Status of background simulation studies for the luminosity measurement

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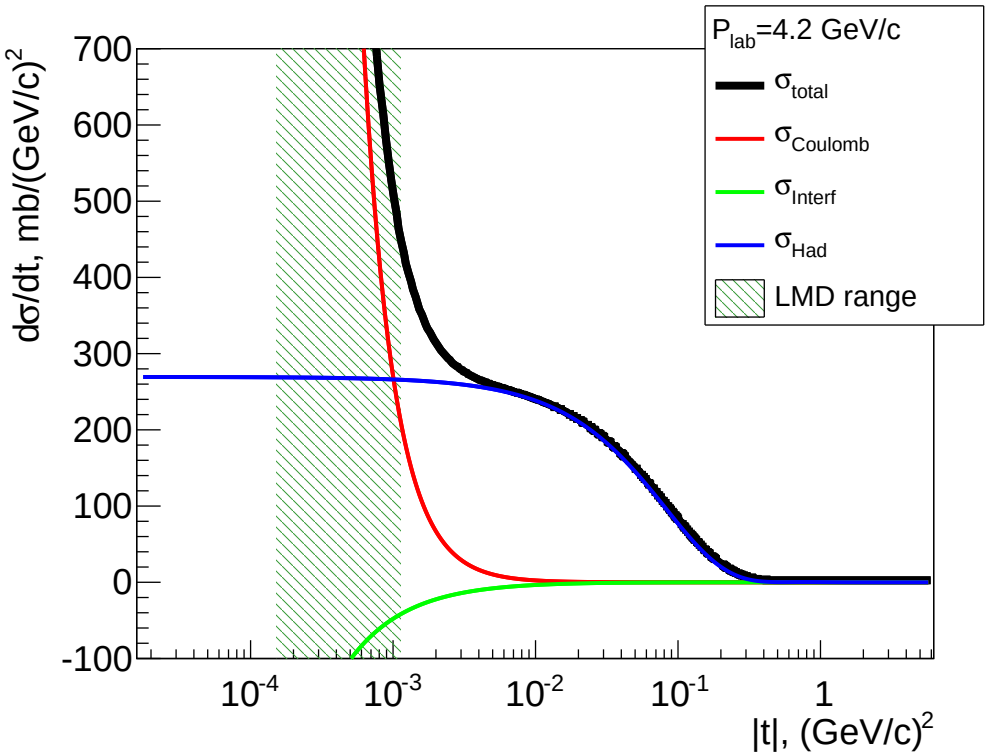
Helmholtz-Institute Mainz
HELMHOLTZ ASSOCIATION
Helmholtz Institute Mainz

PANDA Collaboration Meeting, March 2014

L extraction from $p\bar{p}$ elastic scattering

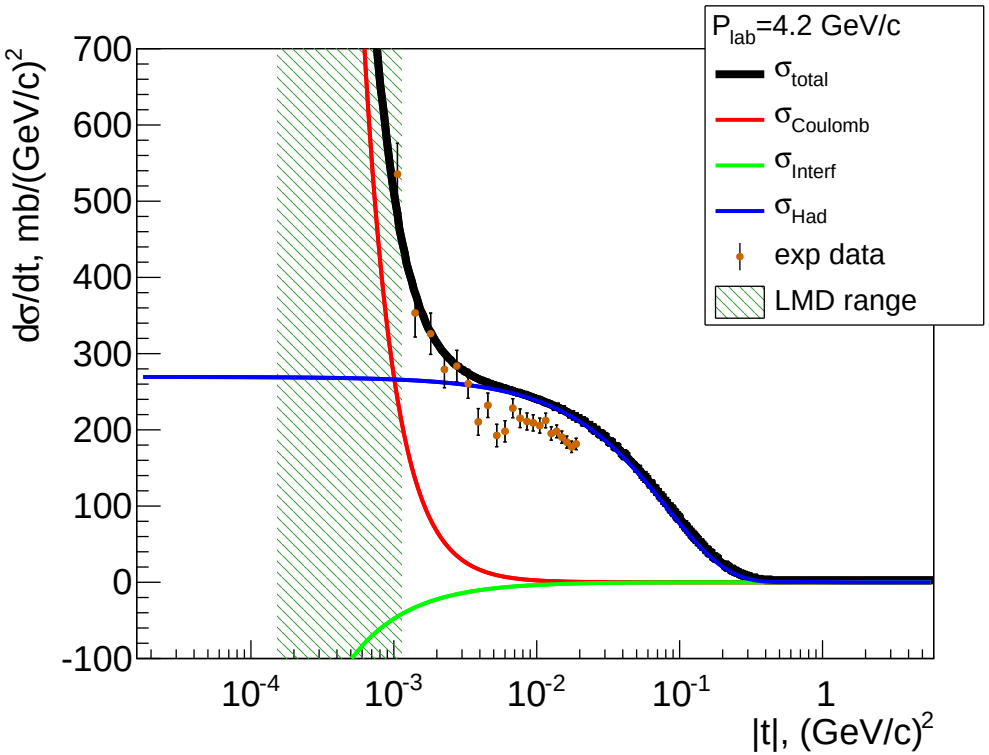


- Coulomb part: QED calculation
- Hadronic part: measurement+models

measurement at small momentum transfer

$t = 2p_{CM}^2(1 - cos\theta_{cm}) \rightarrow$ small θ (3-8 mrad)

L extraction from $p\bar{p}$ elastic scattering



- Coulomb part: QED calculation
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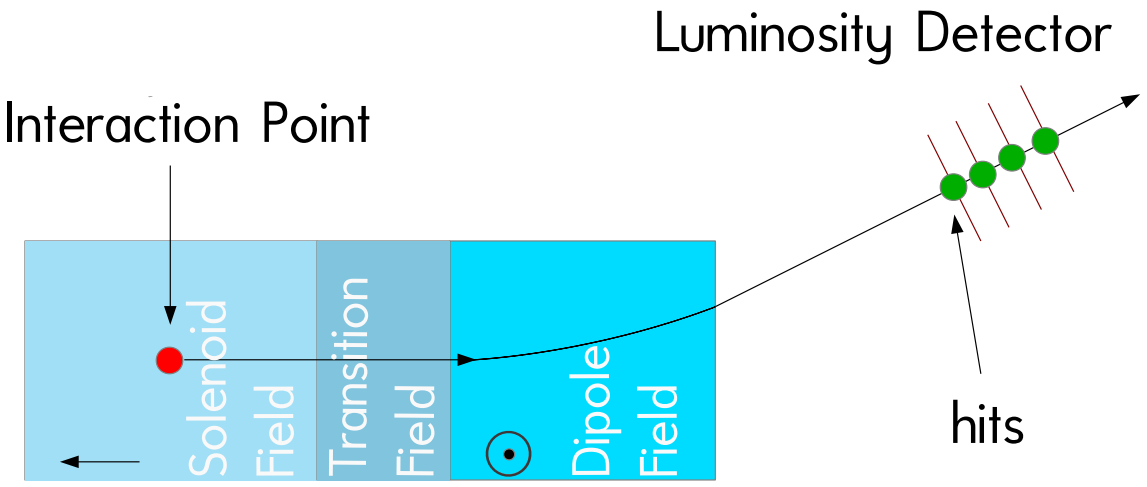
measurement at small momentum transfer

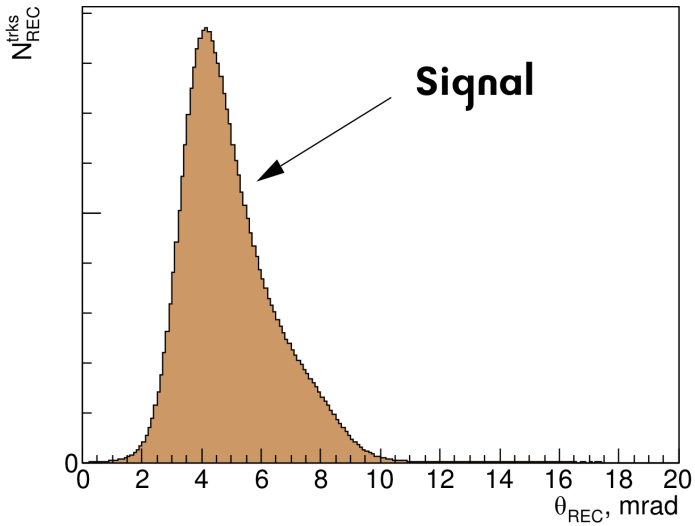
$t = 2p_{CM}^2(1 - cos\theta_{cm}) \rightarrow$ small θ (3-8 mrad)



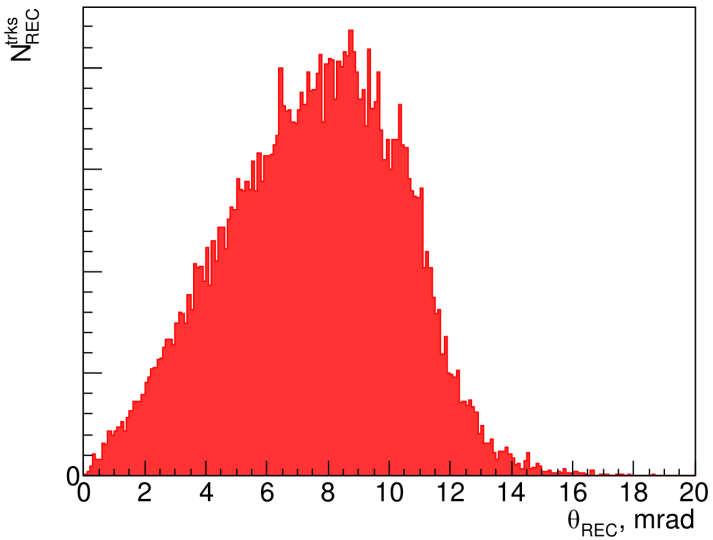
- Contribution of elastic hadronic part
  $\Rightarrow$ Luminosity extraction by the fit of θ distribution

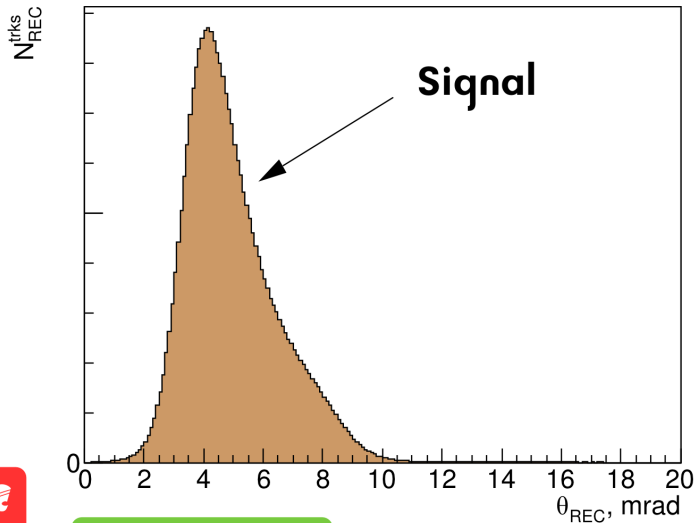
- Measurement after magnetic field
- Shift & tilt of beam
  $\Rightarrow$ registration of tracks in full ϕ range

