Implementing Pion and Kaon Structure Function Experiments at JLEIC

Pion and Kaon Structure at an Electron-Ion Collider

June 1-2nd, 2017 at ANL

Kijun Park

Why pion/kaon structure function is interested in ?

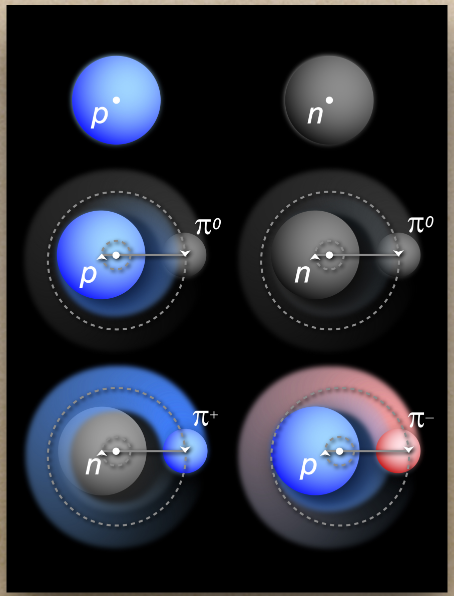
* To sensibly evolve PDFs, <u>must</u> include not only valence quarks but also sea & glue at hadronic scale
* Flavor dependence of DCSB modulates the strength of SU(3) flavor symmetry breaking in meson PDFs.

