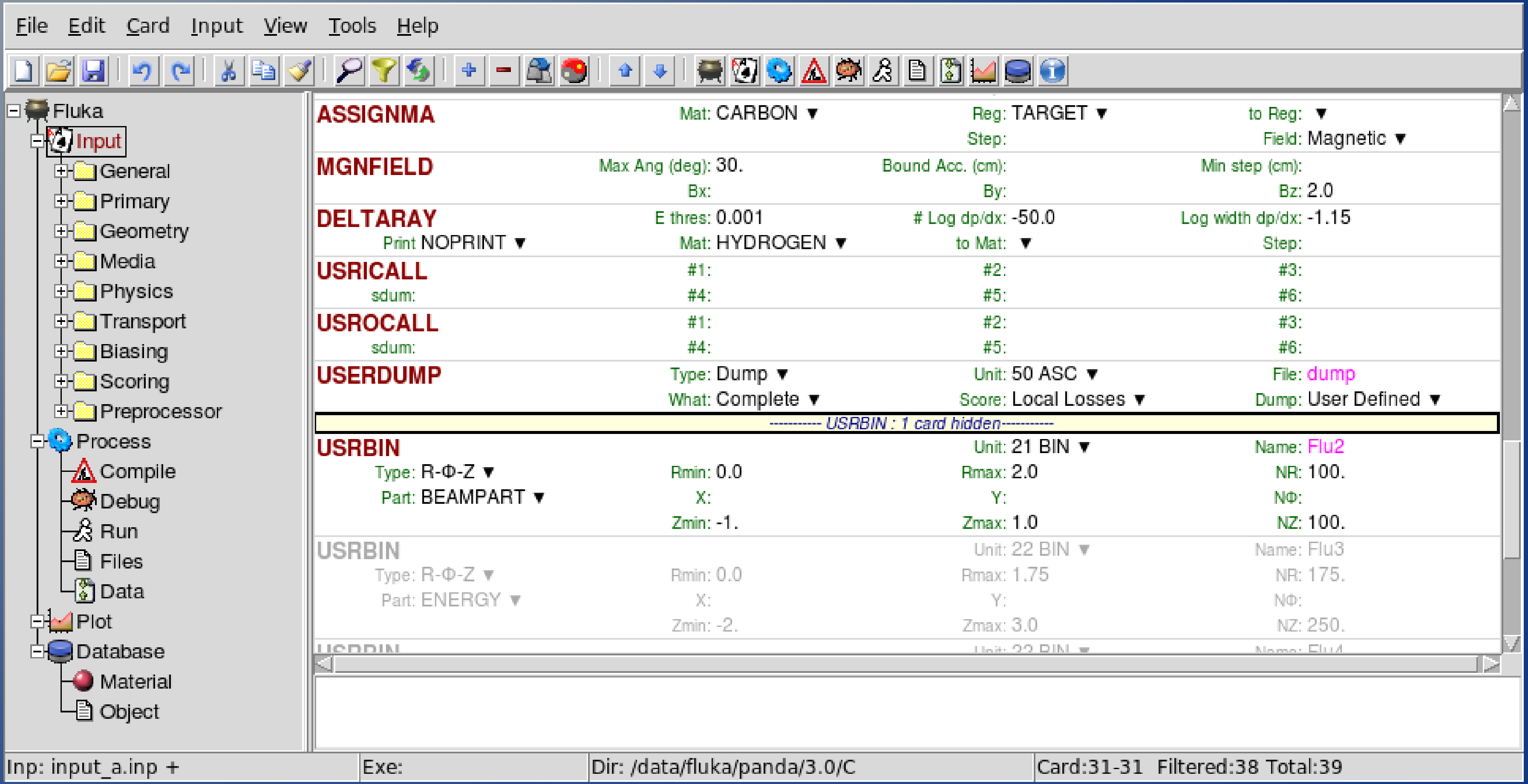
- Starting point: using FLUKA as “event generator” for generic pbar-p/pbar-A events
- Interface: root files (example from fluka homepage)
- mgdraw.f → BXDRAW
    - Register boundary-crossing tracks which emerge from the target
    - Collect them in a root tree (ascii file)
    - Read output into PandaRoot

FLUKA input

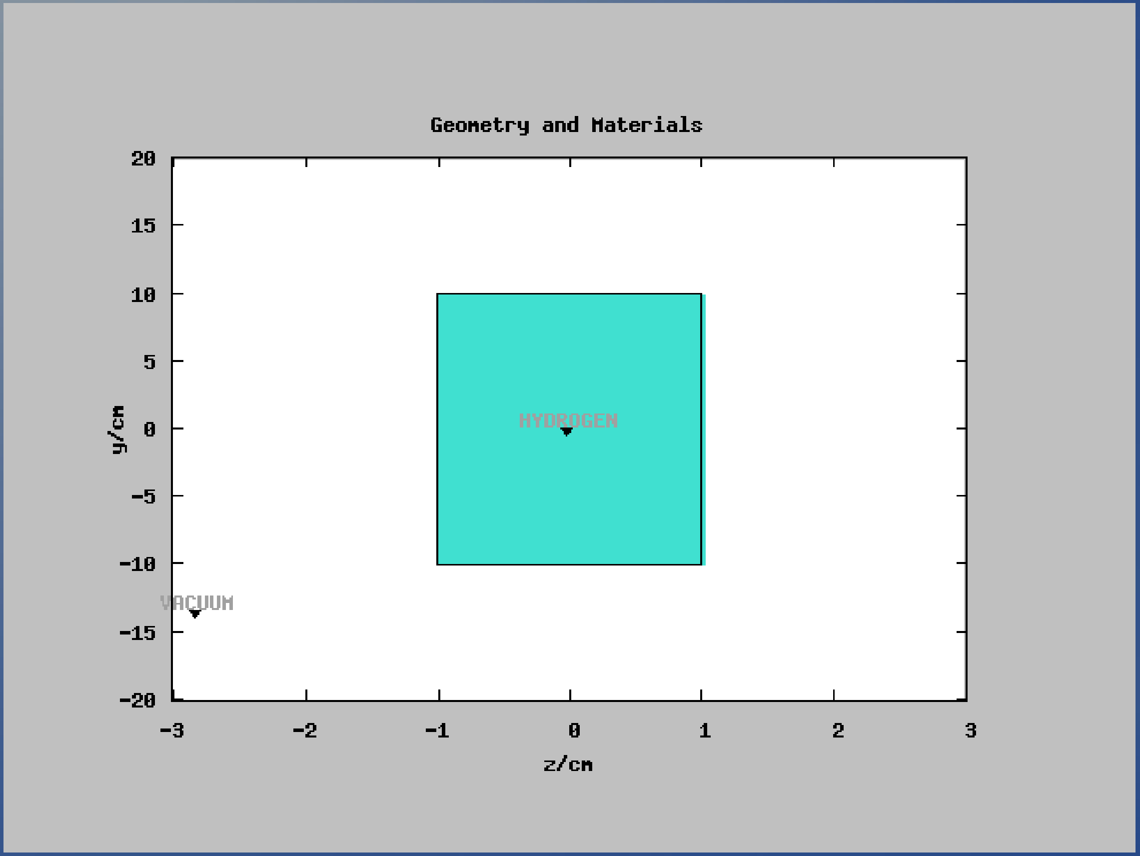


Antiproton beam $\Delta p/p = 10^{-4}$, FWHM = 3 mm

FLUKA input


File Edit Card Input View Tools Help
Fluka
Input
General
Primary
Geometry
Media
Physics
Transport
Biasing
Scoring
Preprocessor
Process
Compile
Debug
Run
Files
Data
Plot
Database
Material
Object
ASSIGNMA Mat: CARBON Reg: TARGET to Reg:
Step: Field: Magnetic
MGNFIELD Max Ang (deg): 30. Bound Acc. (cm): Min step (cm):
Bx: By: Bz: 2.0
DELTARAY E thres: 0.001 # Log dp/dx: -50.0 Log width dp/dx: -1.15
Print NOPRINT Mat: HYDROGEN to Mat: Step:
USRICALL #1: #2: #3:
sdum: #4: #5: #6:
USROCALL #1: #2: #3:
sdum: #4: #5: #6:
USERDUMP Type: Dump Unit: 50 ASC File: dump
What: Complete Score: Local Losses Dump: User Defined
---------- USRBIN : 1 card hidden----------
USRBIN Unit: 21 BIN Name: Flu2
Type: R-Φ-Z Rmin: 0.0 Rmax: 2.0 NR: 100.
Part: BEAMPART X: Y: NΦ:
Zmin: -1. Zmax: 1.0 NZ: 100.
USRBIN Unit: 22 BIN Name: Flu3
Type: R-Φ-Z Rmin: 0.0 Rmax: 1.75 NR: 175.
Part: ENERGY X: Y: NΦ:
Zmin: -2. Zmax: 3.0 NZ: 250.
Inp: input_a.inp +
Exe:
Dir: /data/fluka/panda/3.0/C
Card:31-31 Filtered:38 Total:39