Our background sources



Our background sources

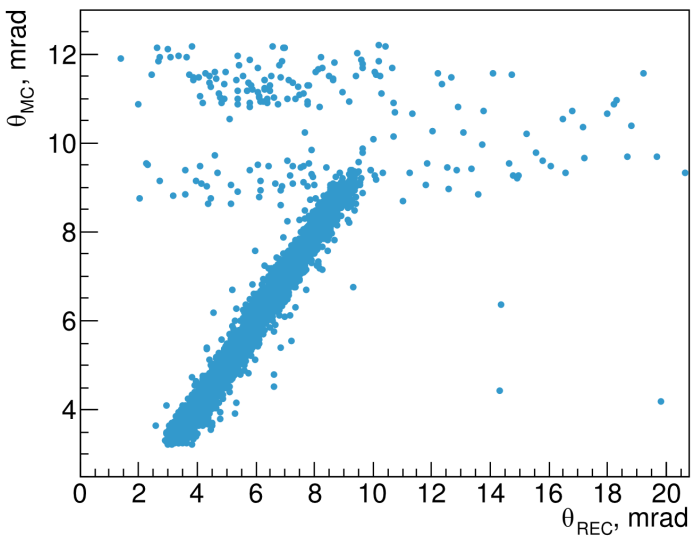


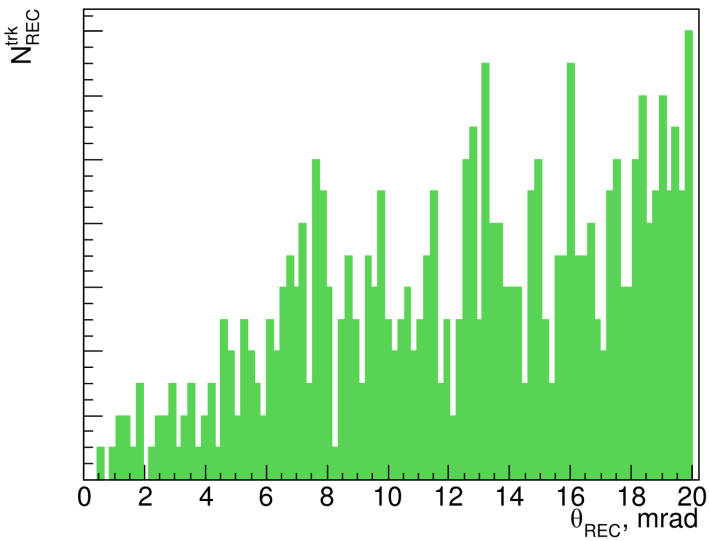


Inelastic
from IP

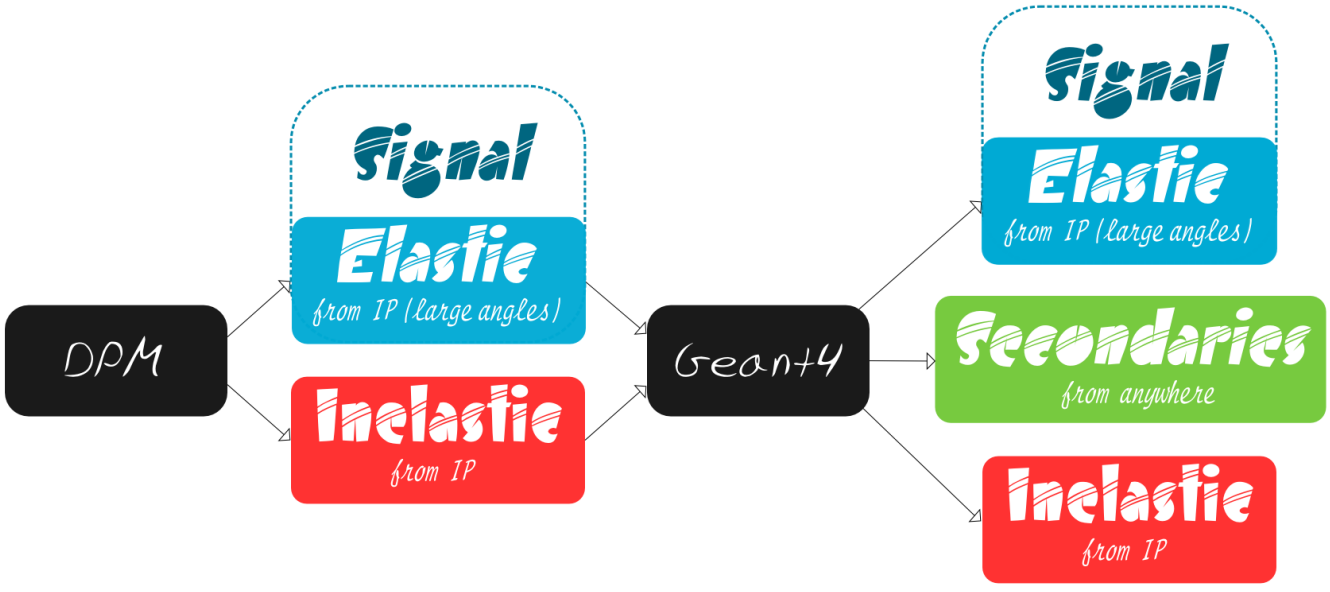
Elastic
from IP (large angles)

Secondaries
from anywhere





Simulation approach



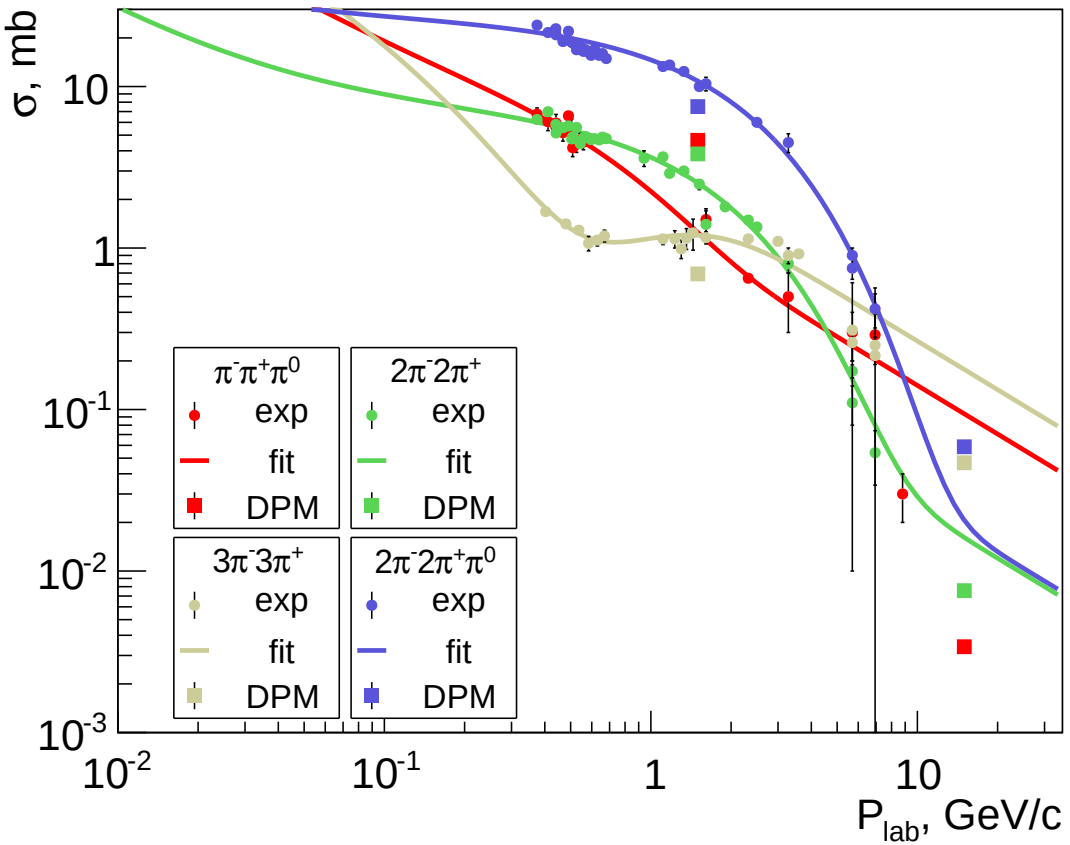
but

- DPM $\neq$ correct kinematics of final inelastic state
  DPM = correct (inelastic) cross-sections?
- Geant4 has different physics models (lists)
  Difference?

DPM

check of cross-sections for inelastic channels

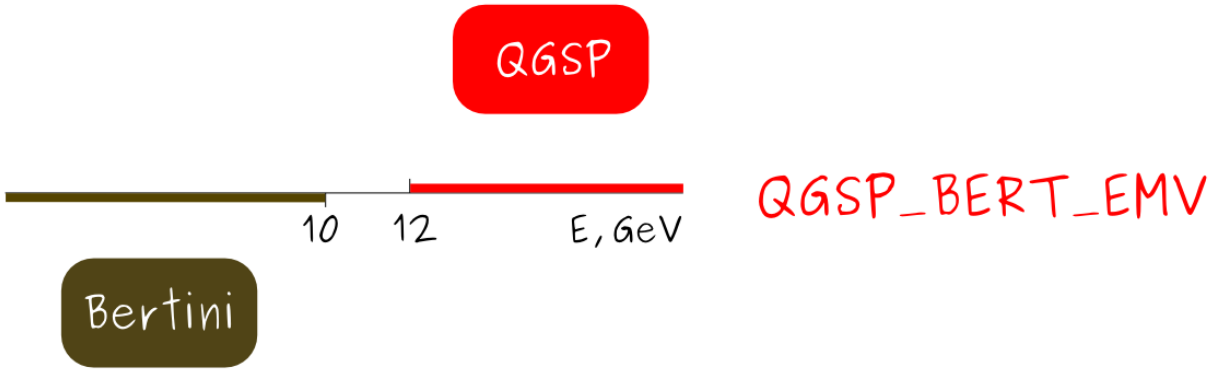
Exp.Data&Fit from "Classification of $\bar{p}p$ induced reaction" (A. Dbeyssi, E. Tomasi-Gustafsson)



P_{beam}, GeV/c	$\sigma_{tot.inel}$, mb	Number of channels
1.5	62.72 ± 0.16	~ 400
15	40.38 ± 0.34	$\sim 13 \cdot 10^3$

Geant4

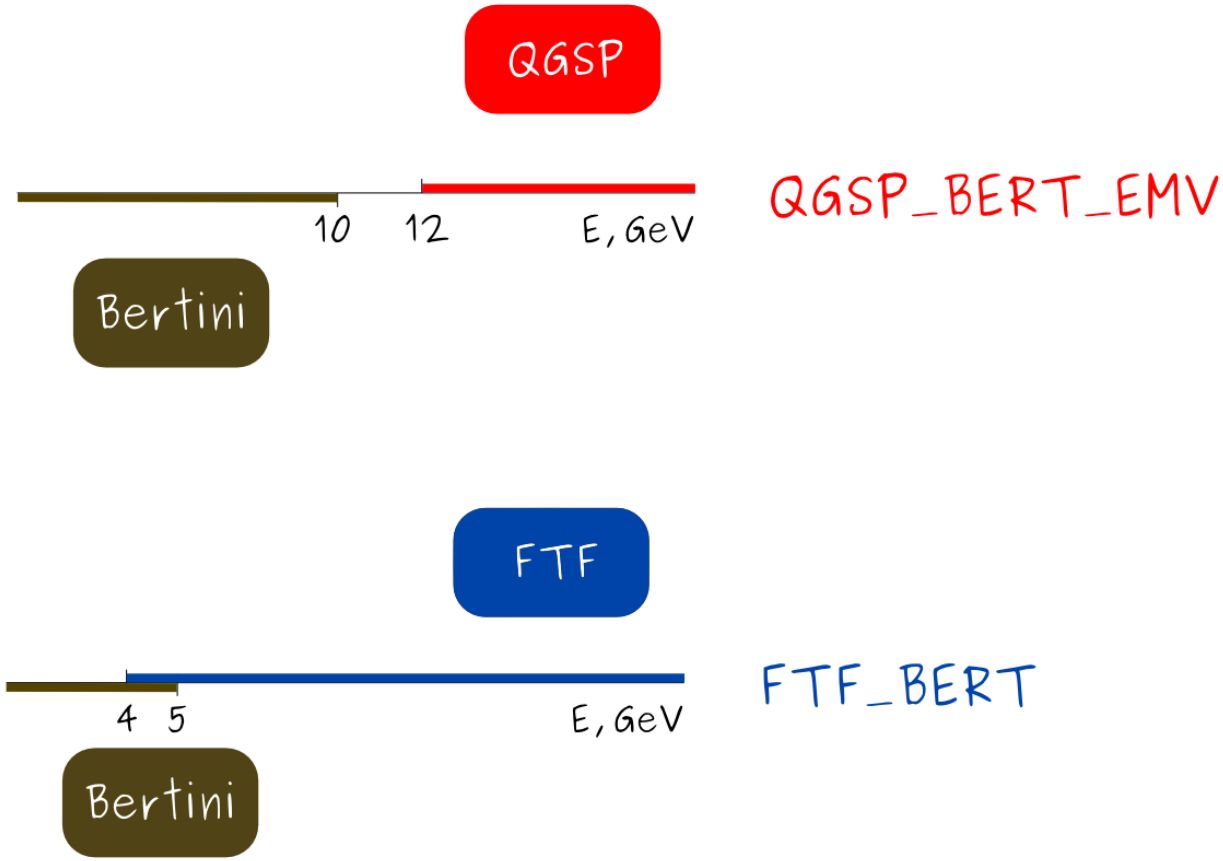
Hadronic models



- "Physics of antiproton-proton and antiproton-nucleus annihilation processes implemented in Geant4" A.Galoyan [PANDA CM, Sep 2013]
- "Geant3-Geant4 Hadronic Response Comparisons" E.Atomssa (PANDA CM, Dec 2013)
- "Recent developments and validation of Geant4 hadronic physics" [J.Phys.Conf.Ser, 396(2012)]