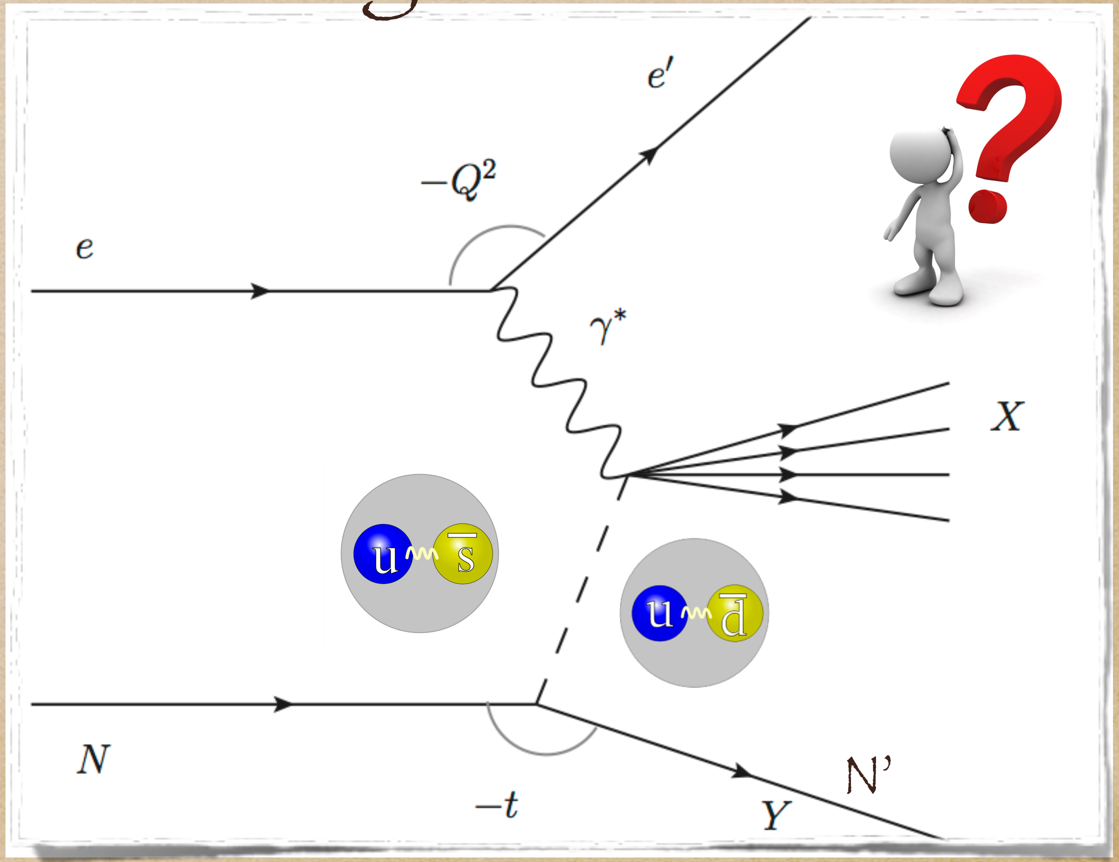
- C. Roberts

* Kaon structure function & Gluon content of kaon
  - Valence quarks carry 95% of kaon's momentum (LQCD & DSE) at perturbative hadronic scale
  - Owing to heavier mass of intermediate states that can introduce sea-quarks, therefore sea-quark content of kaon is effectively zero !!
  - LF-Momentum fraction carried by glue as a parameter through k/pi ratio of u-quark

Tagged Deep Inelastic Scattering (TDIS)

- Sullivan Process
  -> Hard electron scattering from meson(kaon) cloud of nucleon
- Direct measure the mesonic-nucleon content

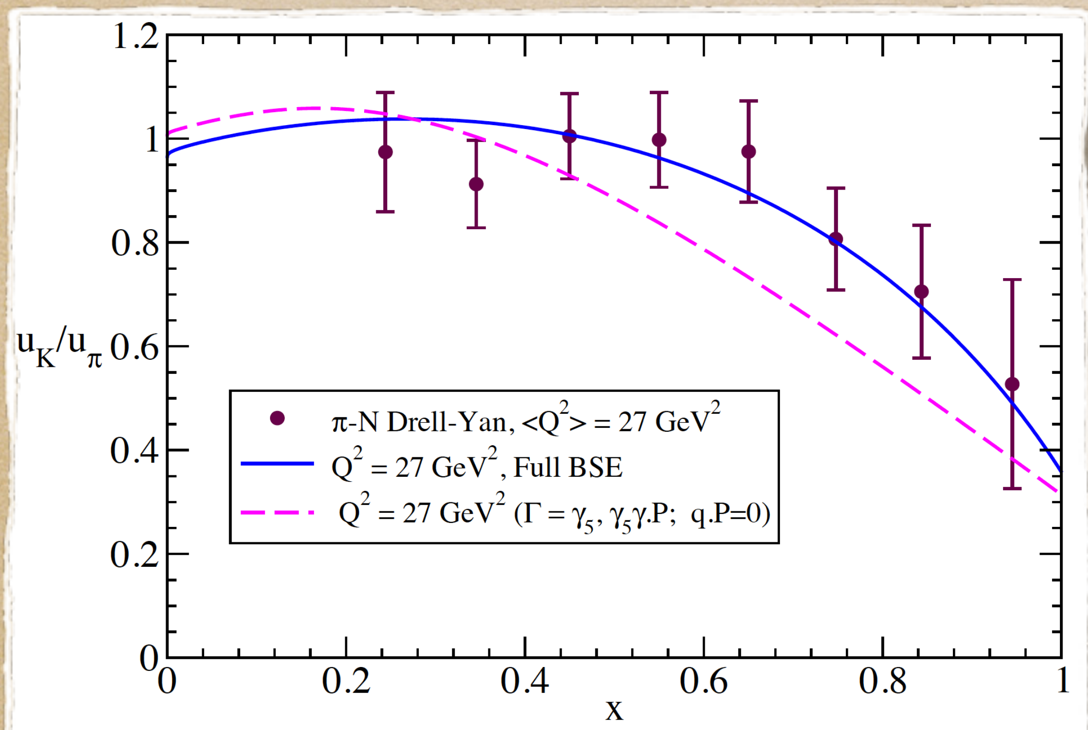




see Rik's Talk

Why pion/kaon structure function is interested in ?