Simple Geometry



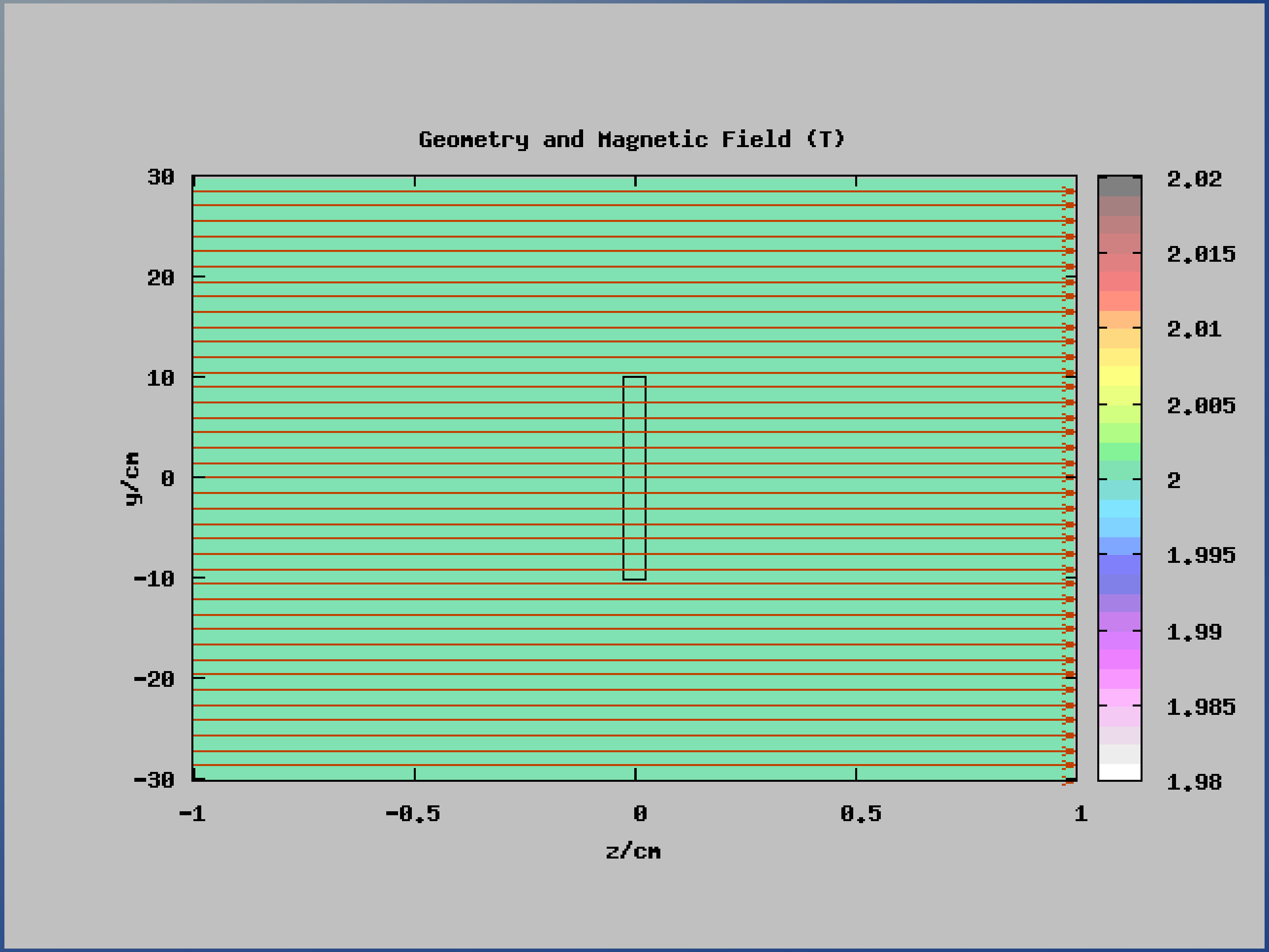
Hydrogen target:

Gas volume
d = 2 cm
h = 20 cm

Nuclear targets:

“wire piece”
d = 500 µm
h = 20 cm

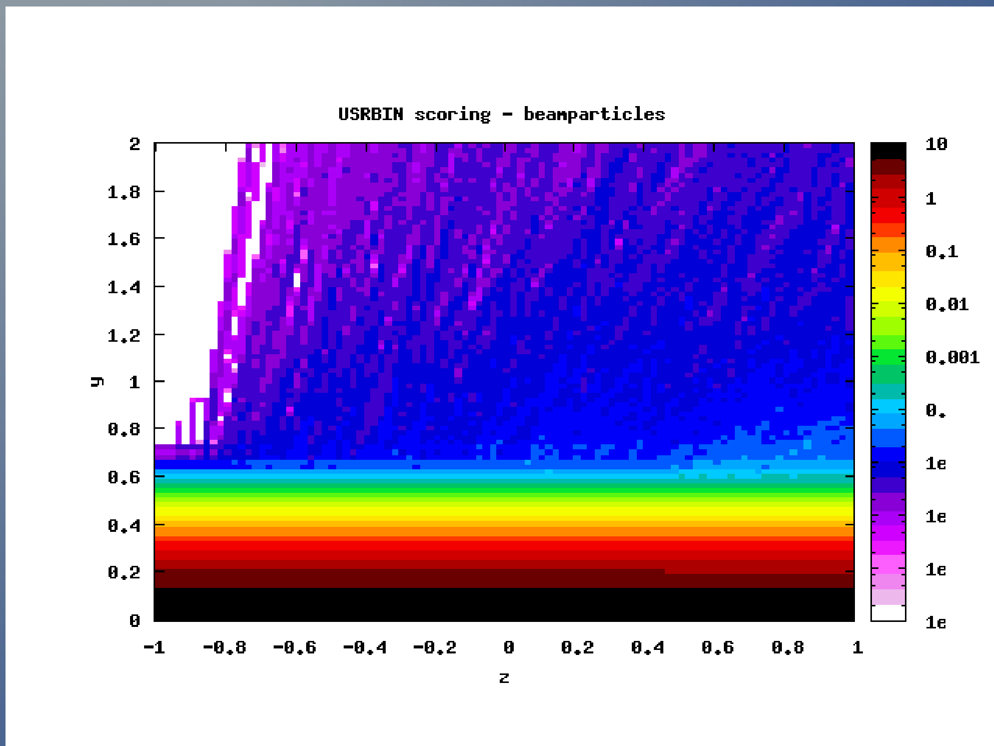
Magnetic Field

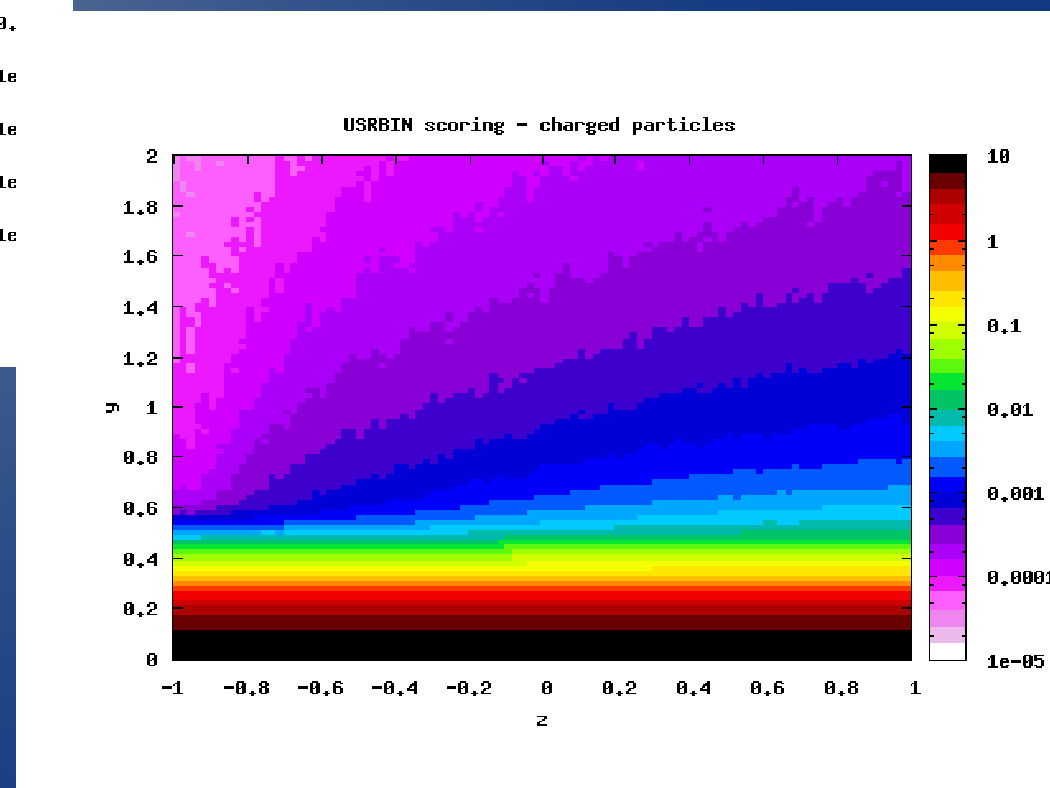


B=(0,0,2T)

USRBIN

r(z) charged particles





r(z) beamparticles

MGDRAW

File Edit View Cmds Tools Options Buffers Help

Open Dired Save Print Cut Copy Paste Undo Spell Replace Mail Info Compile Debug News

mgdraw.f

```
      ENTRY BXDRAW ( ICODE, MREG, NEWREG, XSCO, YSCO, ZSCO )
      if(JTRACK.LE.0)RETURN
      test_cross = mod(icode,10)
      IF(test_cross.eq.9) then
         CALL GEOR2N ( MREG,   MRGNAM, IERR1 )
         CALL GEOR2N ( NEWREG, NRGNAM, IERR2 )
         IF(IERR1 .NE. 0 .OR. IERR2 .NE. 0)
     +       STOP "Error in name conversion"

c     -onh- identify regions by name
         IF((MRGNAM .EQ. "TARGET" .OR. MRGNAM .EQ. "BPIPE")
     +        .AND.
     +        (NRGNAM .EQ. "VOID"))
     +       THEN

           IF(ETRACK.GE.AM(JTRACK).AND.LTRACK.GT.1) THEN

             if(noftracks.eq.0) EVENTCOUNT=EVENTCOUNT+1
             noftracks=noftracks+1
             if(noftracks.gt.maxtrack)then
                goto 888
             endif

             fpid = Jtrack

             call f2g3(fpid,g3pid)
             call f2pdg(fpid,pdgcode)

             energy(noftracks) = Etrack
             px(noftracks)     = Cxtrck*Ptrack
             py(noftracks)     = Cytrck*Ptrack
             pz(noftracks)     = Cztrck*Ptrack
             pid(noftracks)    = pdgcode
```