Geant4

Hadronic models



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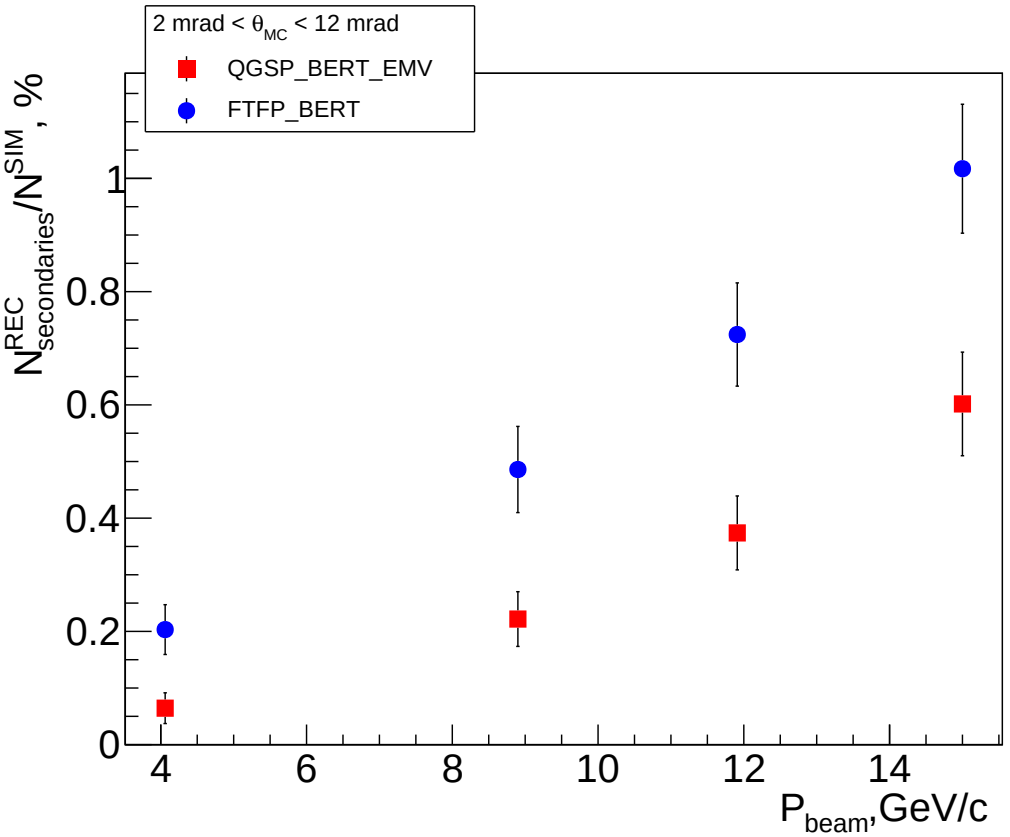
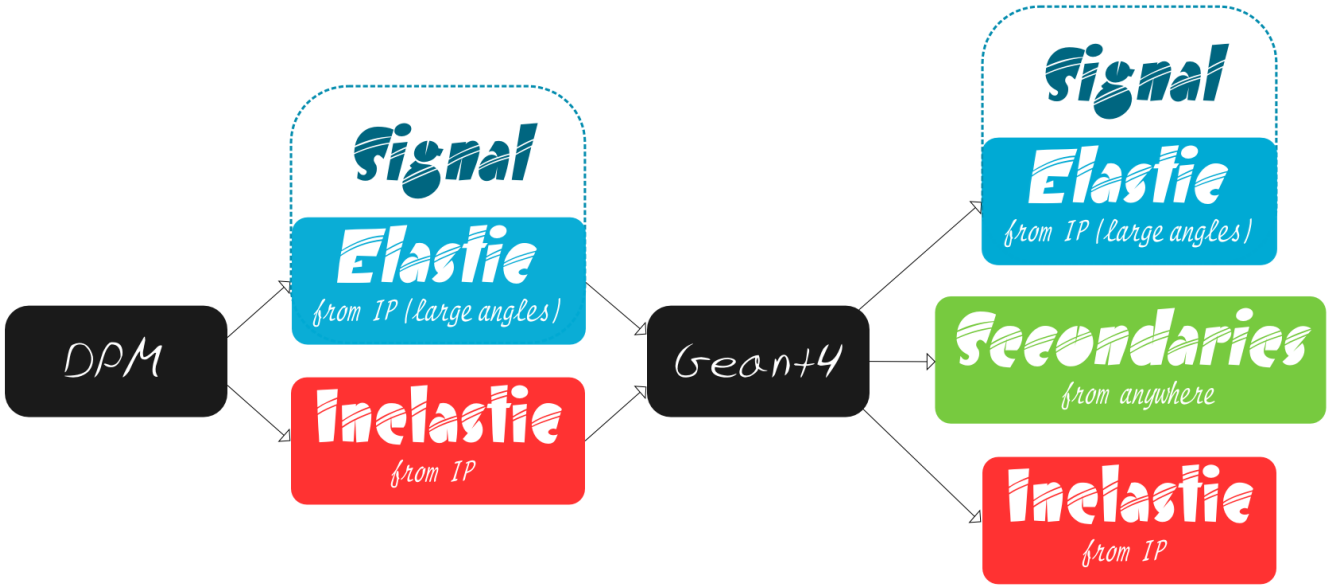
Geant4
QGS vs FTF

- BOX (uniform) generator: $\bar{p}$ with $\theta \in$ [2,12] mrad, $\phi \in$ [0,2π] rad
- All PANDA sub-systems included (see next slide)
- Reconstruction in LMD



FTF model predicts $\sim$ 2 times more secondaries

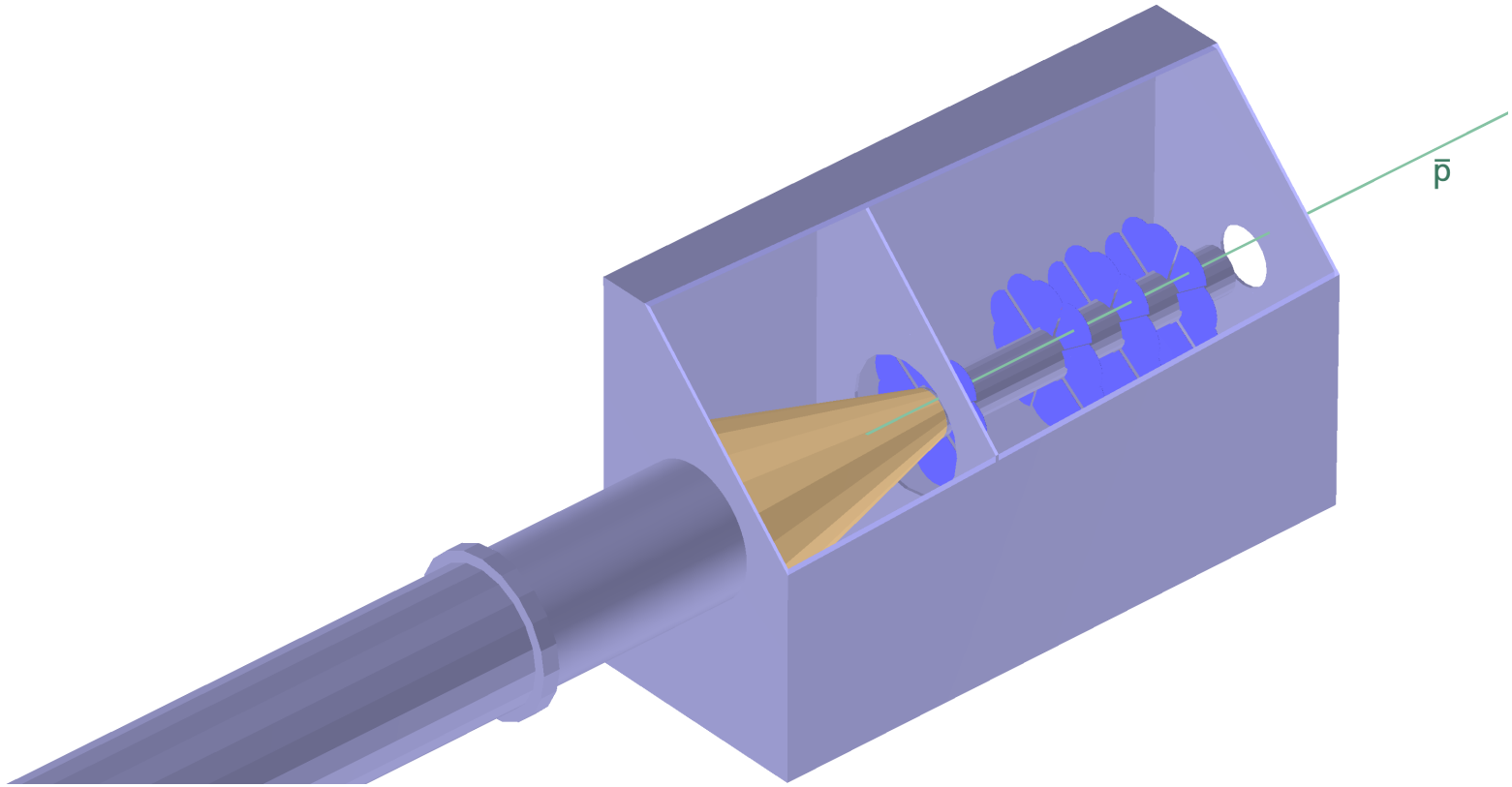
Simulation approach



but

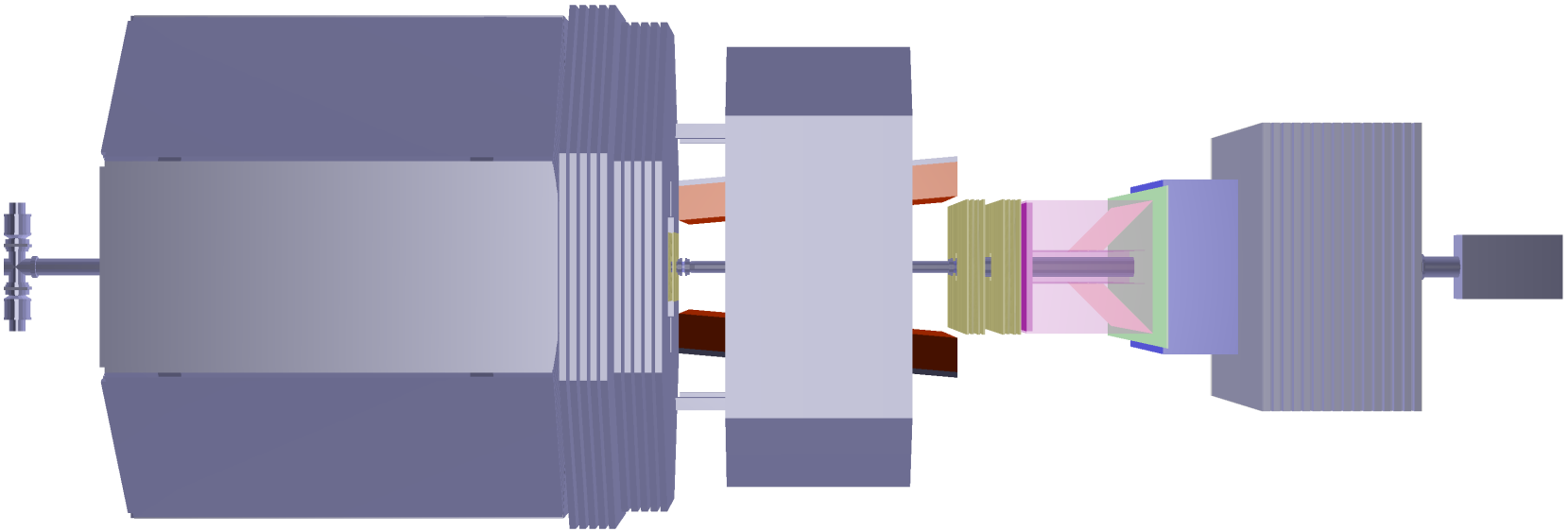
- DPM $\neq$ correct kinematics of final inelastic state
  DPM = correct (inelastic) cross-sections?
  $\rightarrow$ No, but we still have nothing better
- Geant4 has different physics models (lists)
  Difference?
  $\rightarrow$ Significant, so pick up the worst one (FTF)

Detector set-up in simulation



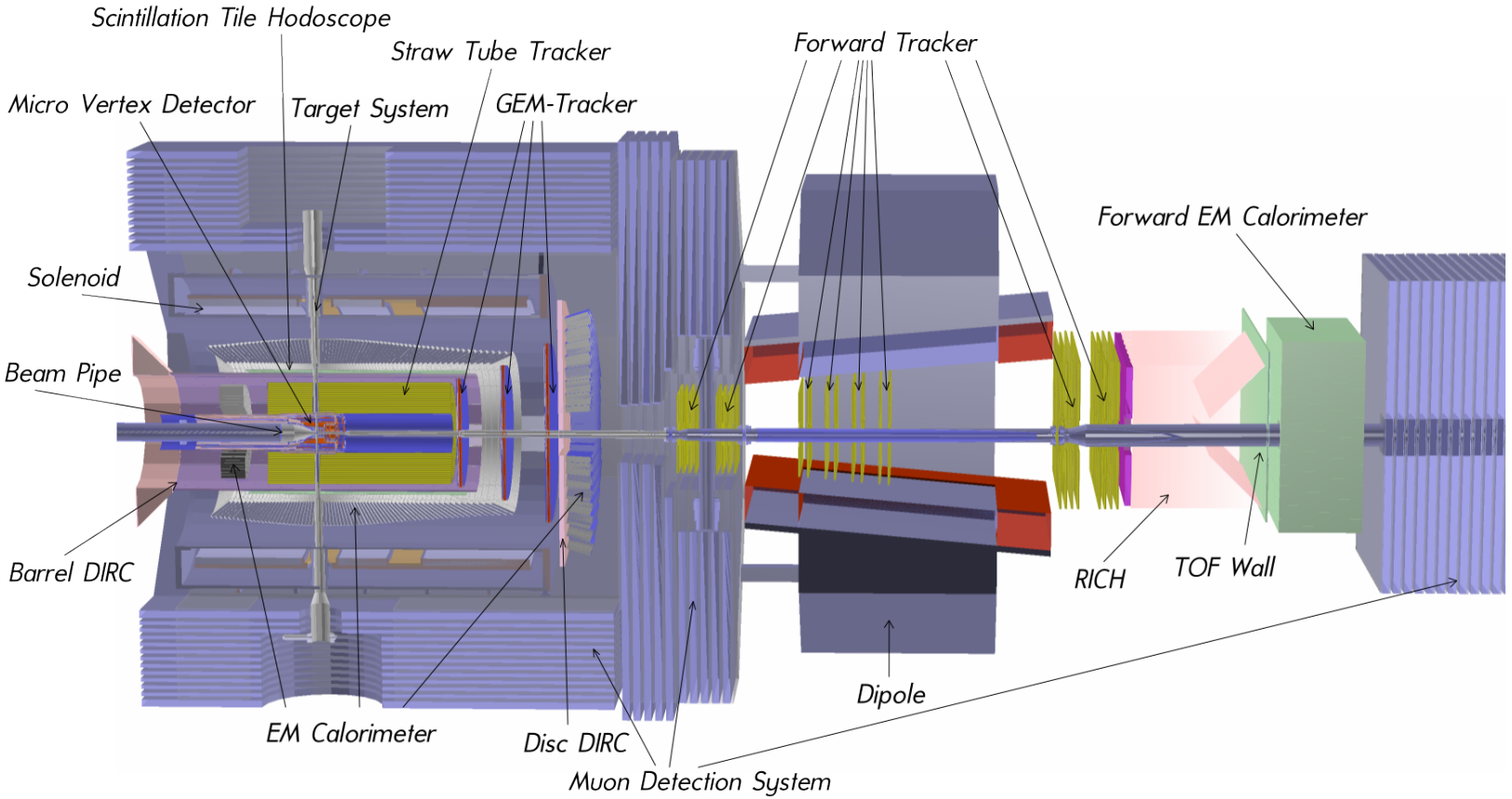
⋆ Luminosity-Detector.root(ver.0)