NA3 Collaboration @ CERN (1980)

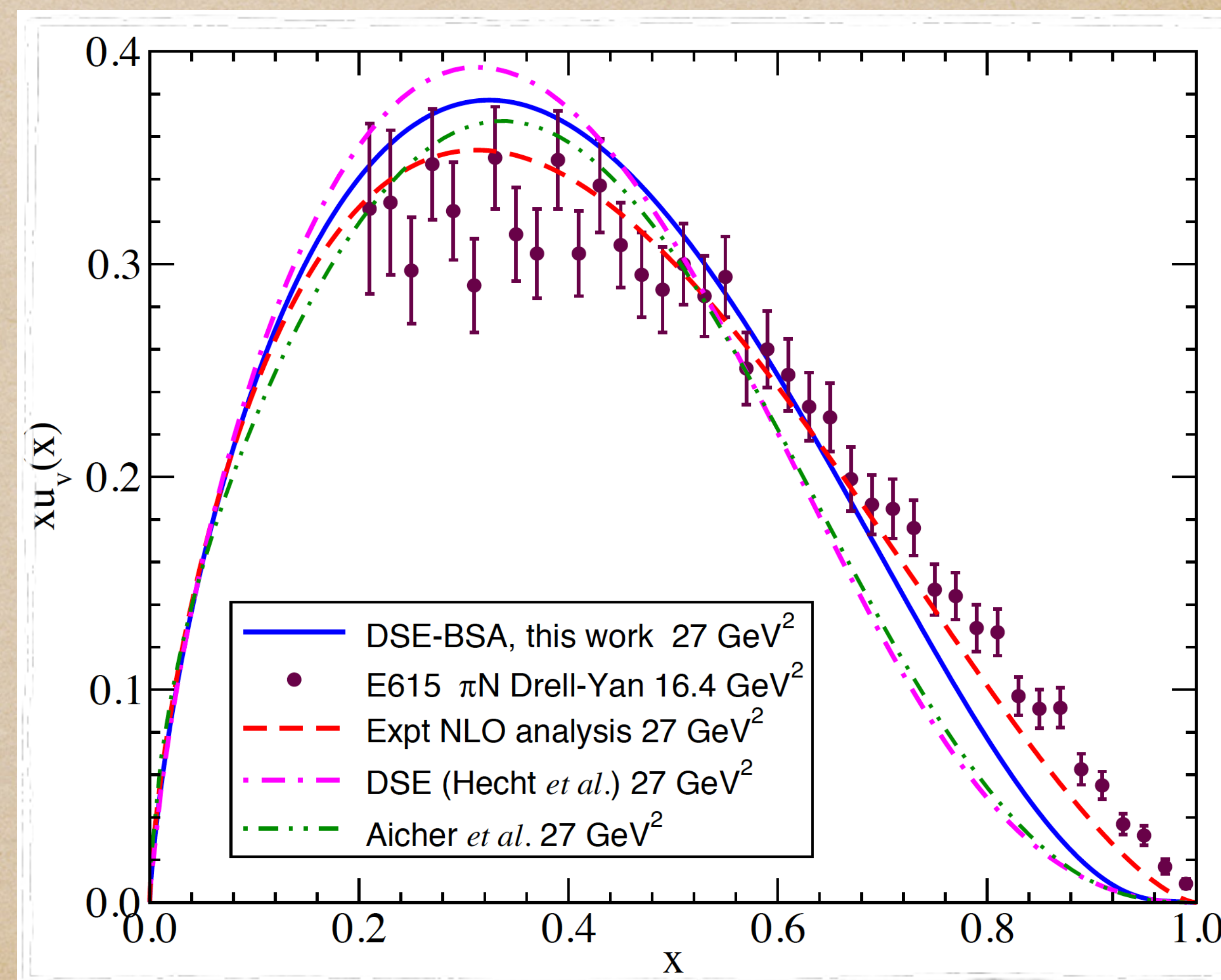


DSE prediction for the ratio of u-quark distributions in the kaon and pion

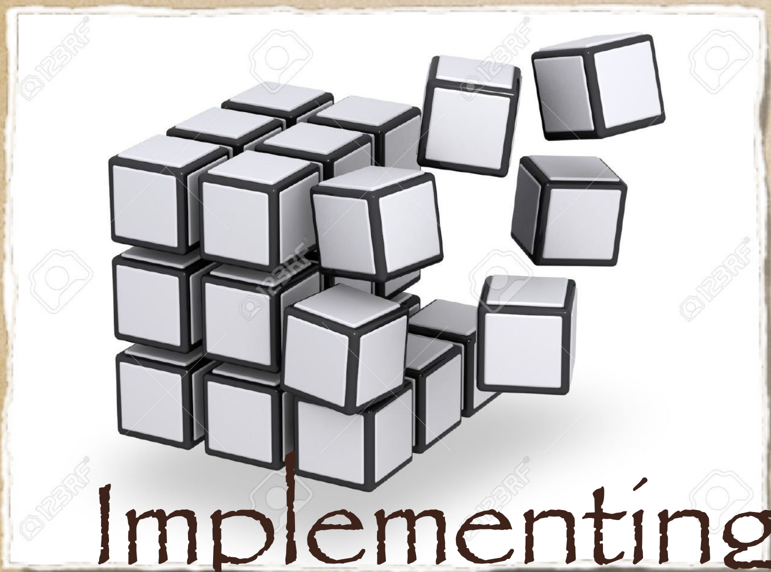
only Drell-Yan Process

see Craig's Talk