UTF8--**-L141 C0 28%   mgdraw.f (...me/olaf/fluka/fluroot)   (Fortran Font)------

boundary crossing from the target to the outside

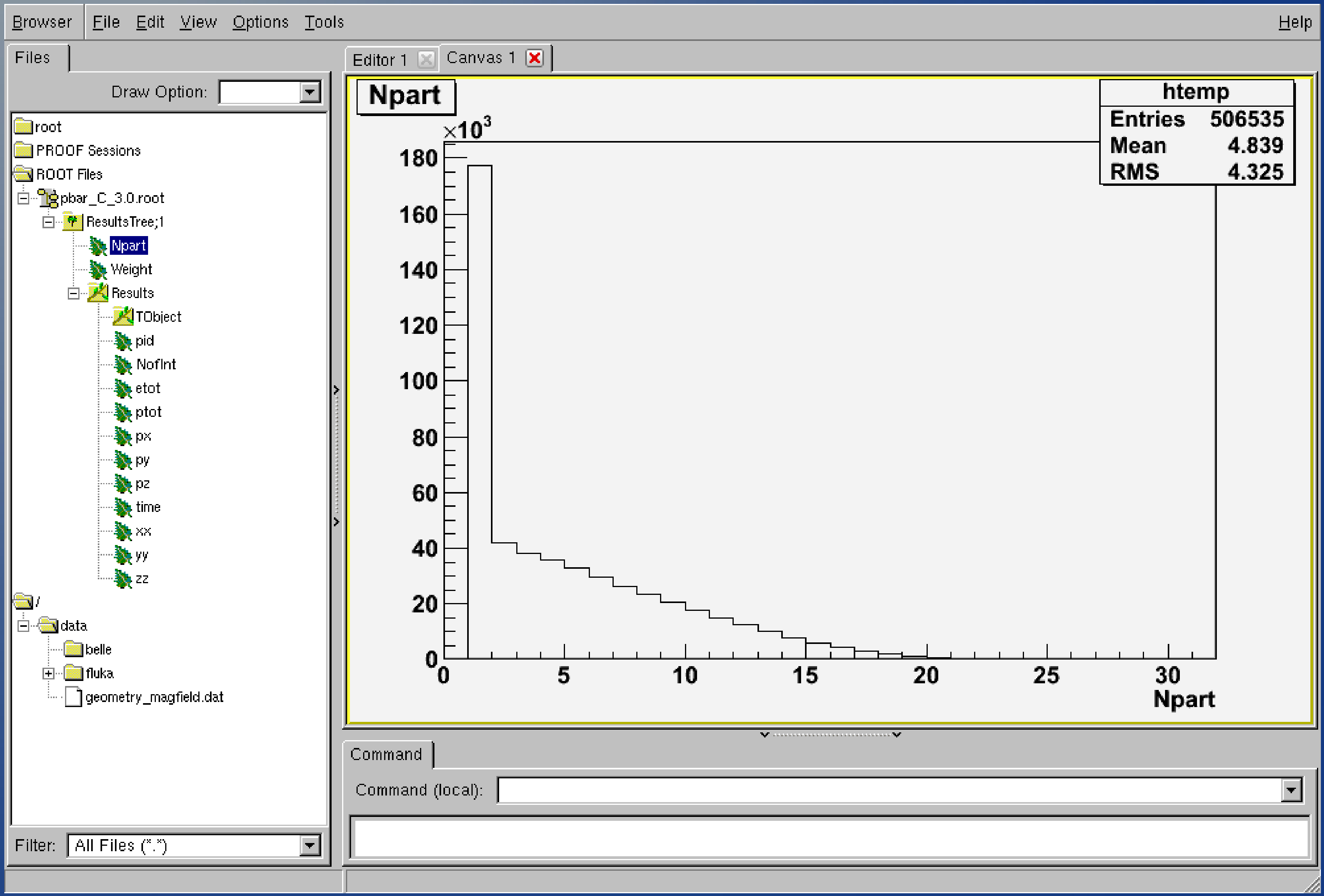
energy > 0

at least one interaction

pid conversion to PDG codes

copy to arrays, later filled into ROOT Tree

The ROOT File



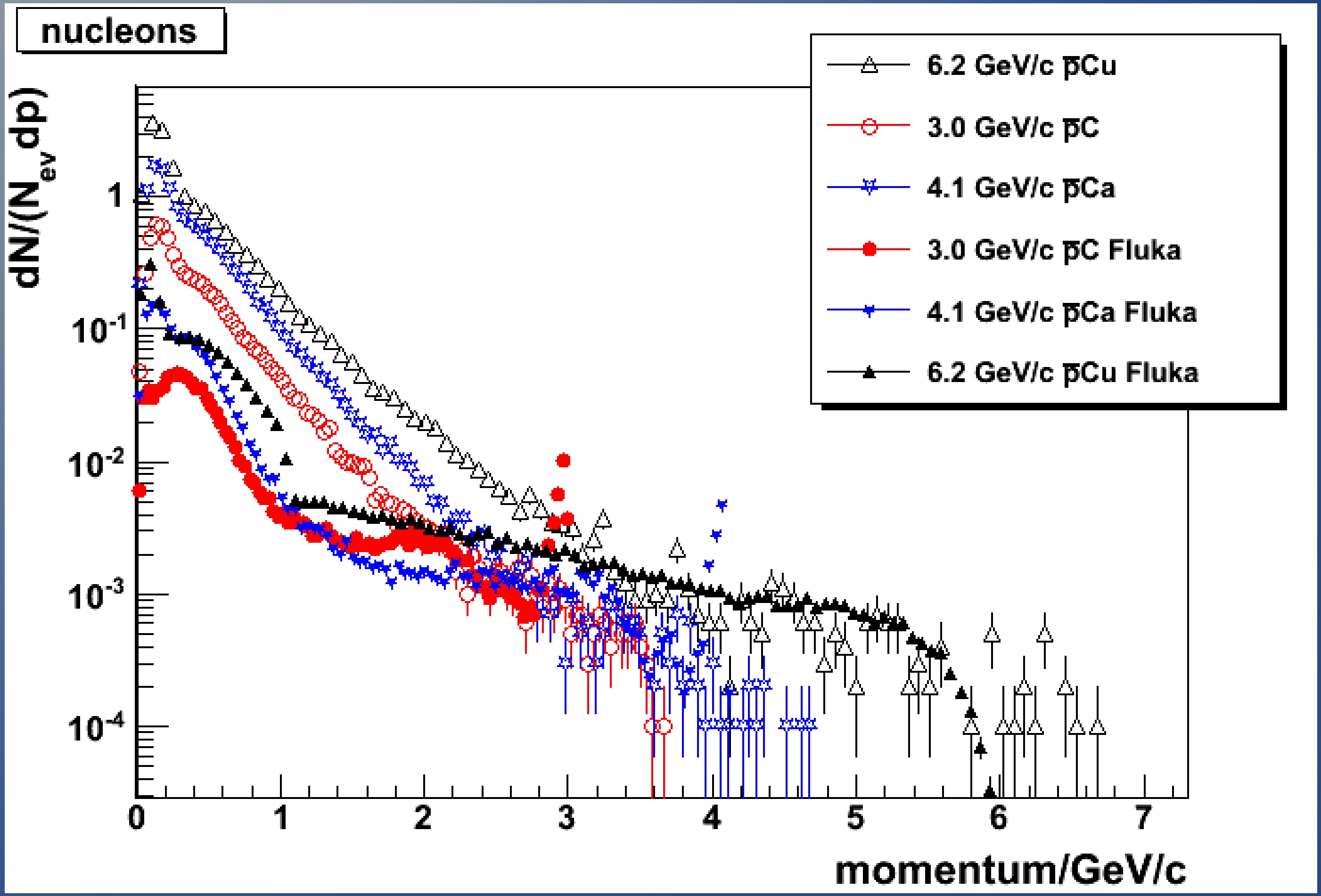
Encountered Problems

- In mgdraw.f
JTRACK has to be >0. In rare cases, fragments with JTRACK<0 occur – and cause a crash when accessing AM(JTRACK).
- Particles curling in the magnetic field
The same particle crosses the region boundary many times → particle array overflow, weird output written to log file. Solution: magnetic field outside switched off
- LTRACK>1 – do not count beam particles which did not interact (majority)

Comparison with other Generators

- Generic background from pbar-p reactions: Dual Parton Model (DPM)
  - Elastic and inelastic scattering
  - Fast calculation of large no. of events
- pbar-A reactions: UrQMD + SMM
  SMM – Statistical Multifragmentation Model
  - SMM works on baryons from UrQMD
  - Calculation takes long (10 kevents$\sim$6 h)
- Note: 1:1 comparison difficult – no “target” in DPM/UrQMD

Comparison: pbar A

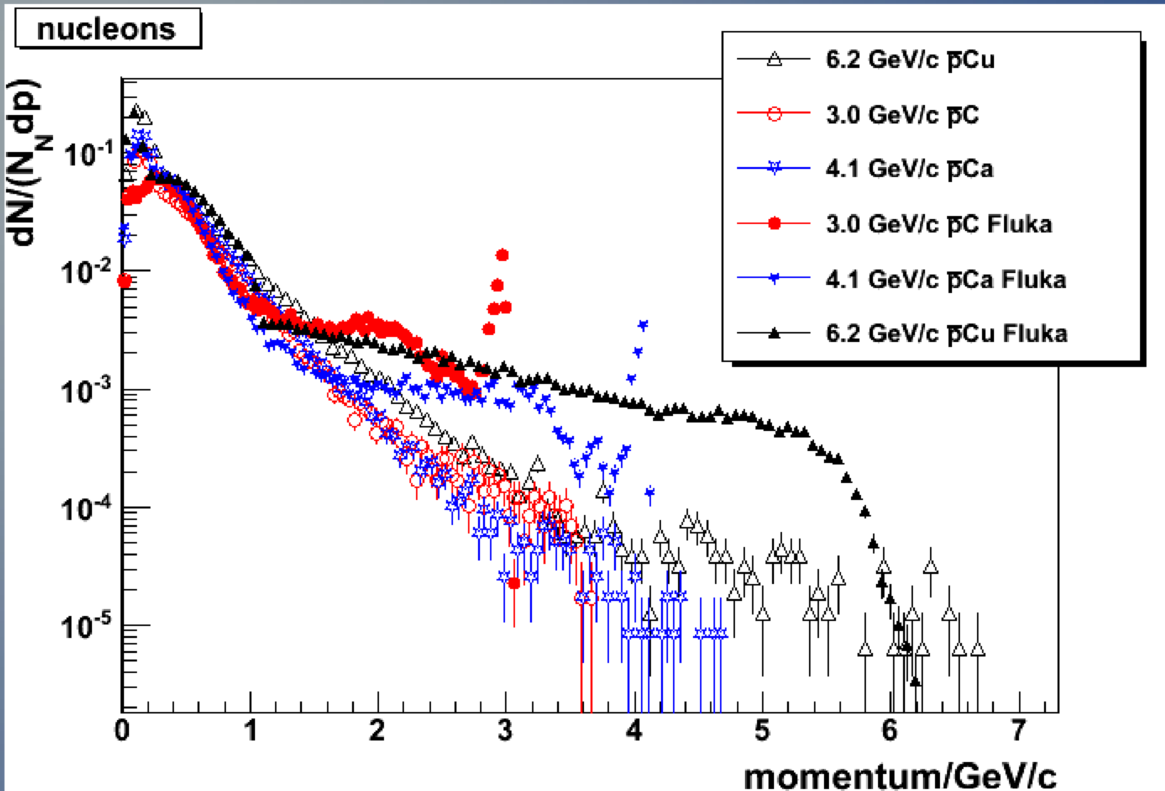


normalization:
no. of events

Peaks around
Beam momenta:

Only in Fluka
at 3.0/4.1 GeV/c

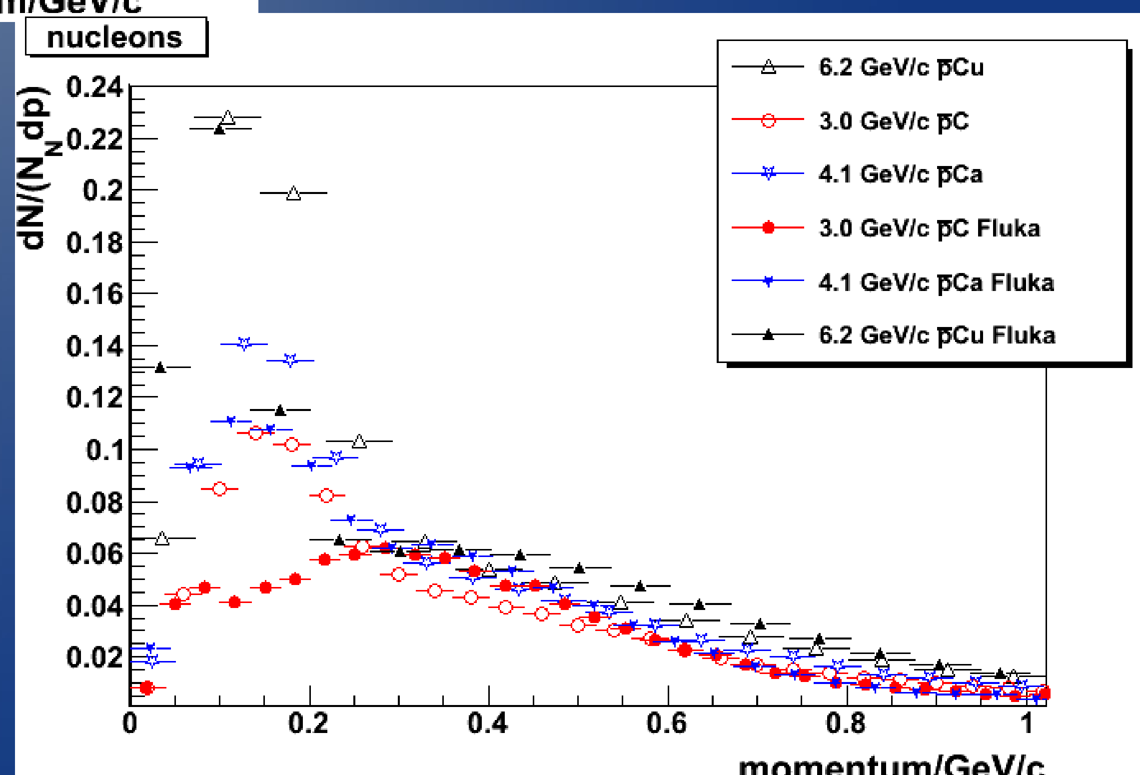
Used target materials: ^{12}C, ^{40}Ca, $^{(63)}Cu$
Beam momenta: 3.0 GeV/c ($\Xi^+\Xi^-$), 4.1 GeV/c (J/Ψ), 6.2 GeV/c (Ψ')



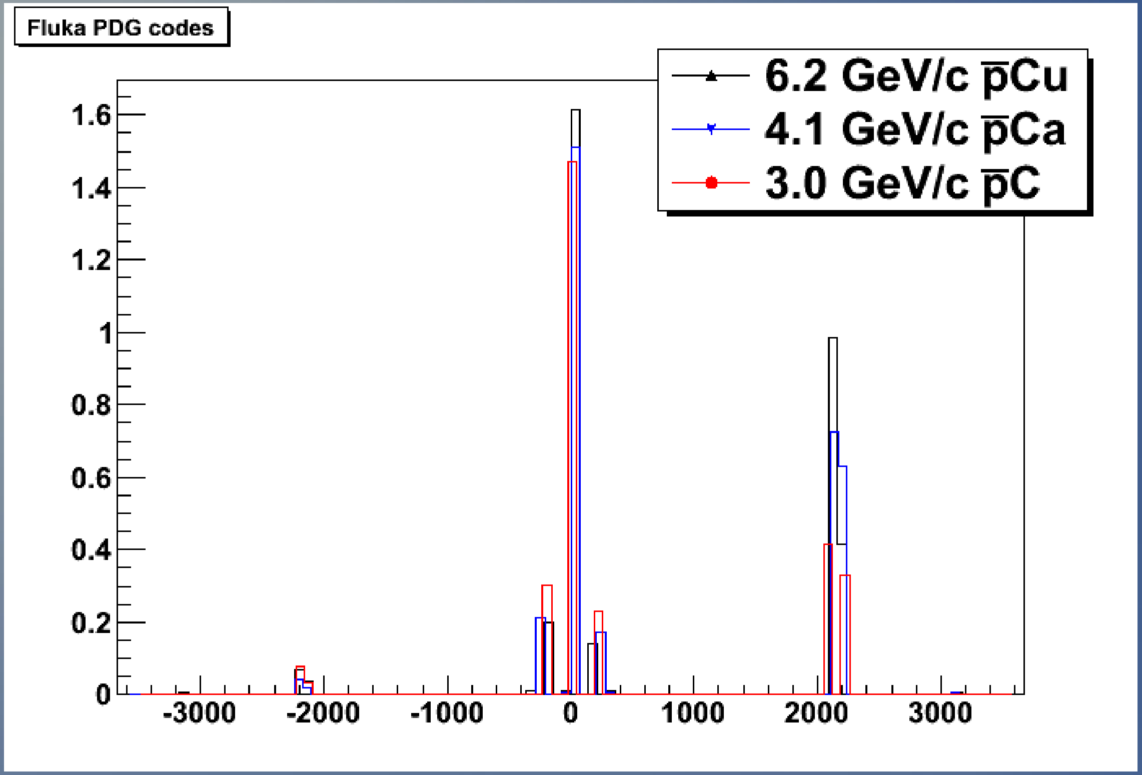
Different normalization:
number of nucleons (n+p)