Detector set-up in simulation



- ⋆ pndcave.geo,FullSolenoid_V842.root,dipole.geo,beampipe_201309.root
- ⋆ Luminosity-Detector.root(ver.0)

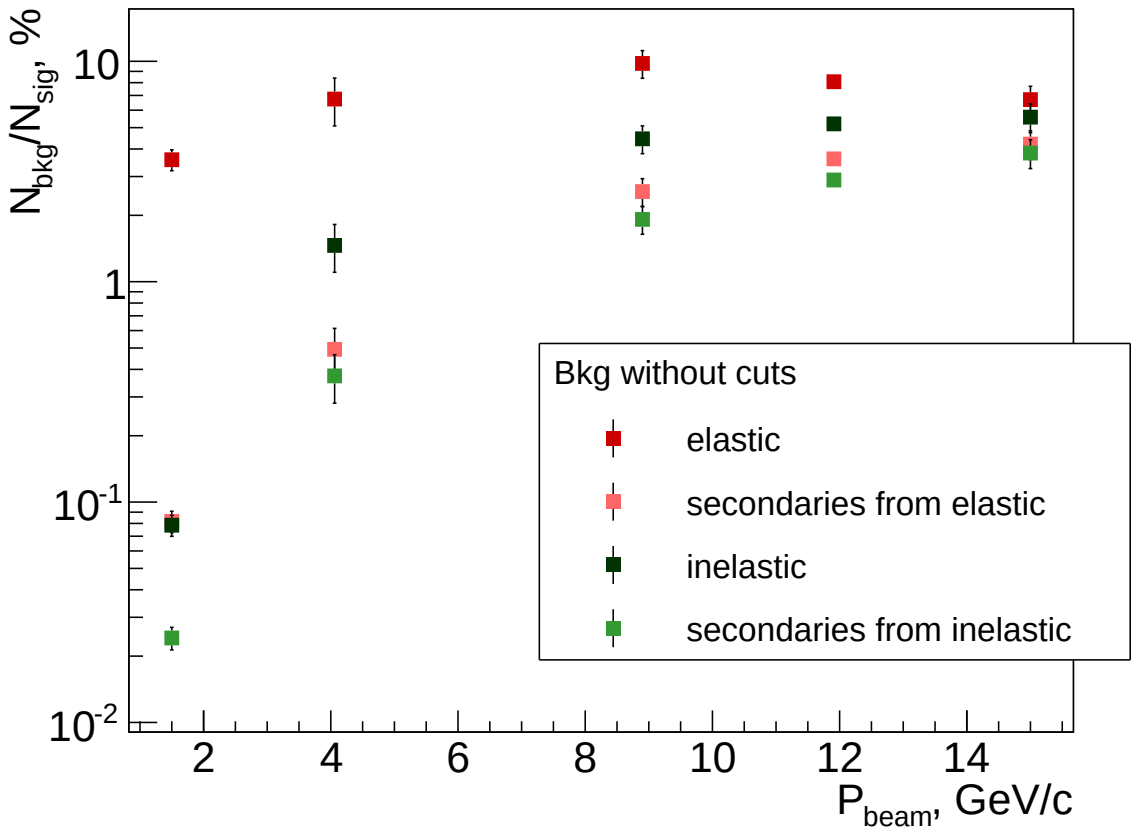
Detector set-up in simulation



- ⋆ pndcave.geo,FullSolenoid_V842.root,dipole.geo,beampipe_201309.root
- ⋆ Luminosity-Detector.root(ver.0)
- ⋆ straws_skewed_blocks_35cm_pipe.geo, Mvd-2.1_FullVersion.root, gem_3Stations.root, EMC geo.ver.1, barrel-SciTil_07022013.root, dirc_l0_p0_updated.root, DSK, MDT, fts.geo, rich_v2_shift.geo

Total amount of background

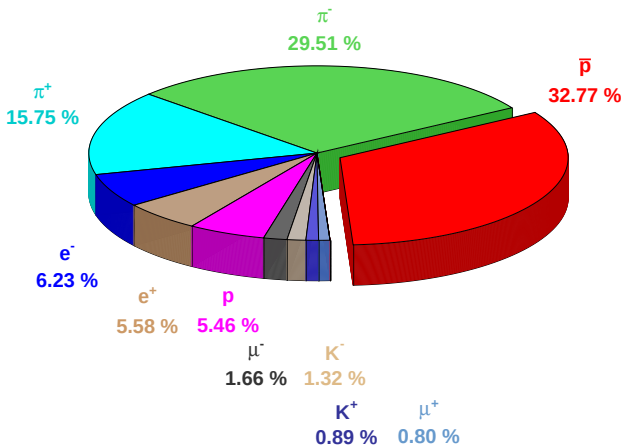
DPM, without cuts

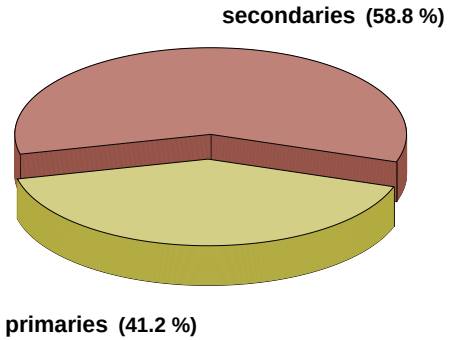


! At 15 GeV/c $\frac{\Sigma Bkg}{Signal} \sim 20\ \%$!

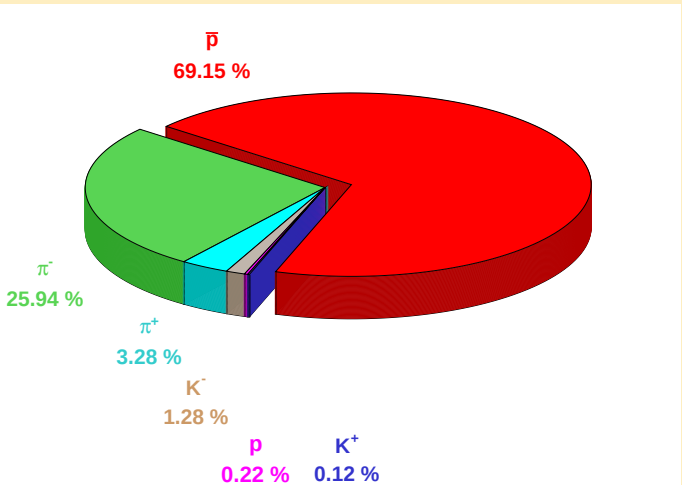
Results with DPM

Particles contributions (15 GeV/c): inelastic & secondaries (no cuts)