E615 Collaboration @ Fermilab (1989)



Pion valence quark distribution function evolution



Implementing Model into Event Generator

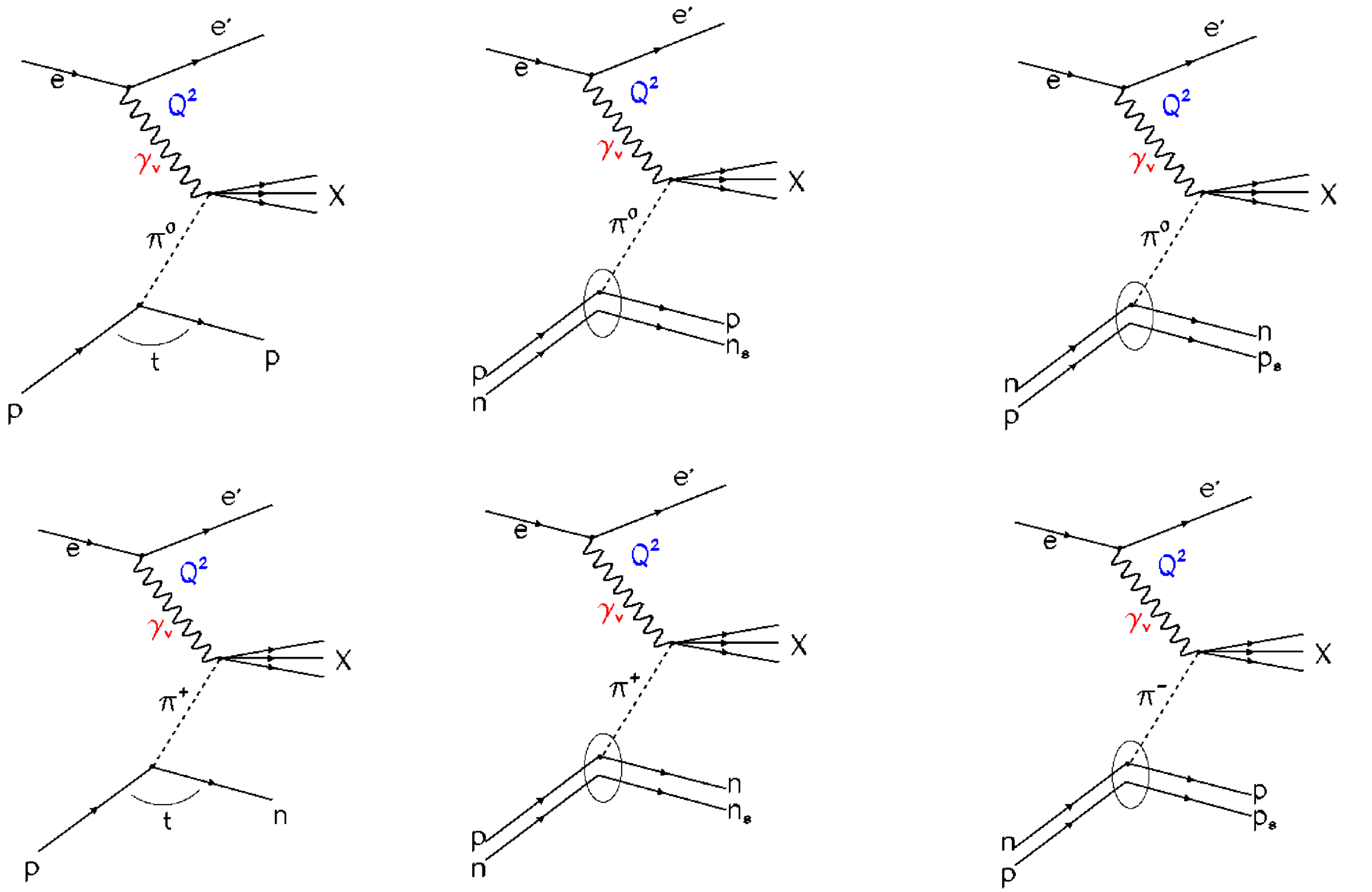
Tagged Deep Inelastic Scattering (TDIS) -Event Generator (EG)