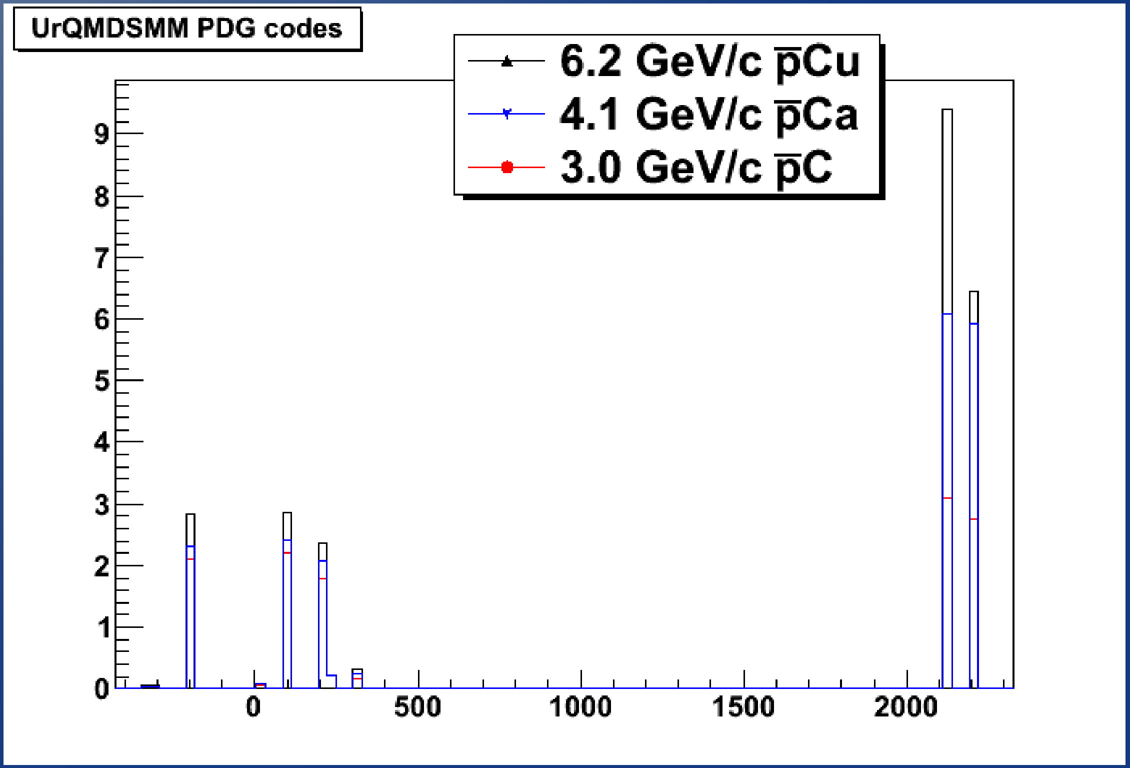
Agreement for .3<p<1.0

Striking difference:
3.0 GeV/c

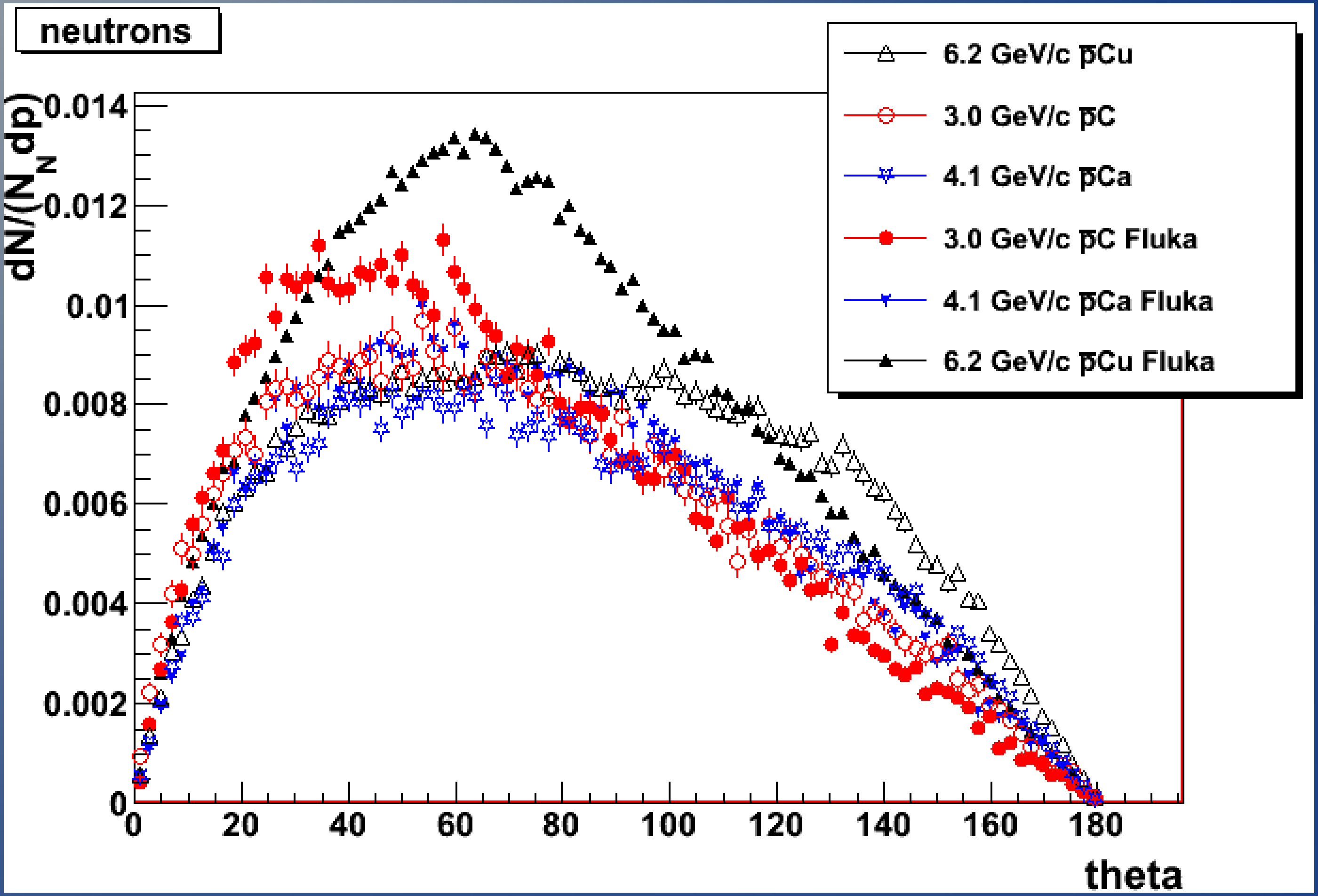


PDG Code distributions

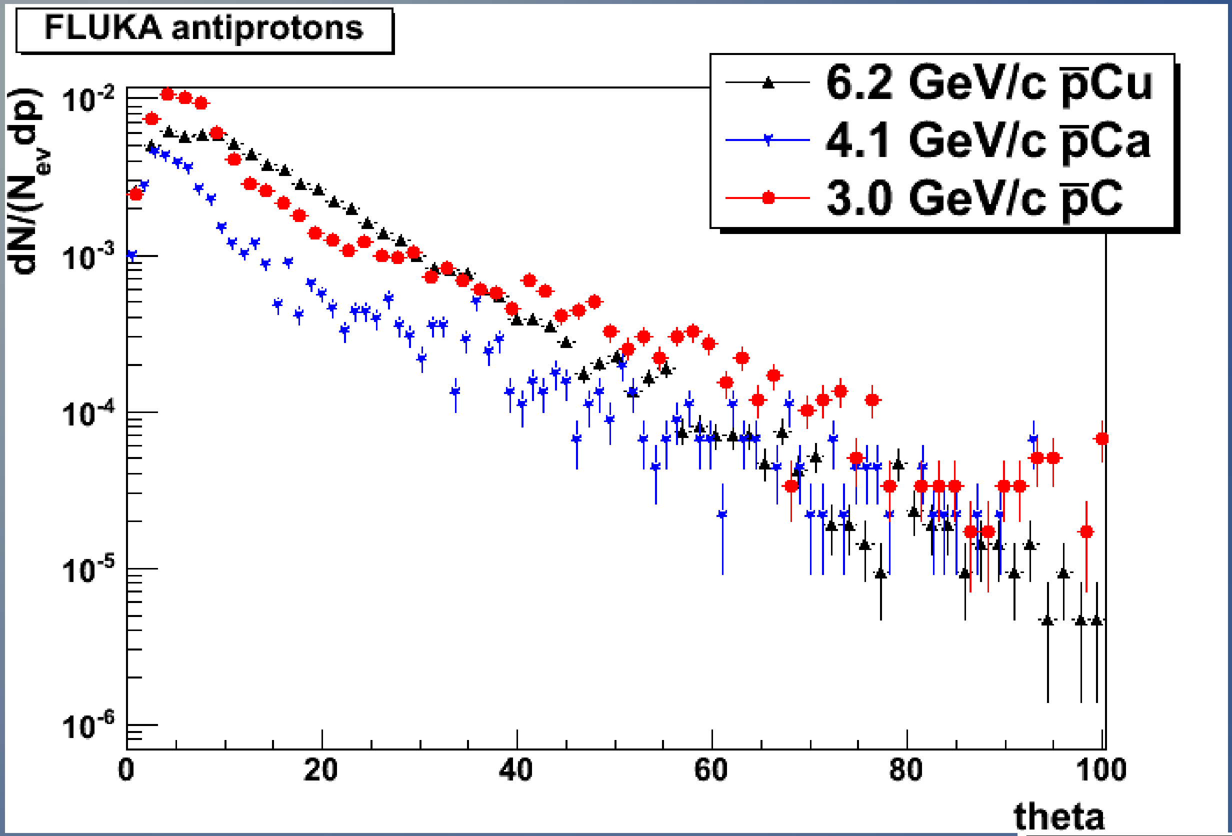




UrQMD:
- no antibaryons
- few electrons
- π^0 not decayed



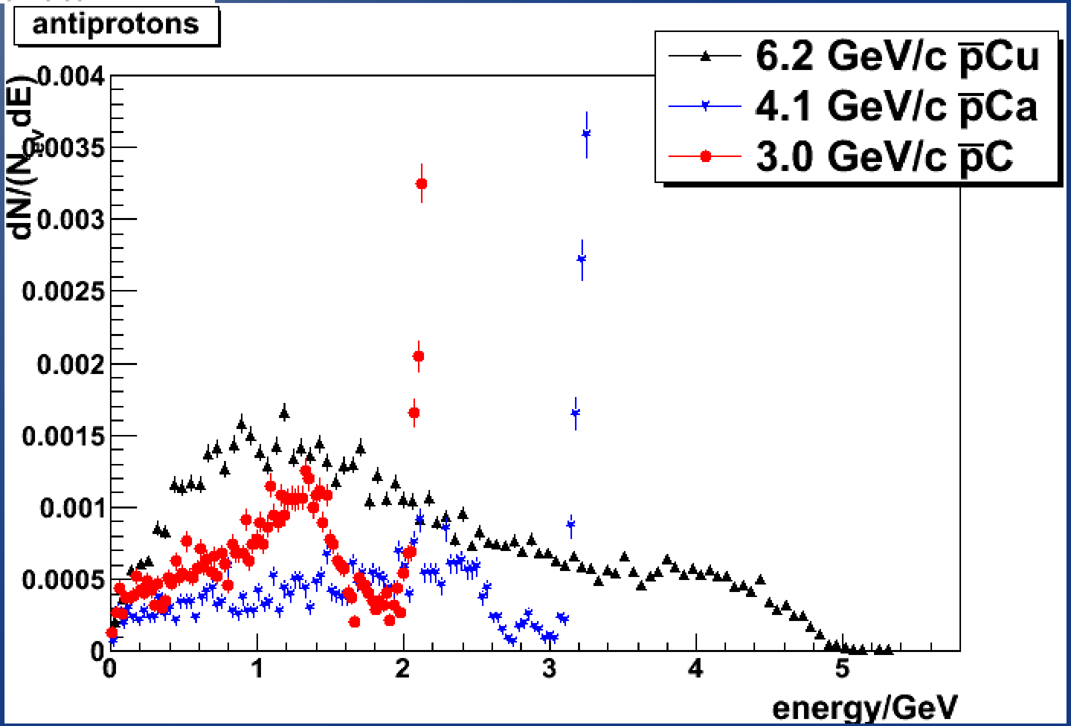
Best agreement: 4.1 GeV/c pbar on ^{40}Ca



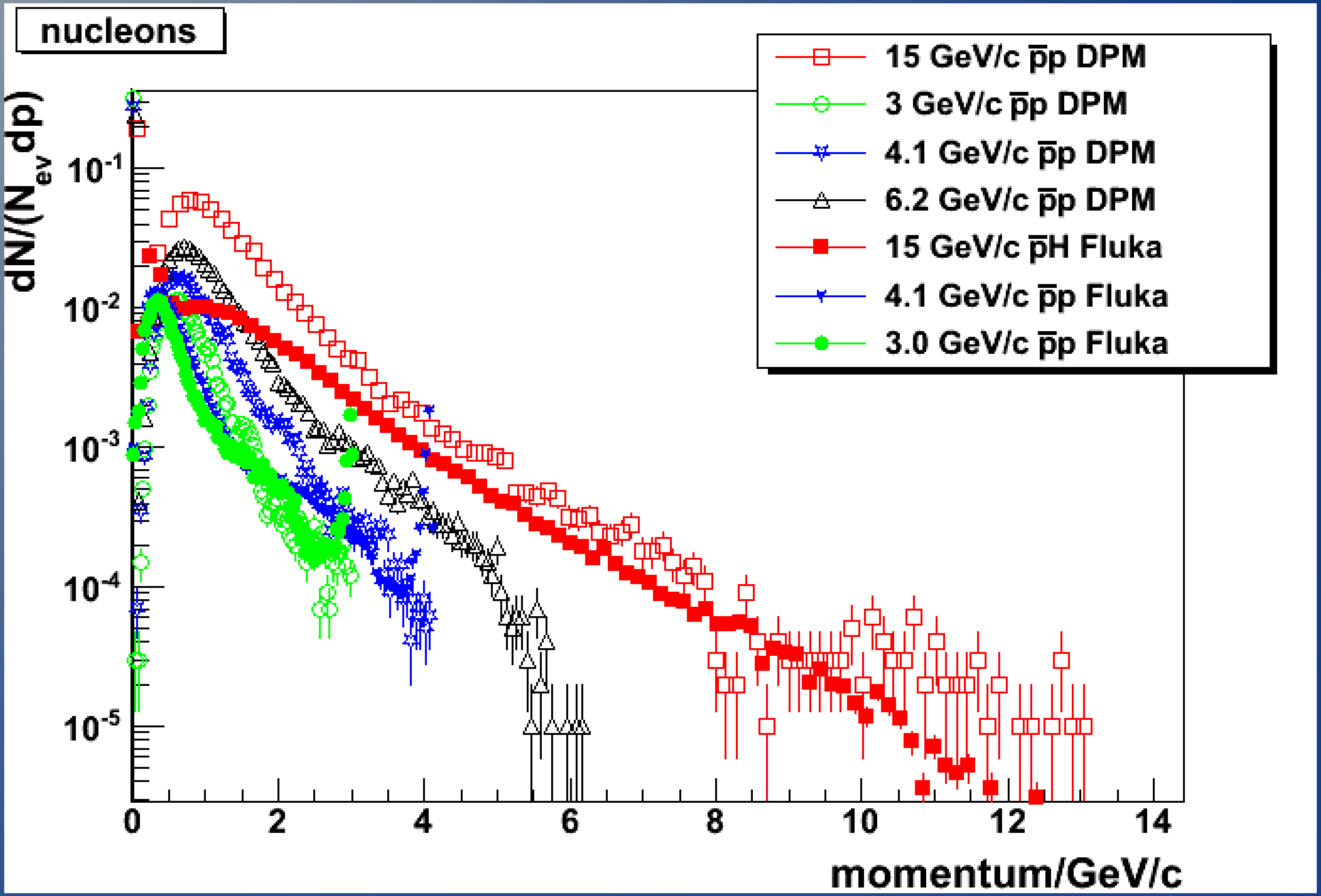
Only in Fluka:
Antiprotons
(i.a. scattered beam particles)

Important feature in Fluka!