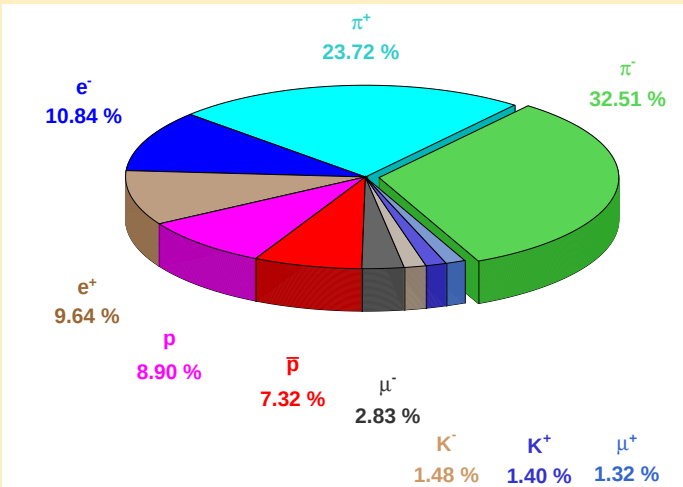




Primary

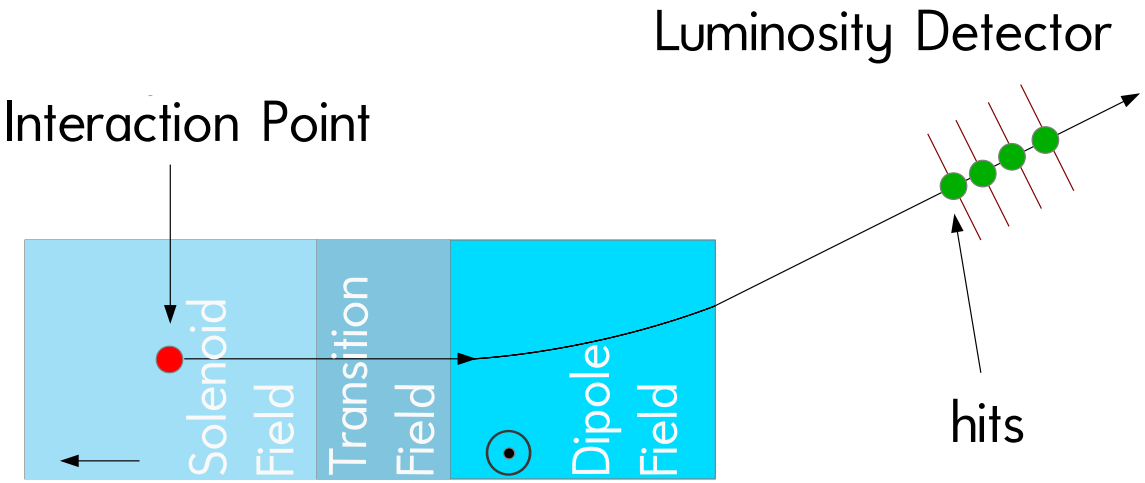


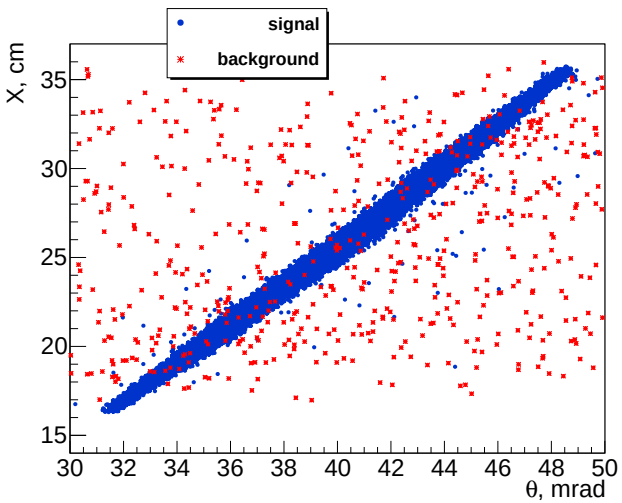
Secondary

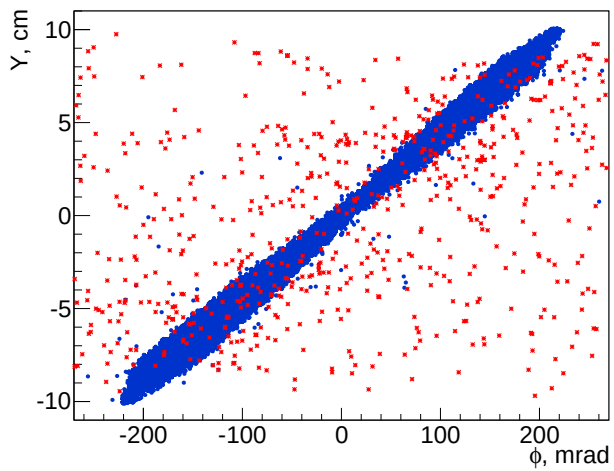


Cuts

Before back-propagation



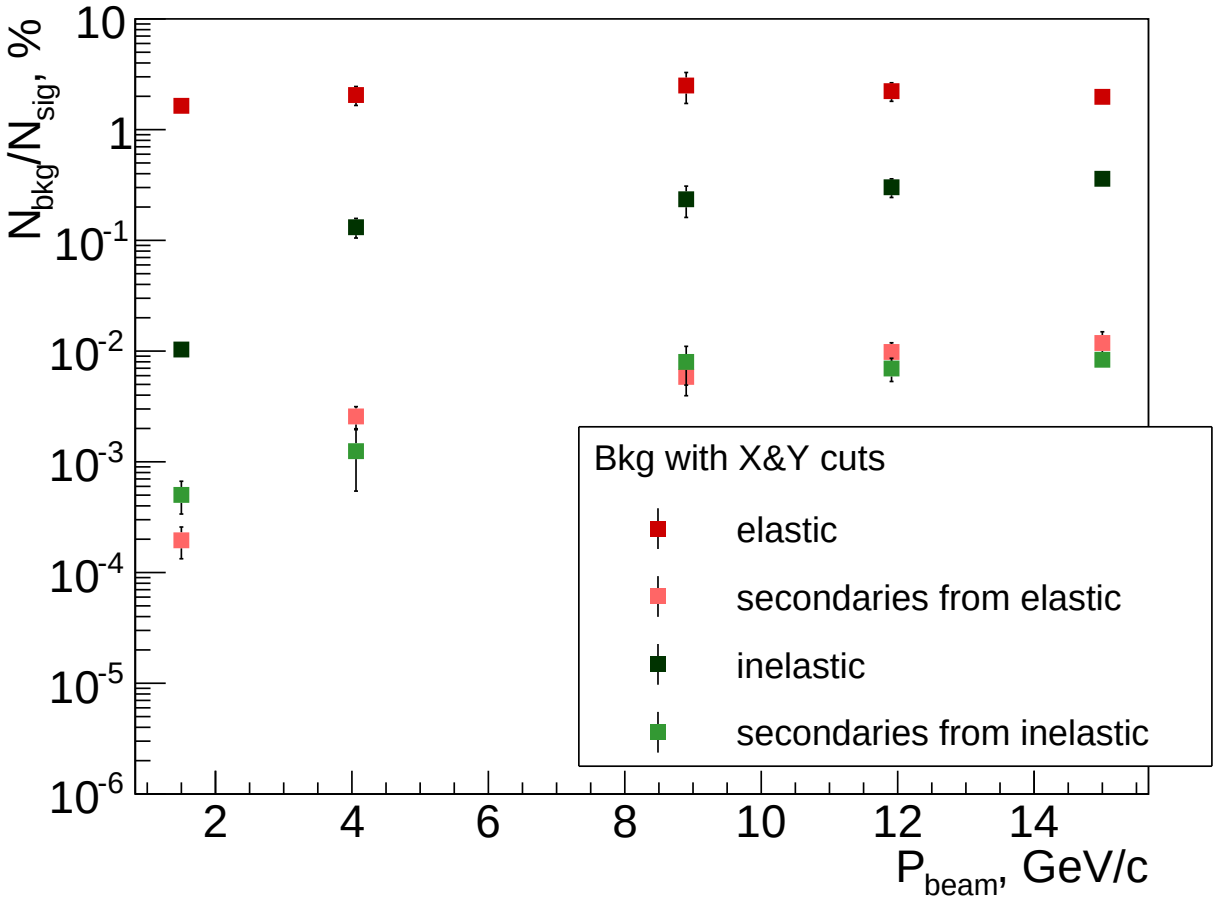




X(θ)&Y(ϕ) cut with $3\Delta_x$ and $3\Delta_y$ widths

Total amount of background

after applied X&Y cuts

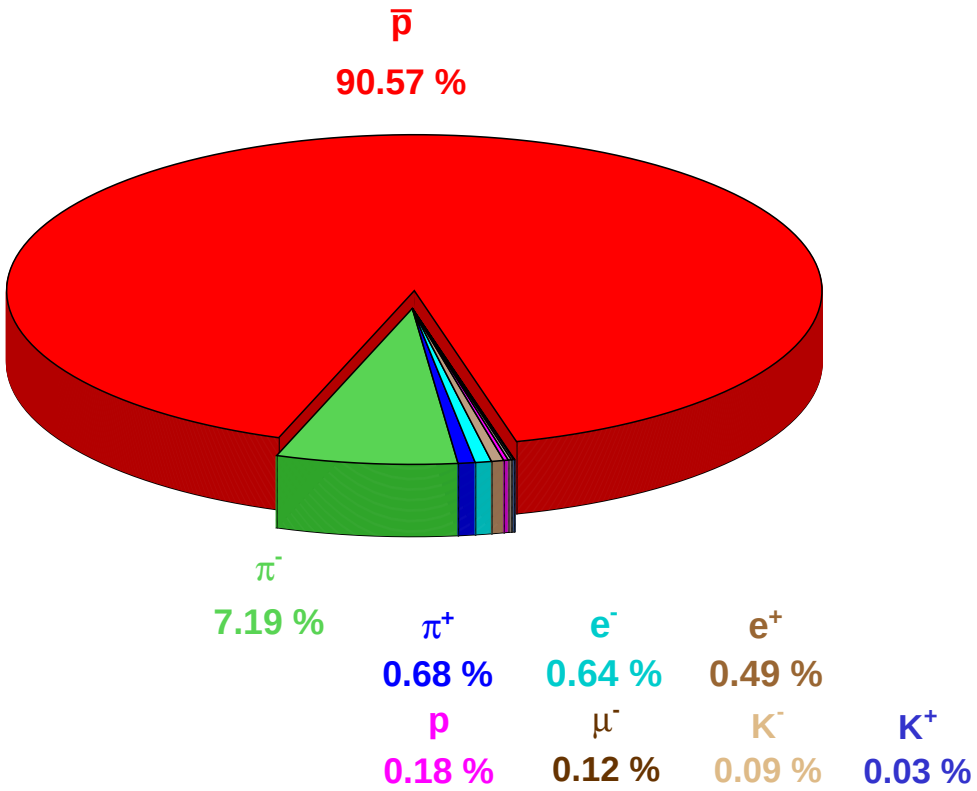


Background goes down to $\sim$ 2 % !

Remaining contribution: elastic at large angles

Total amount of background

after applied X&Y cuts

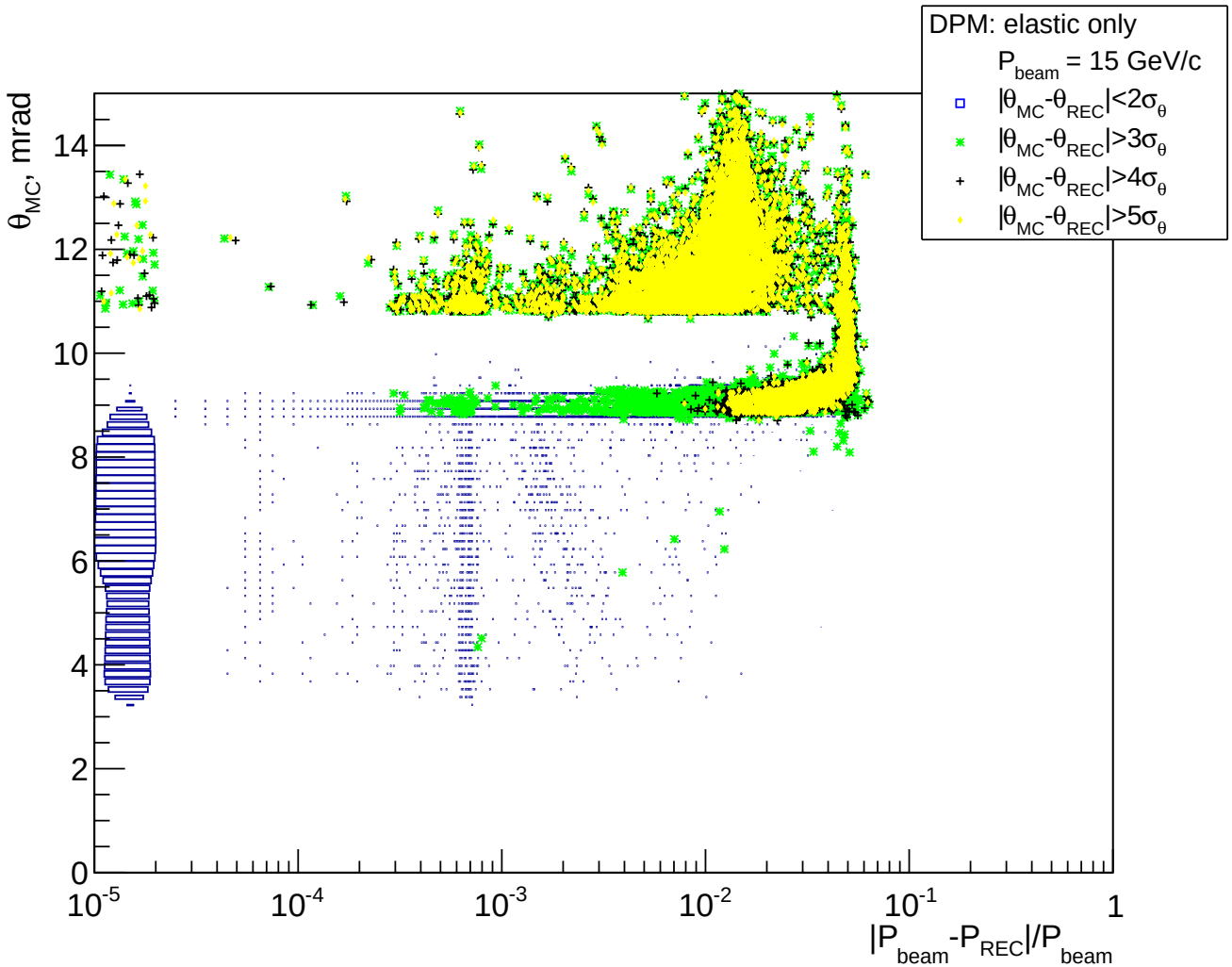


Inelastic: $\bar{p}$ with momentum close to P_{beam}

Cuts

After back-propagation

We don't measure momentum: P_{beam} value is used in back-propagation

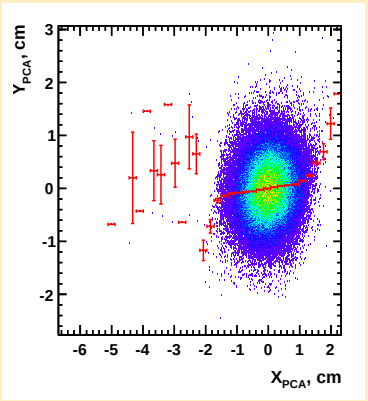


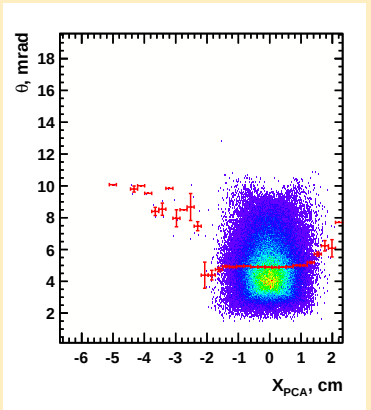
Momentum cut can be used above 1.5 GeV/c

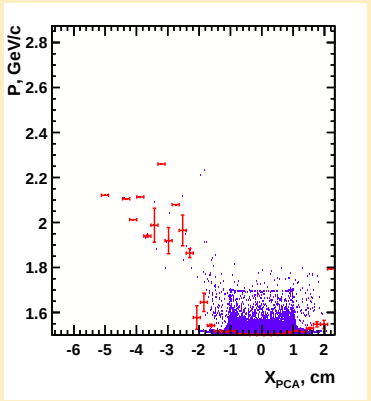
Cuts

After back-propagation

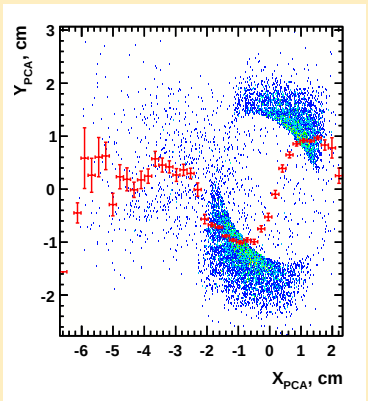
Signal

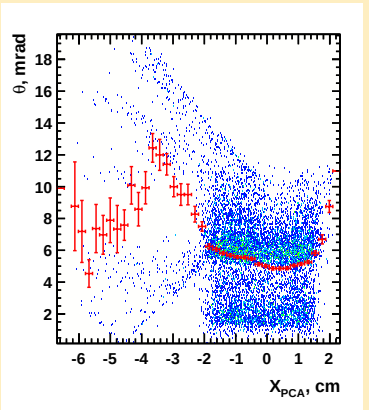


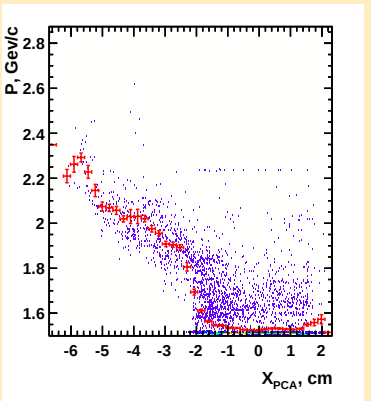




Background







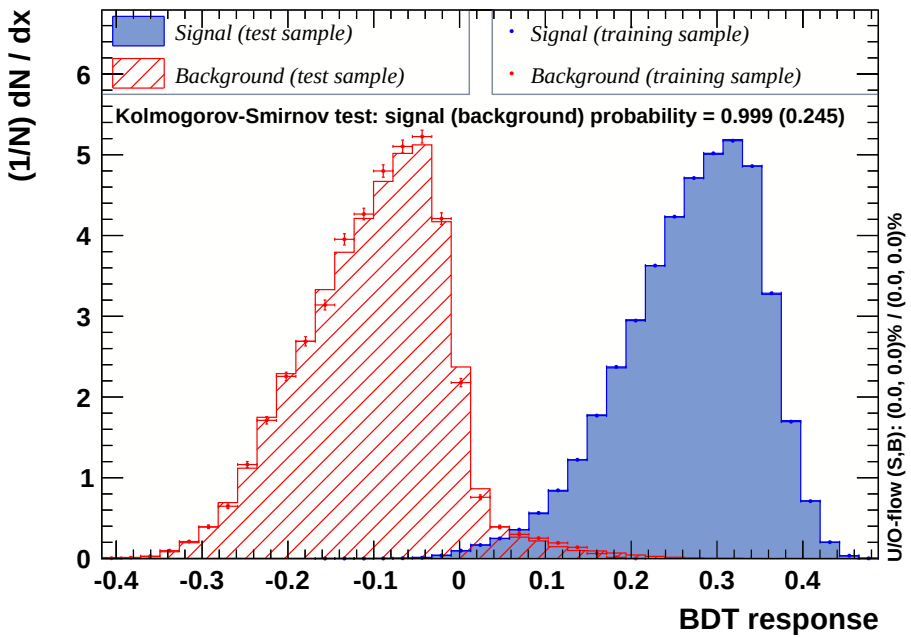
MVA @ 1.5 GeV/c and momentum cut above $\Rightarrow$ M cut

TMVA Results

M cut at P_{beam} 1.5 GeV/c

Training on reconstructed DPM elastic events

Signal: $|\theta_{MC}-\theta_{REC}|<3\sigma_\theta$, Background: $|\theta_{MC}-\theta_{REC}|>3\sigma_\theta$