INGREDIENTS

- Implementing accelerator info
  - Beam emittances($\epsilon^n_{e,i}$, $\beta^*_{e,i}$) IP, Cross-angle: 50 mrad, $[E_e x E_D]$ = [5x100] GeV^2, $p_R < 300$ MeV
  - Longitudinal p and angular spread of the beam: $dp/p = 3 \times 10^{-4}$, $d\theta = 2 \times 10^{-4}$
- User inputs:
  - cross-section model/ nucleon Struc.Func./ deuteron Wav.Func./
- Resolution and Uncertainty
  - Initial State Smearing (ISS) is $\ll \pm 1\%$
  - Intrinsic MC Statistical Uncertainty is $\leq 1\%$
  - Sufficient t' resolution for the onshell-extrapolation
  - FSI (D, on-going work, developement of theorety code)
- Codes are built with C^{++} (phase-space) and ROOT v5.34.34
- Very compact and stand alone code**(running MacOS/CentOS6.5)
  - TDISMC_EIC.cpp, TDISMC_EIC.h for proton tagged
  - TDISMC_EICn.cpp, TDISMC_EICn.h for neutron tagged
  - Theory Inputs:
  – moment_ld2b.dat
  – cteq/cteqpdf.h
  – cteq-tbls/ctq66m/ctq66.00.pds
- Produce outputs:
  - TDIS-MC05x100.root (Ntuple/Histograms)
  - TDIS_lund.txt (ASCII/GEMC Input)