Peaks: beam Energy.
Missing for
6.2 GeV/c + Cu

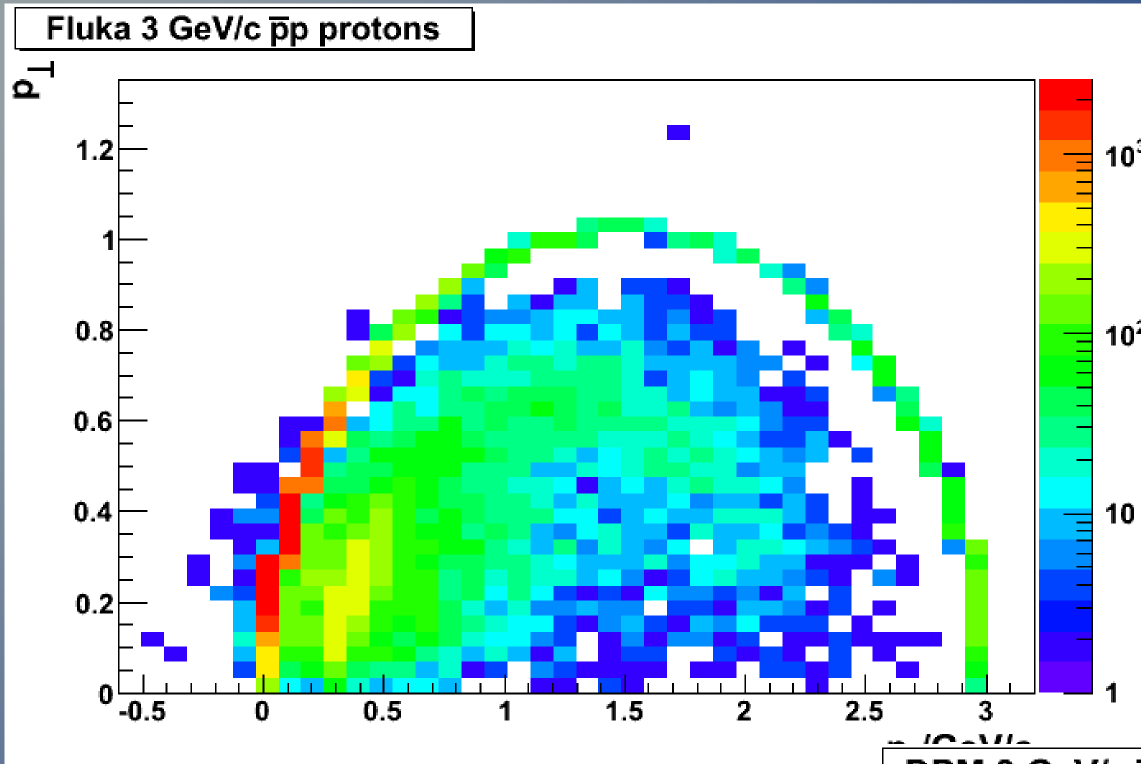


pbar p



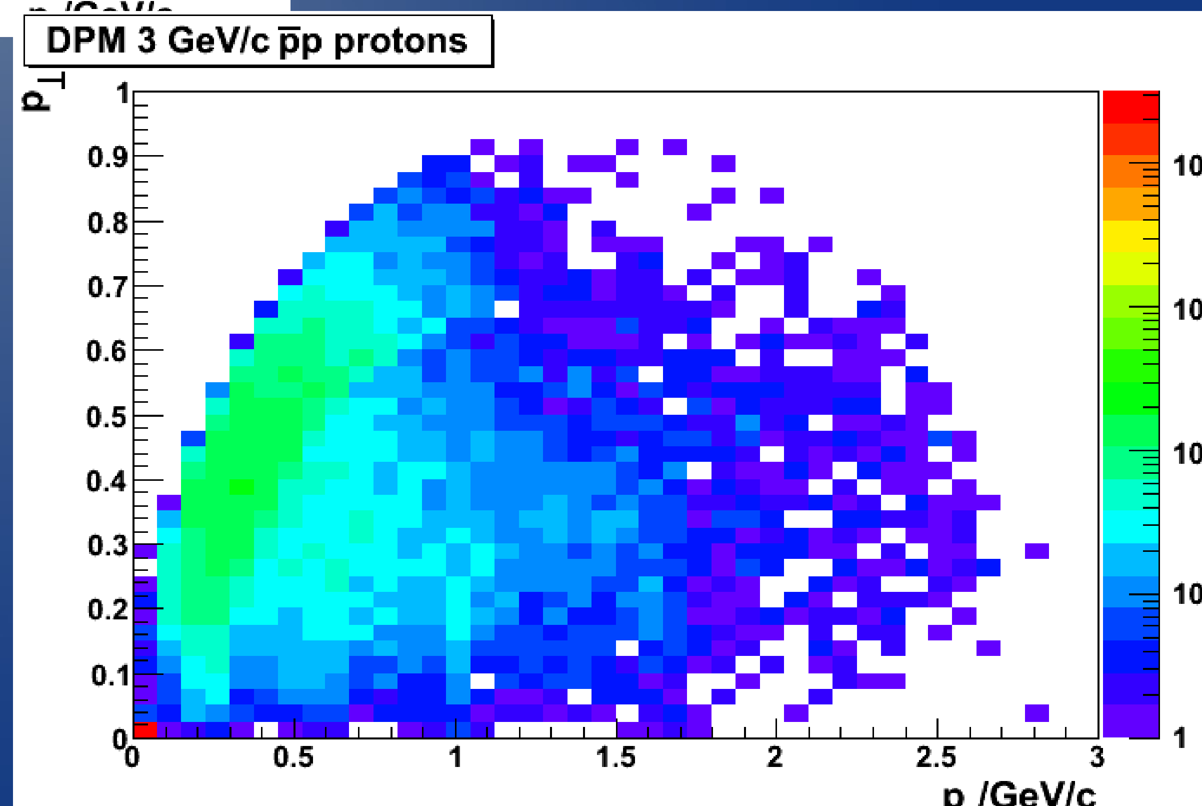
Nucleons with p≈0 in DPM

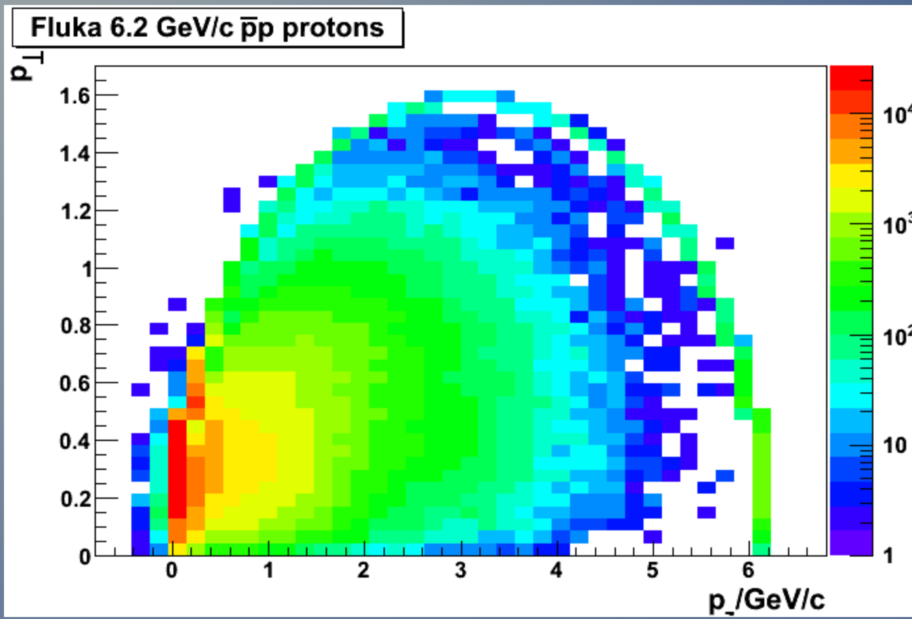
Shifts for small momenta

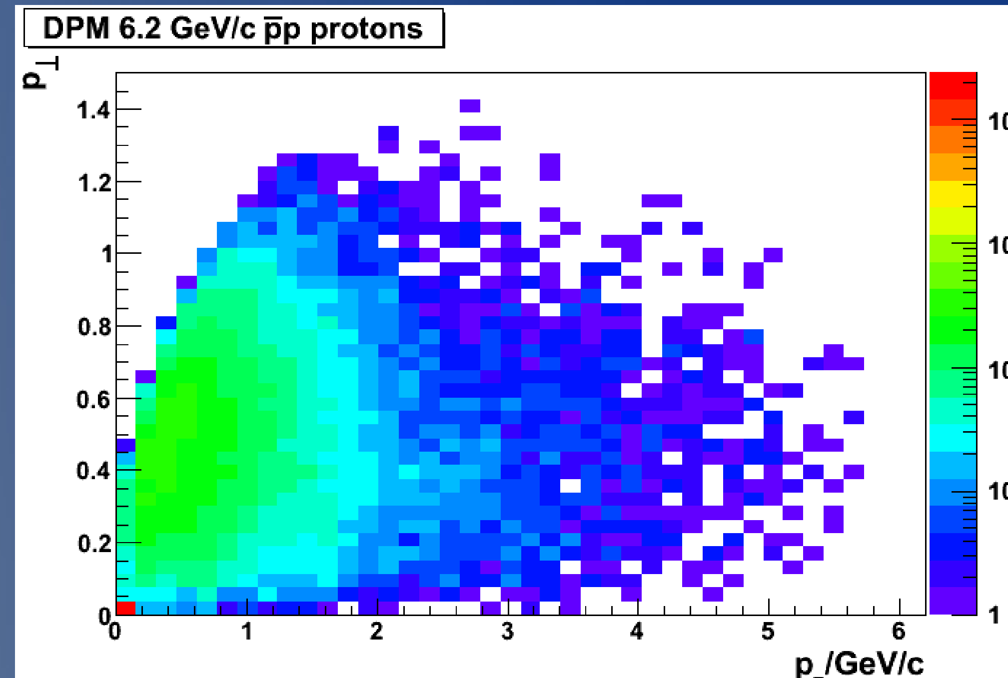


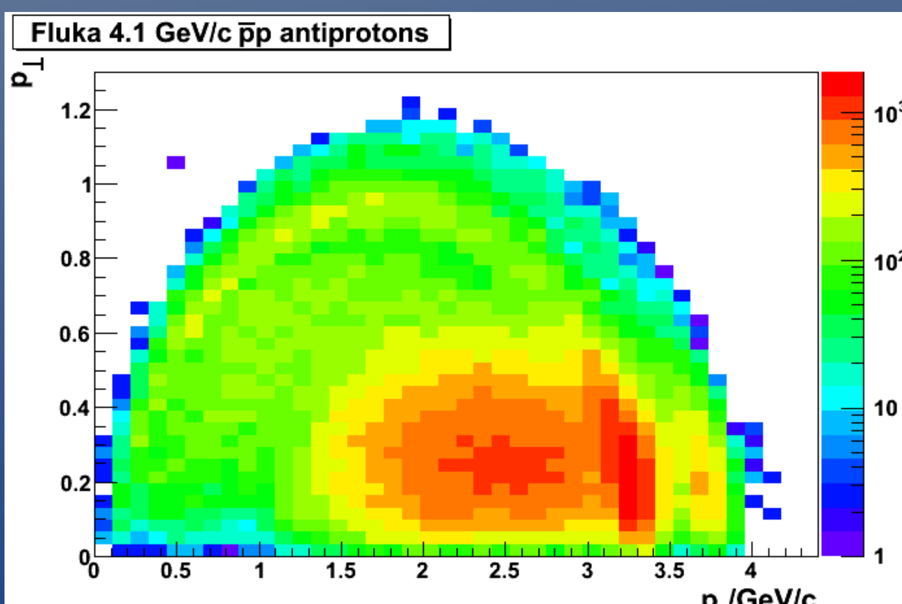
some phase space distributions ...

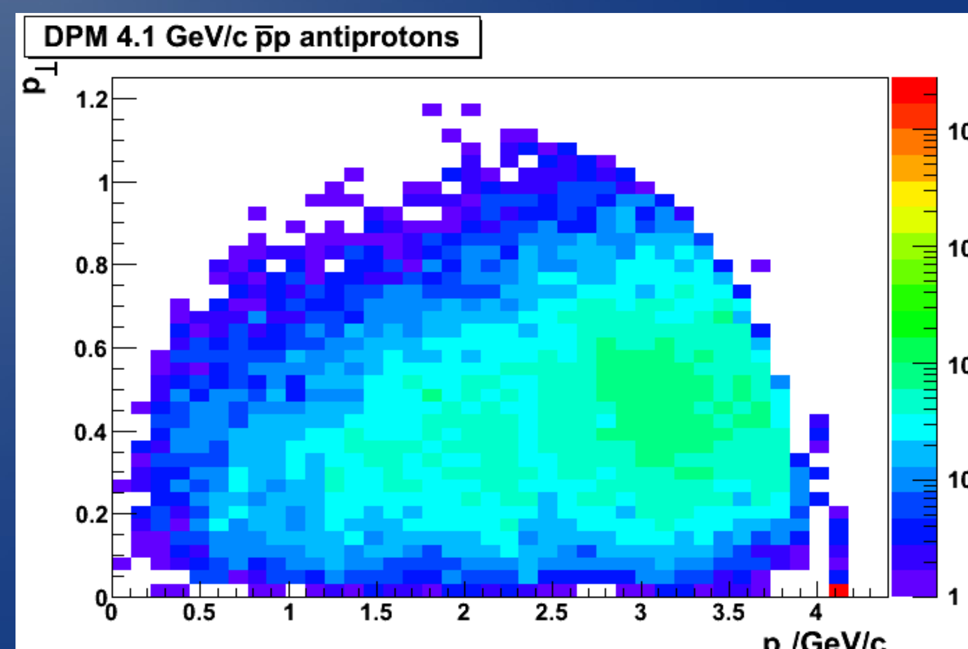
Protons

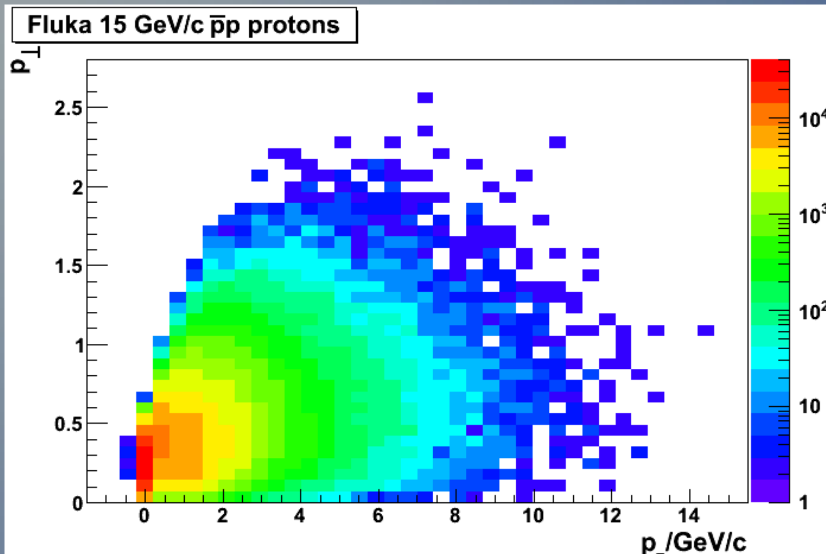