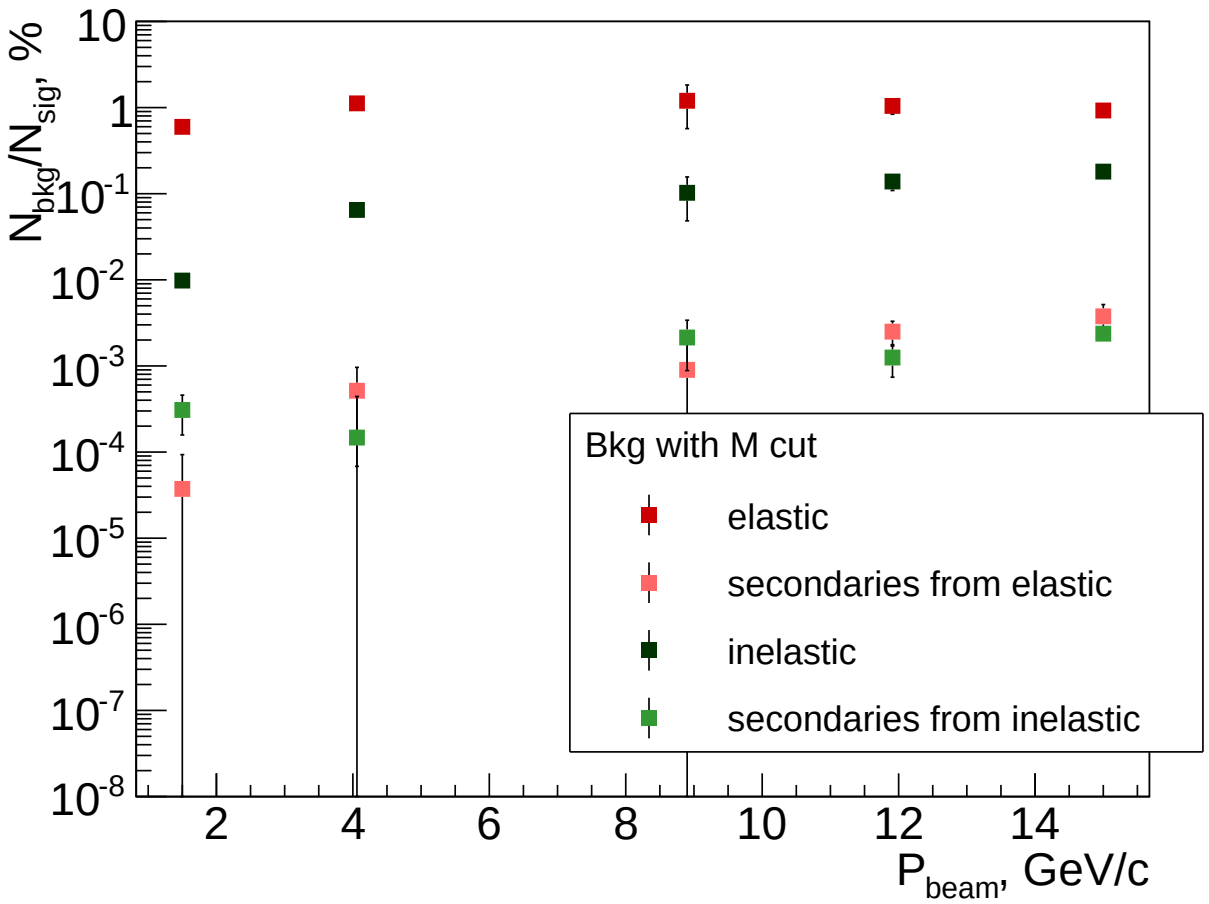


Boosted Desicion Tree

- good performance «out of box»
- response cut at 0: 0.5% signal loss 95.4% bkg rejection

Total amount of background

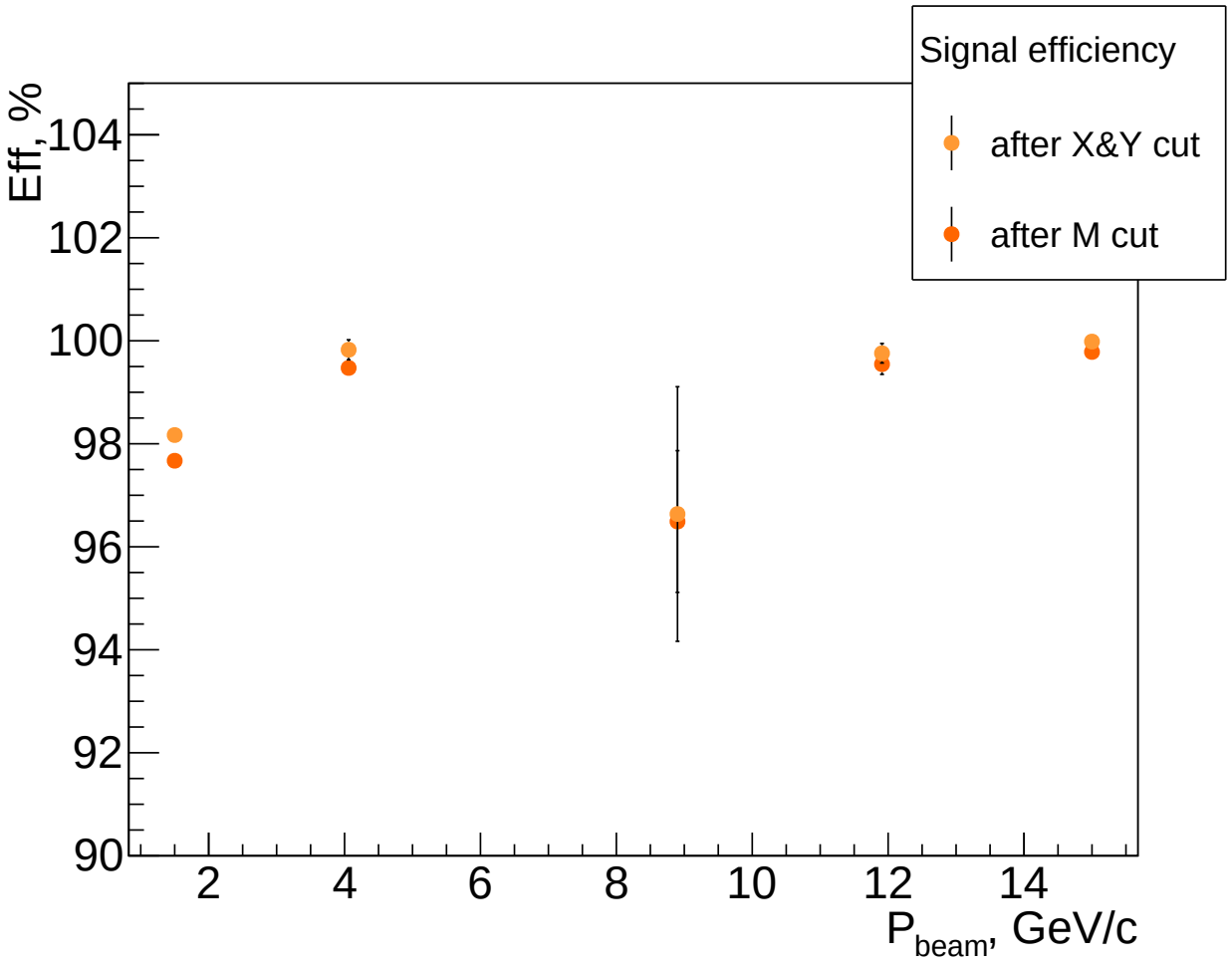
after applied M cut



Background goes down to 1 % !

Total amount of background

after applied M cut



Background goes down to 1 % !

Efficiency close to 100 %

Results

The Lumunosity extraction by the maximum Likelihood fit

$$\frac{dN}{d\theta} = L \cdot \left(\frac{d\sigma}{d\theta} \cdot \epsilon\right) \bigotimes \theta_{RES}$$

N - number of events

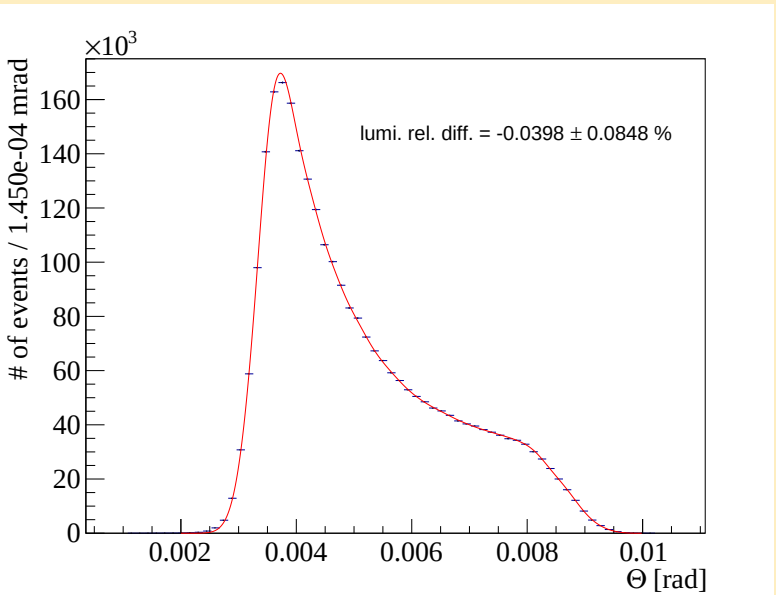
σ - cross section

L - luminosity

ϵ - efficiency

θ_{RES} - resolution function

P_{beam} 4.06 GeV/c (DPM, elastic only)



Cut	Backgroud, %	Δ_{syst}, %
No	6.75 ± 0.4	2.42 ± 0.09
X&Y	2.07 ± 0.3	0.39 ± 0.08
M	1.15 ± 0.2	-0.04 ± 0.08

Conclusion & Outlook

Summary

- In GEANT4 FTF model predicts more secondaries
- Background challenge: signal-like behavior
- Help of variable correlations (dipole)
- Suppression 10-20% $\rightarrow$ 2% $\rightarrow$ 1%
- Main (remaining) contribution:
  elastic at large angles

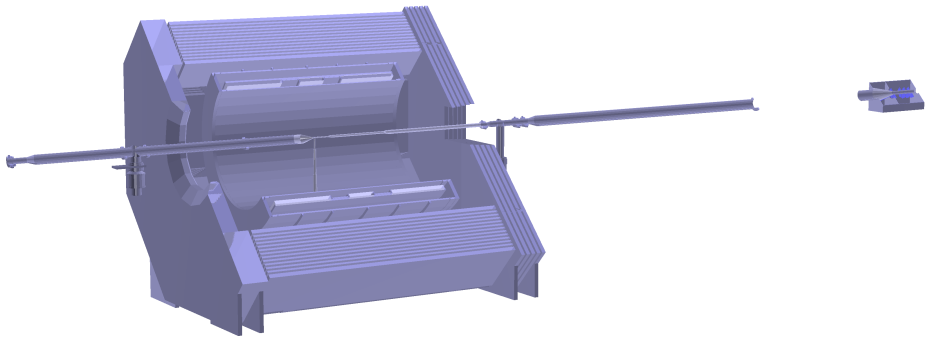
Plans

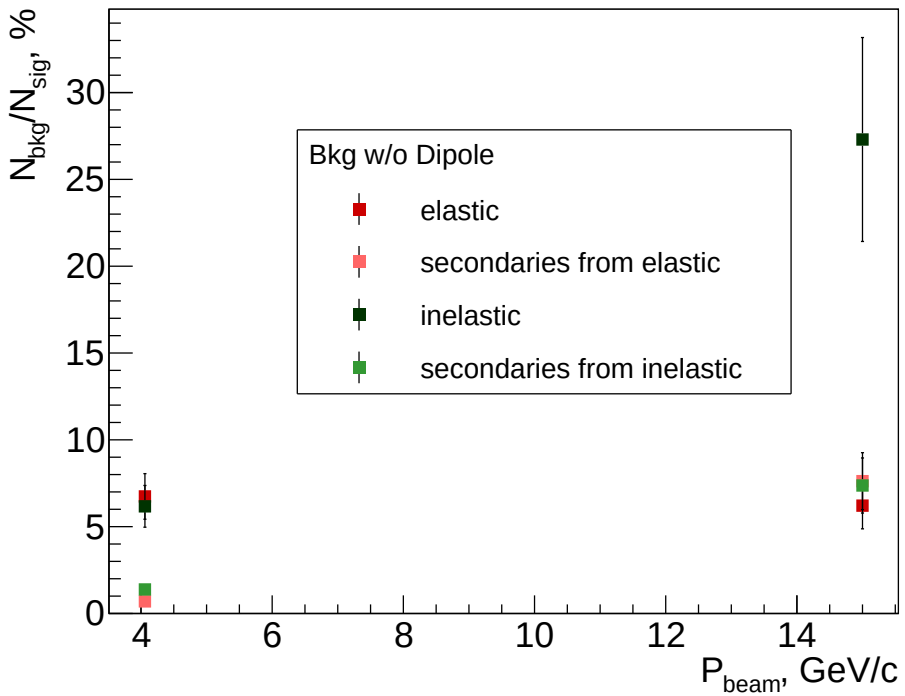
- DPM $\rightarrow$ FTF as inelastic background generator
- Synchronization with PANDA (time-based simulation)

Thank you for attention!

Just in case ...