Dissociation Mode

■ $ep \to e' XN$ ■ ■ $eD \to e' XNN_s$ ■ ■ $eD \to e' XNN_s$ ■



Neutral

Charged

Kinematic Variables

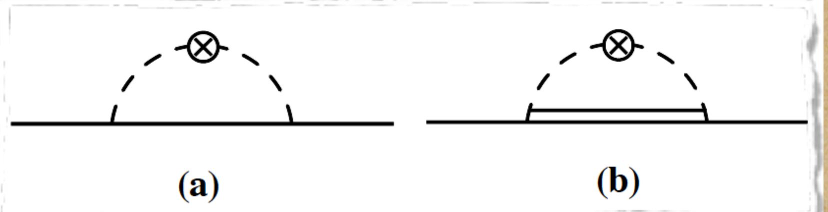
- x $(= x_{BJ})$: scaling variable, Bjorken x
- Q^2: virtuality of the exchanged photon $= -(k_i - k_f)^2$
- $y_e = \frac{Q^2}{x \cdot s}$: scaling variable, electron fractional energy loss in the target rest frame
- p^+: proton momentum in light cone frame
- k^+: pion momentum in light cone frame
- y**(or** z**)** $= \frac{k^+}{p^+}$**: light-cone momentum fraction of the initial nucleon carried by the interacting pion** (kaon)
- $x_F = 1 - y$: light-cone momentum fraction of the initial nucleon carried by the neutron
  $\rightarrow$ leading neutron production at HERA
- $x_\pi = \frac{x}{x_F} = \frac{x}{1-y}$: pion momentum fraction (x_K = kaon momentum fraction)