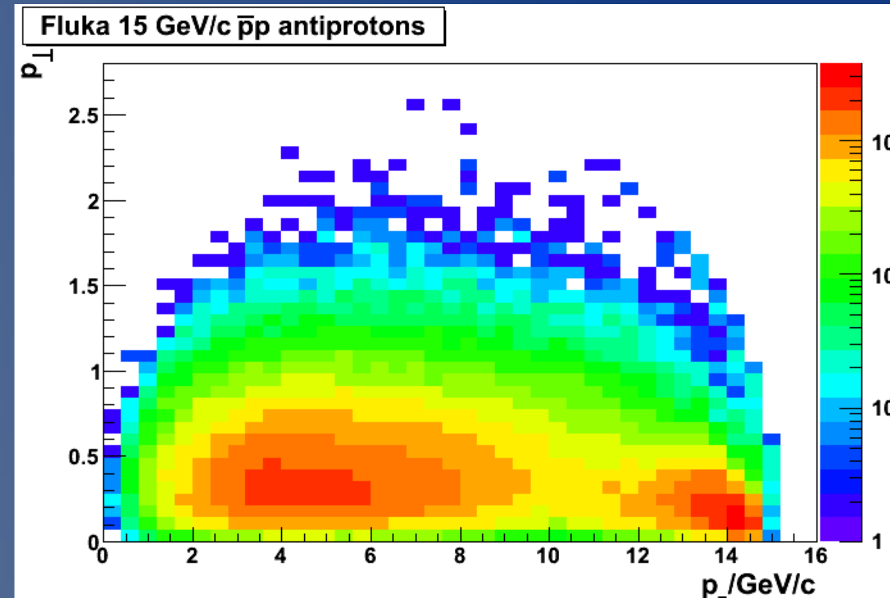

Fluka 6.2 GeV/c p̄p protons
p⊥
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
p_/GeV/c
10^4
10^3
10^2
10
1

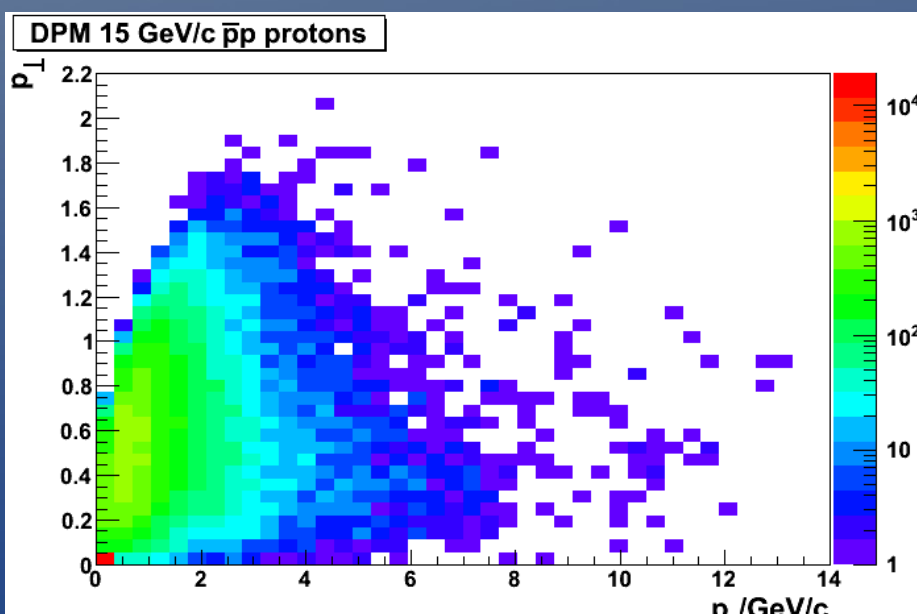

DPM 6.2 GeV/c p̄p protons
p⊥
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
p_/GeV/c
10^4
10^3
10^2
10
1

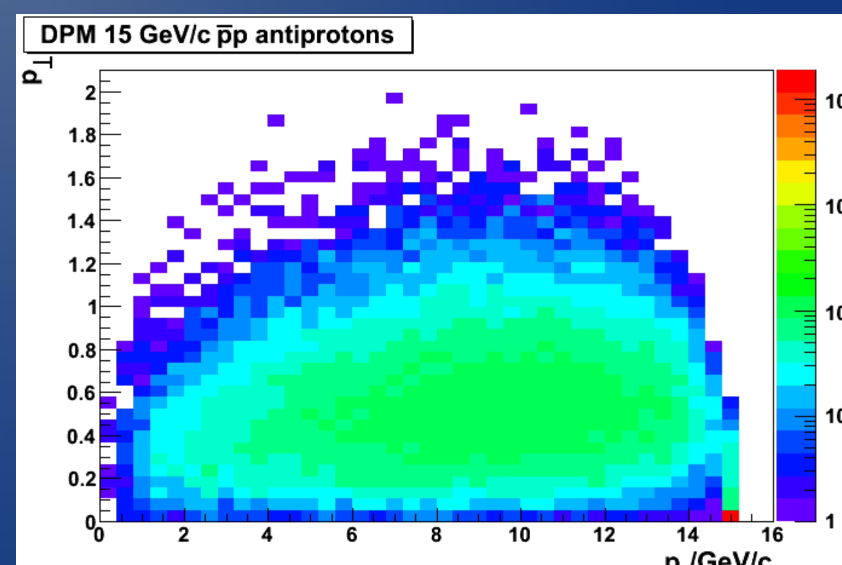

Fluka 4.1 GeV/c p̄p antiprotons
p⊥
1.2
1
0.8
0.6
0.4
0.2
0
0.5
1
1.5
2
2.5
3
3.5
4
p_/GeV/c
10^3
10^2
10
1