Without Dipole Field

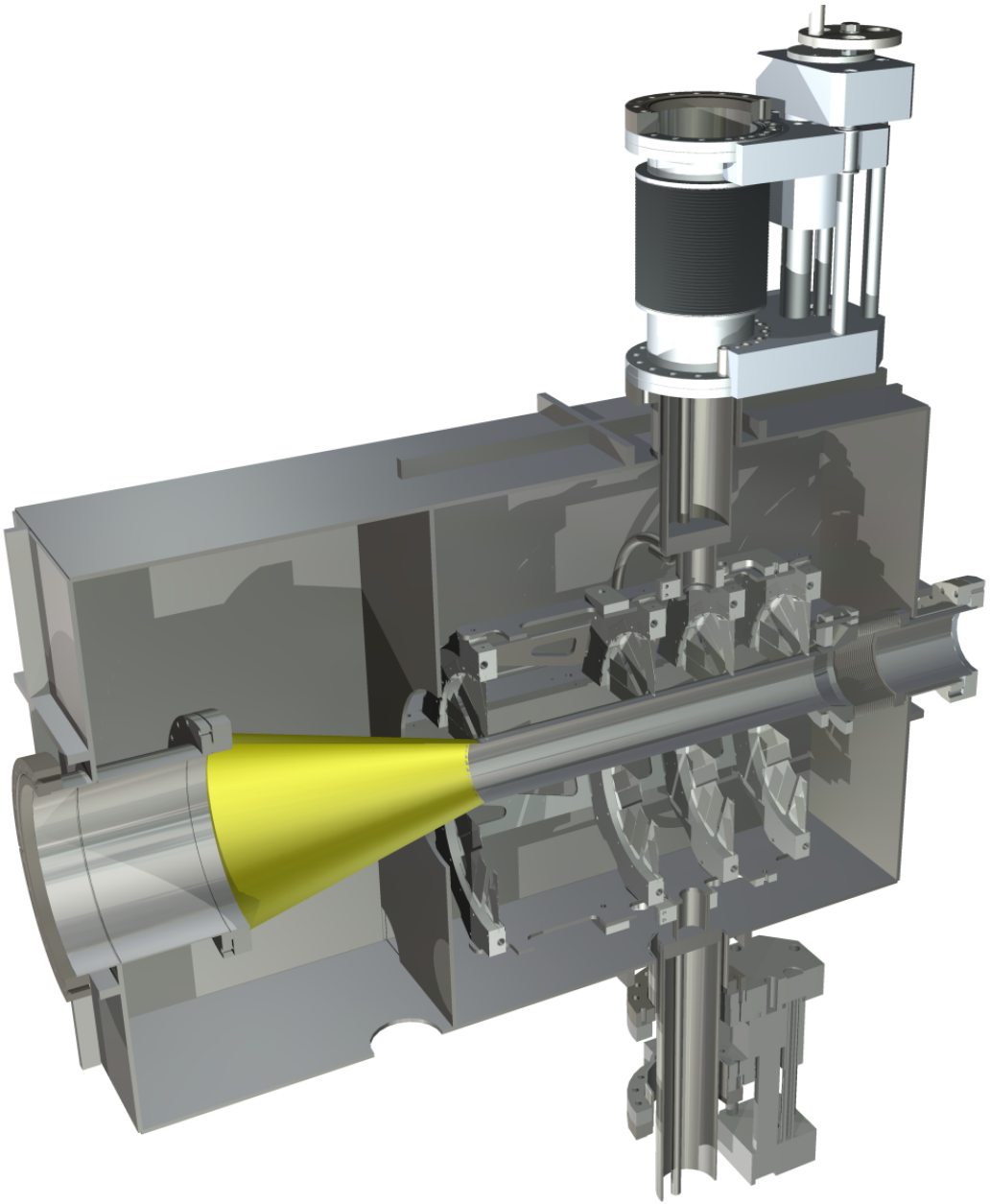




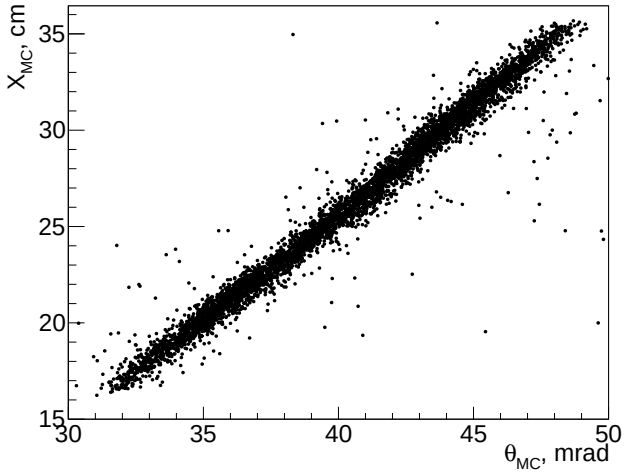
Total Background
@4.06 GeV/c:
14.99 ± 1.81 %
@15 GeV/c:
48.50 ± 6.44 %

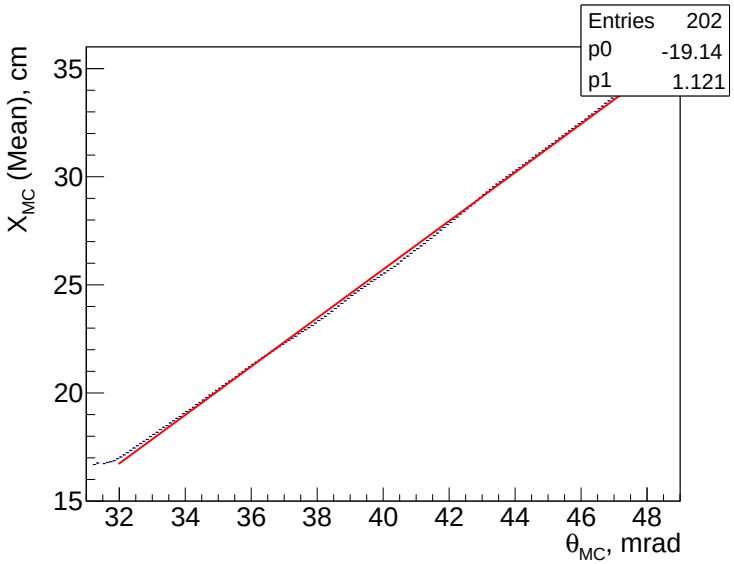
The Luminosity Detector

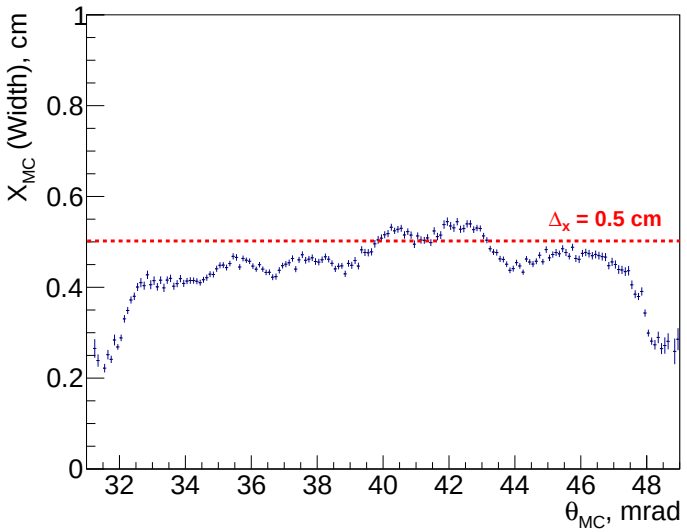
Design



Local cuts

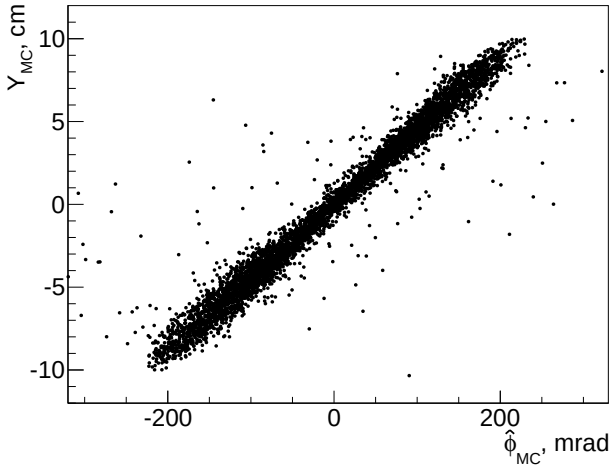


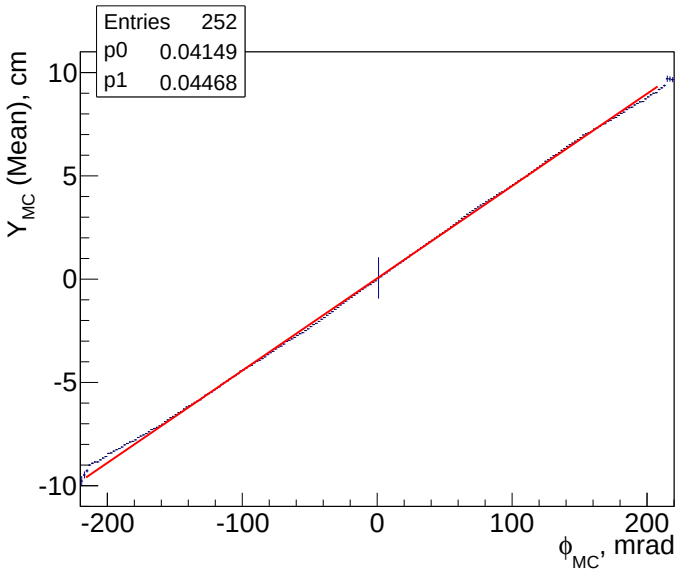


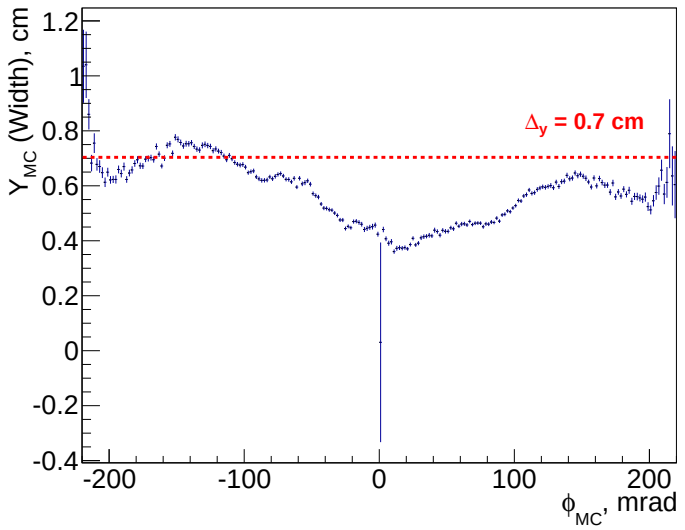


X&Y cut with $3\Delta_x$ and $3\Delta_y$ widths

Local cuts





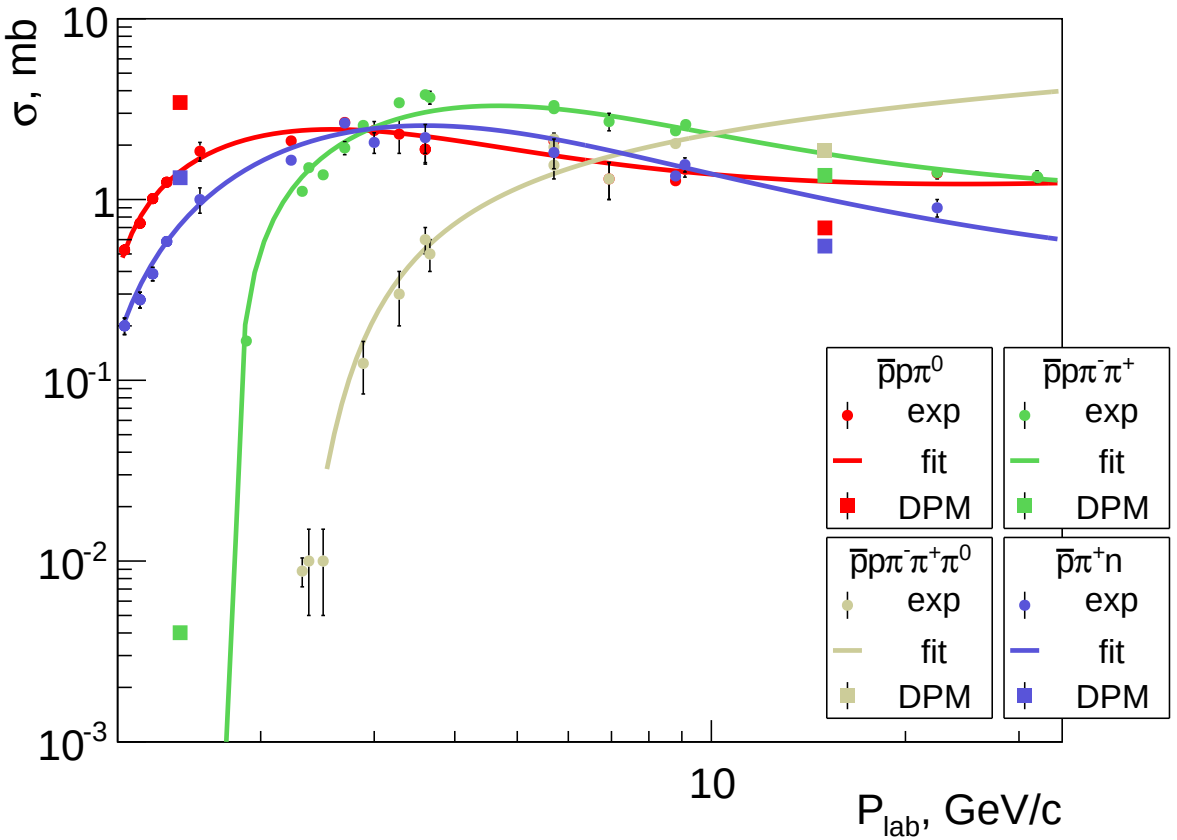


X&Y cut with $3\Delta_x$ and $3\Delta_y$ widths

DPM

check of cross-sections for inelastic channels

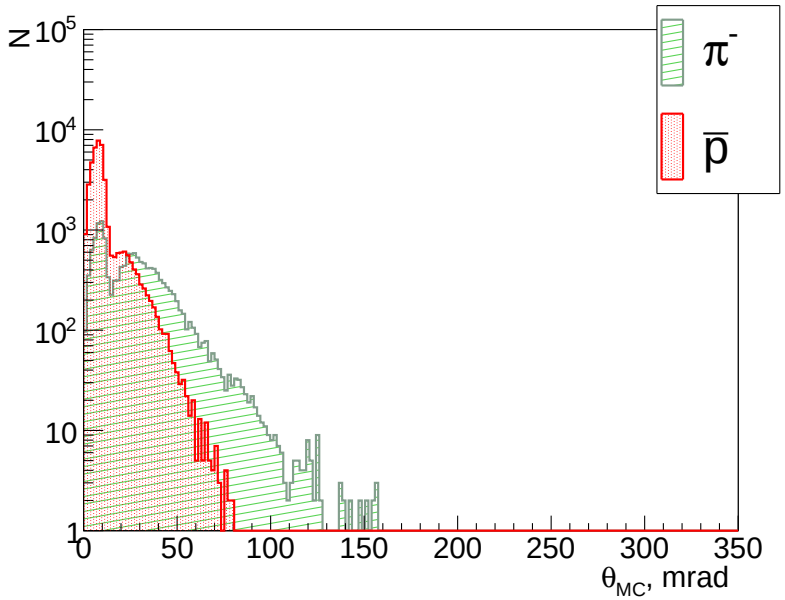
Exp.Data&Fit from "Classification of $\bar{p}p$ induced reaction" (A. Dbeyssi, E. Tomasi-Gustafsson)