DPM 4.1 GeV/c p̄p antiprotons
p⊥
1.2
1
0.8
0.6
0.4
0.2
0
0.5
1
1.5
2
2.5
3
3.5
4
p_/GeV/c
10^4
10^3
10^2
10
1

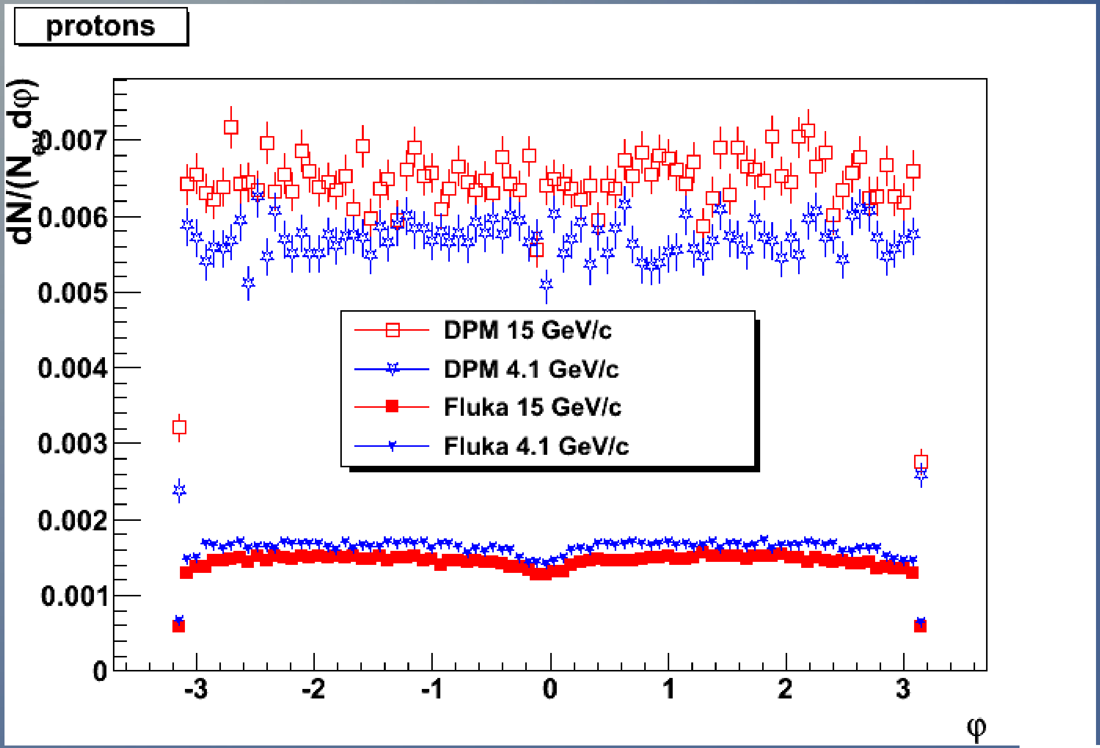

Fluka 15 GeV/c p̄p protons
p⊥
p_/GeV/c

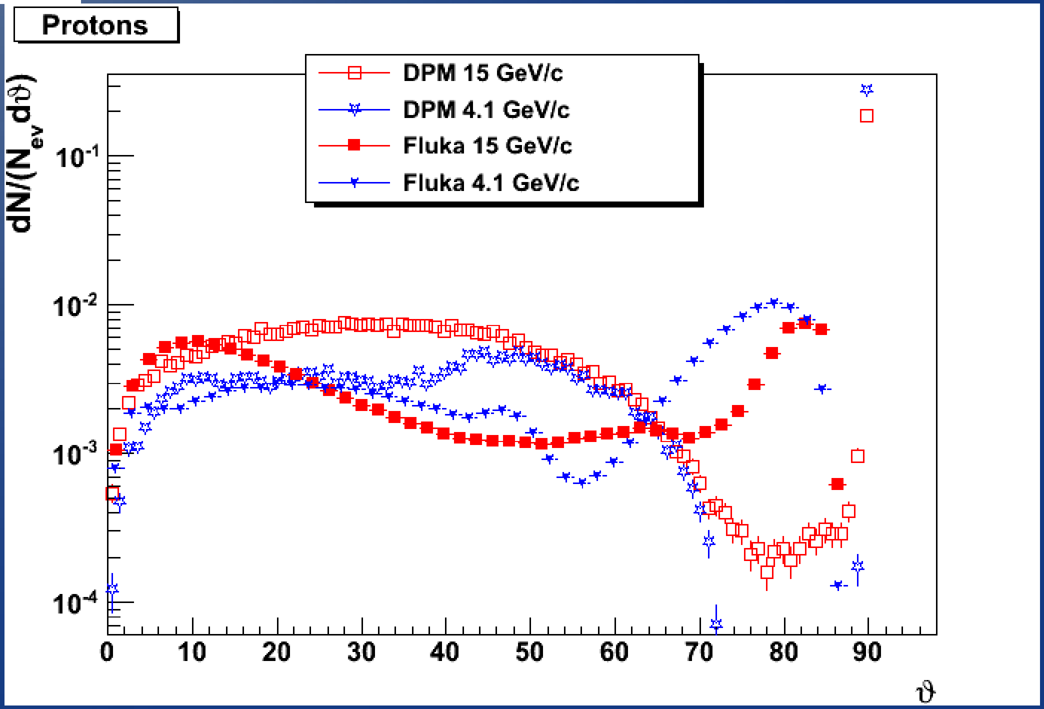

Fluka 15 GeV/c p̄p antiprotons
p⊥
p_/GeV/c


DPM 15 GeV/c p̄p protons
p⊥
p_/GeV/c


DPM 15 GeV/c p̄p antiprotons
p⊥
p_/GeV/c

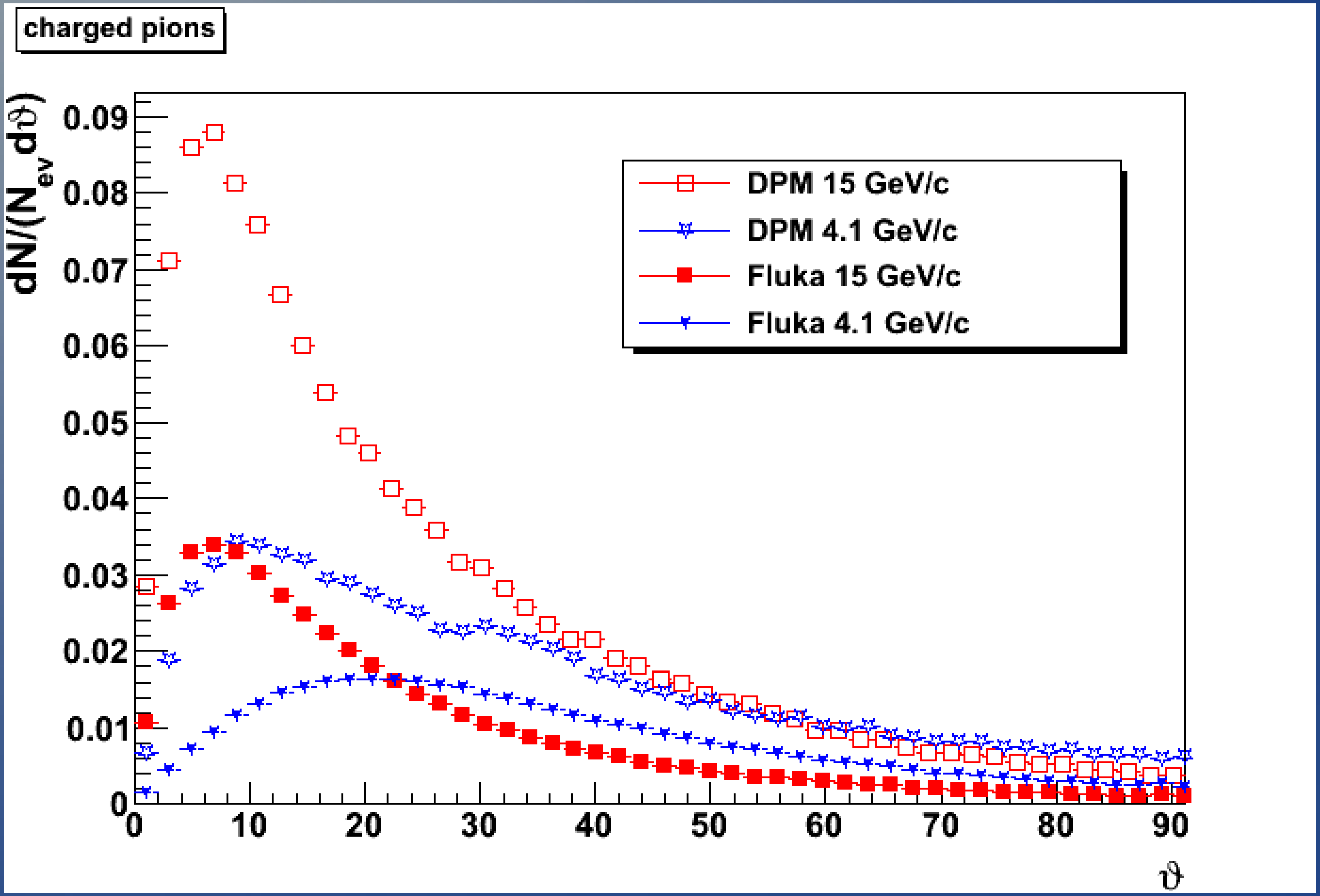
Angular distributions





scattering peak in Fluka much broader and shifted to smaller angles

Charged Pions



DPM has much higher yield at small angles

Discussion and Outlook

- Fluka works as “event generator”
- No target effects in DPM and UrQMD+SMM
- More realistic beam-target geometries in Fluka
  - Example: restgas particles
- For thin targets too many events are without any interaction (slows down the simulation)
  - Biasing?
- For multiuser purposes: slim input files as interface? Code distribution? (Licenses)
- Particle transport has to be done in Geant3/4

Outlook

- Next step: make the Panda geometry available in Fluka
  - In a flexible manner (frequent changes)
  - Radiation map of the detector (useful tools like fluscw.f, ...)
- Fluka integration into PandaRoot? (~~VMC~~)
- Revisit steering parameters for simulations with Fluka
- Later on, comparison/adaption to real data