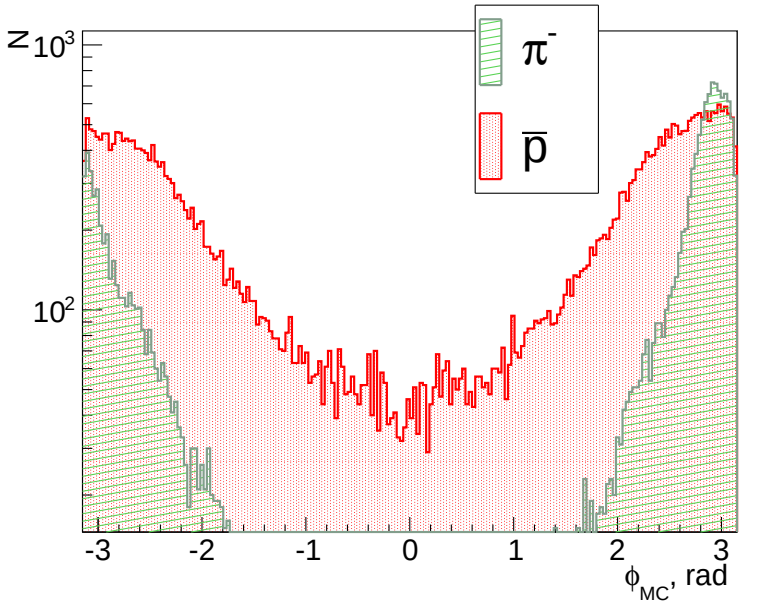


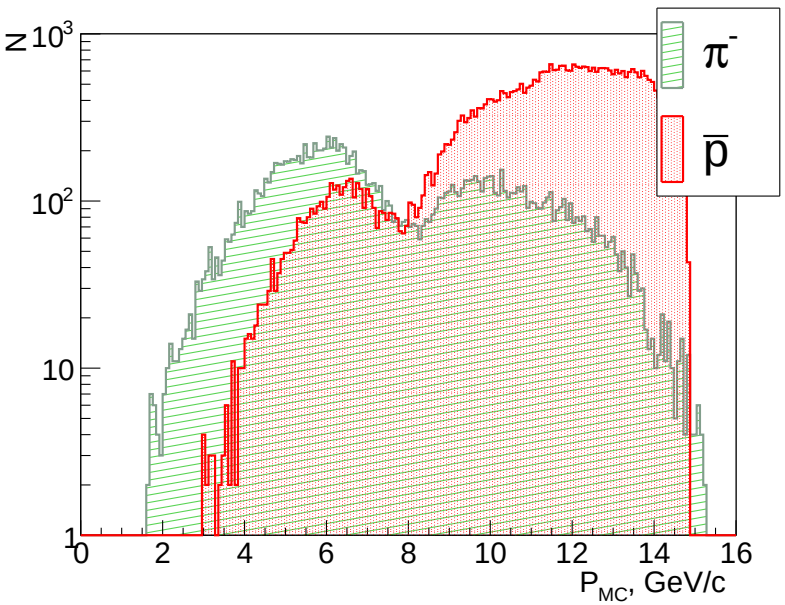
P_{beam}, GeV/c	$\sigma_{tot.inel}$, mb	Number of channels
1.5	62.72 ± 0.16	~ 400
15	40.38 ± 0.34	$\sim 13 \cdot 10^3$

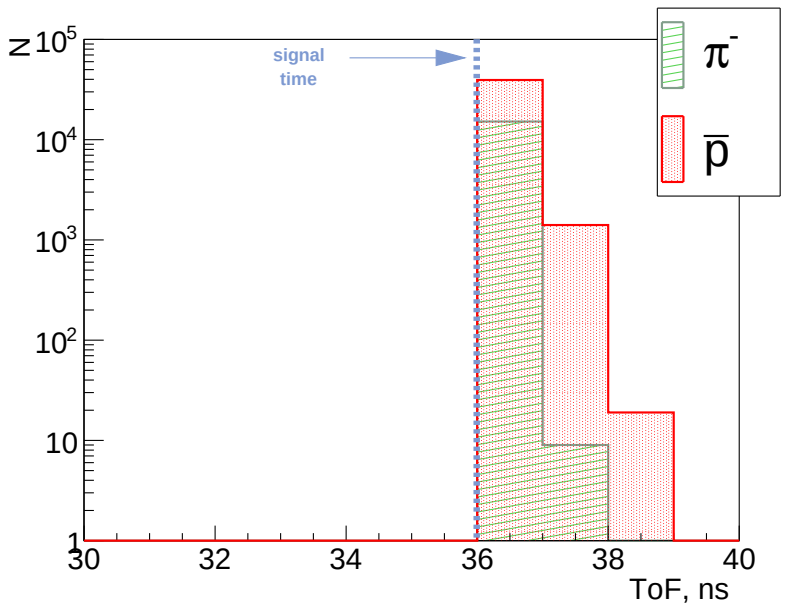
Results with DPM

True variables distributions (15 GeV/c): inelastic (no cuts)





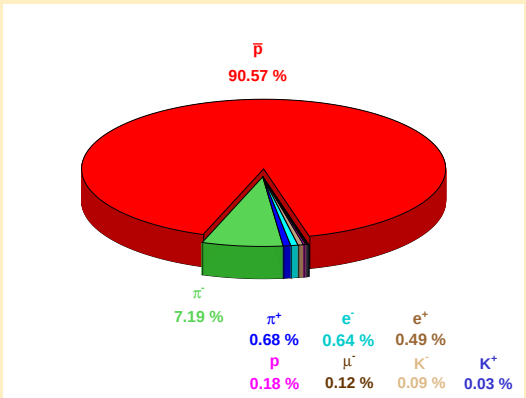


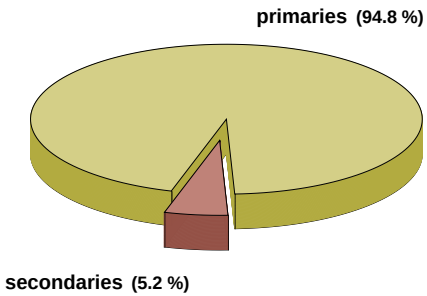


Results with DPM

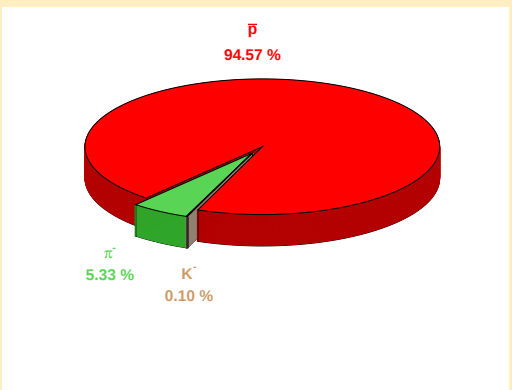
Particles contributions (15 GeV/c, after X&Y cuts)

Primary and Secondary

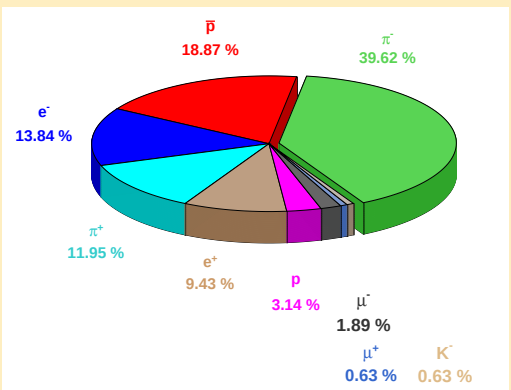




Primary

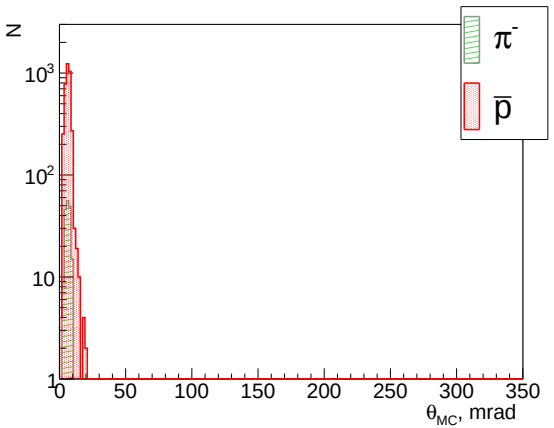


Secondary

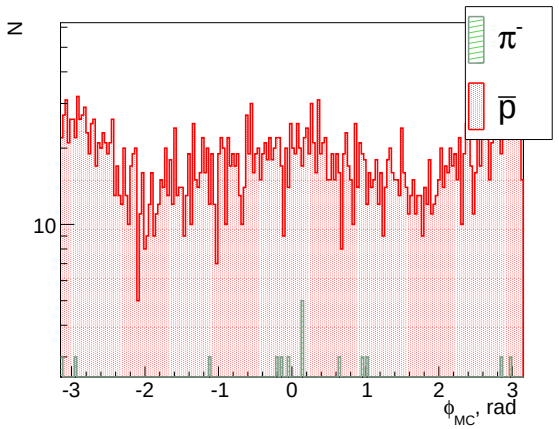


Results with DPM

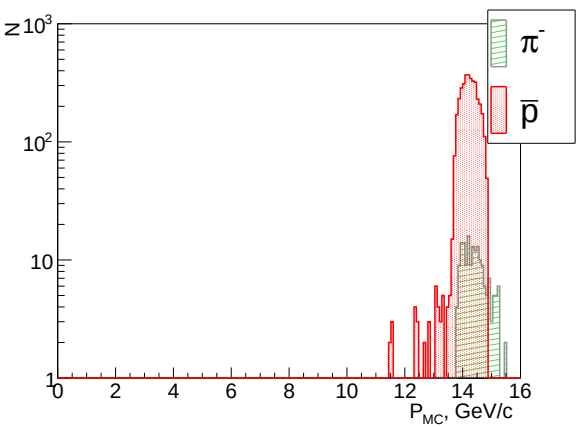
True variables distributions (15 GeV/c): inelastic (after X&Y cuts)



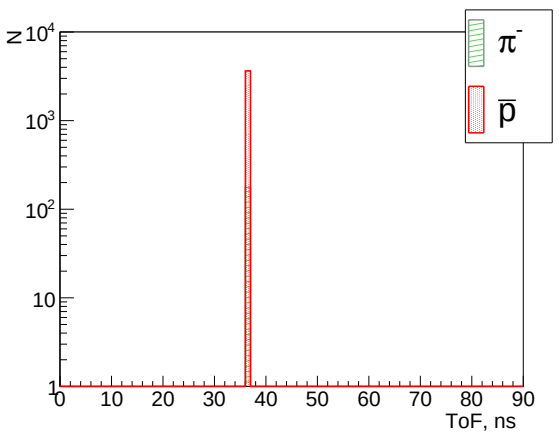
θ_{MC}



ϕ_{MC}



momentum$_{MC}$



Time of Flight

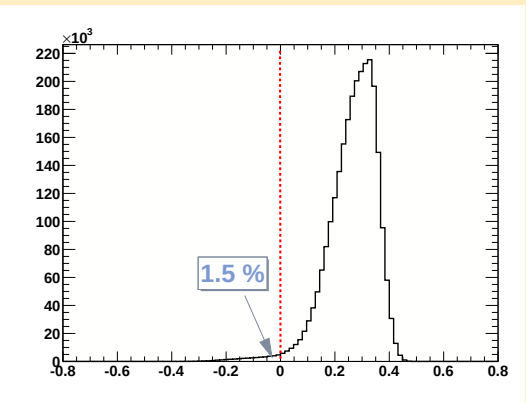
TMVA Results

M cut at P_{beam} 1.5 GeV/c

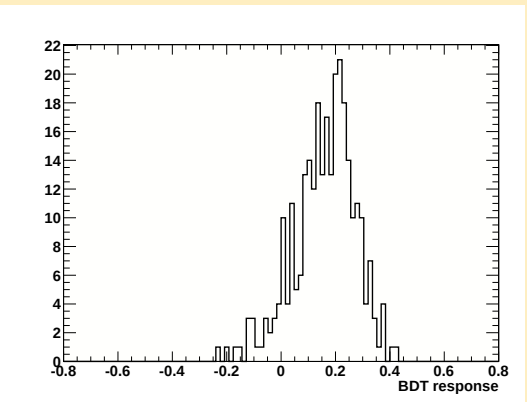
Training on reconstructed DPM elastic events

Signal: $|\theta_{MC}-\theta_{REC}|<3\sigma_\theta$, Background: $|\theta_{MC}-\theta_{REC}|>3\sigma_\theta$

Elastic



Inelastic



$\Rightarrow$