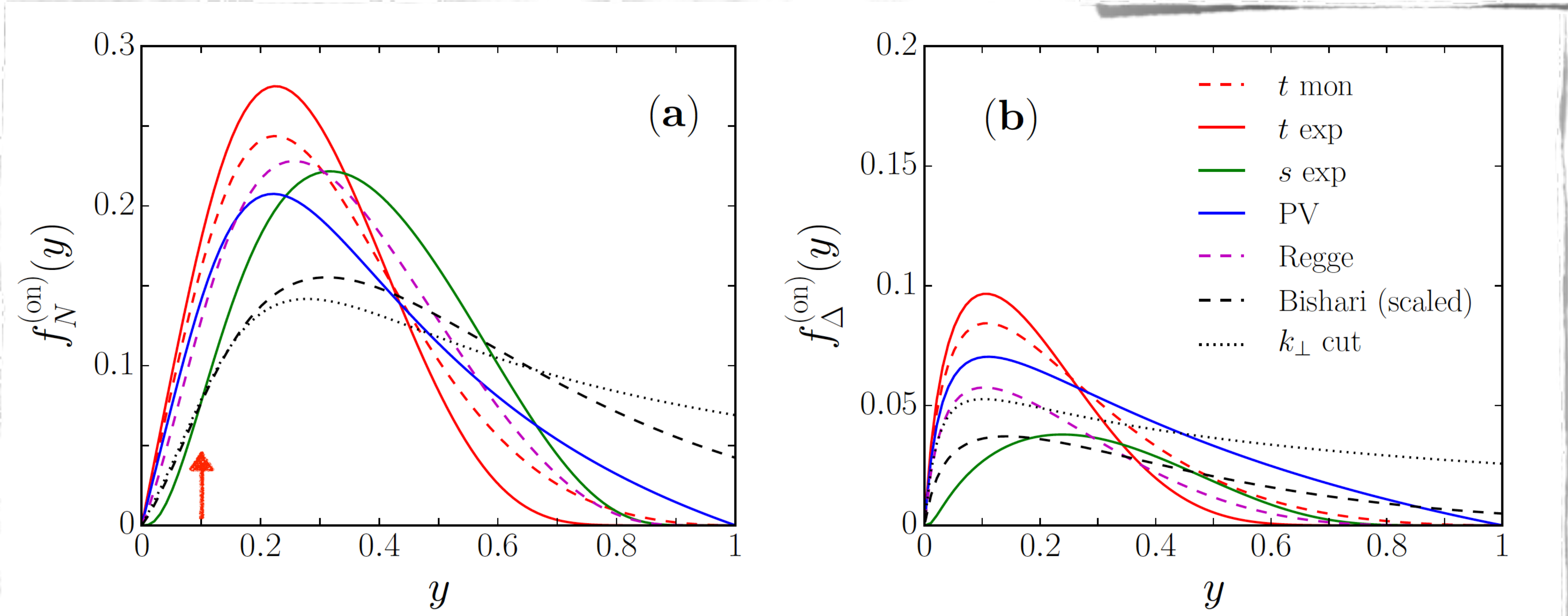
Splitting Function for Nucleon

see Wally's Talk

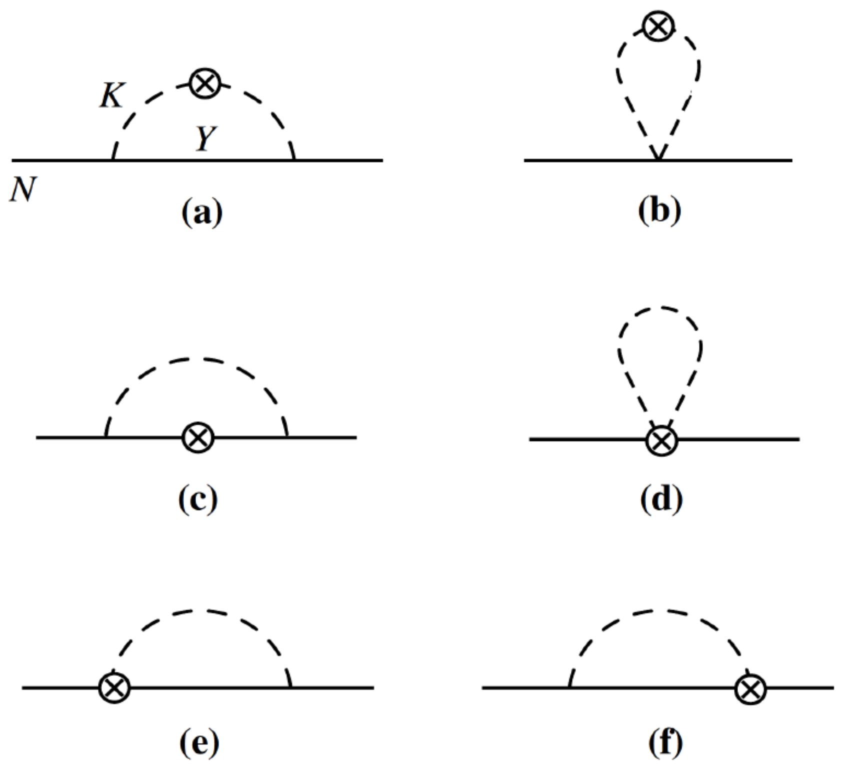
$$f_N^{(on)}(y) = \frac{g_A^2 M^2}{(4\pi f_\pi)^2} \int dk_\perp^2 \frac{y(k_\perp^2 + y^2 M^2)}{(1-y)^2 D_{\pi N}^2}$$

- M: nucleon mass, $g_A = 1.267$: axial charge, $f_\pi = 93$ MeV: pion decay constant
- $D_{\pi N}$: on-shell nucleon intermediate state
  $= t - m_\pi^2 = -\frac{1}{1-y}\left(k_\perp^2 + y^2 M^2 + (1-y) m_\pi^2\right)$
- $t = k^2 = -(k_\perp^2 + y^2 M^2)/(1-y)$: pion virtuality





Feynman Diagrams for KY



- (a) kaon rainbow
  $f_{KY}^{(rbw)}(y) = \kappa \left[f_Y^{(on)}(y) + f_K^{(\delta)}(y) \right]$
- (b) kaon buble diagram ($\bar{s}$ PDFs)
  $= f_K^{(bub)}(y)$
- (c) Hyperon rainbow
  $= f_{YK}^{(rbw)}(y)$
- (d) kaon tadpole (s PDFs)
  $= f_K^{(tad)}(y)$
- (e), (f) Kroll-Ruderman diagrams
  $= f_{YK}^{(KR)}(y)$

Fact:

arXiv.org > hep-ph > arXiv:1610.03333

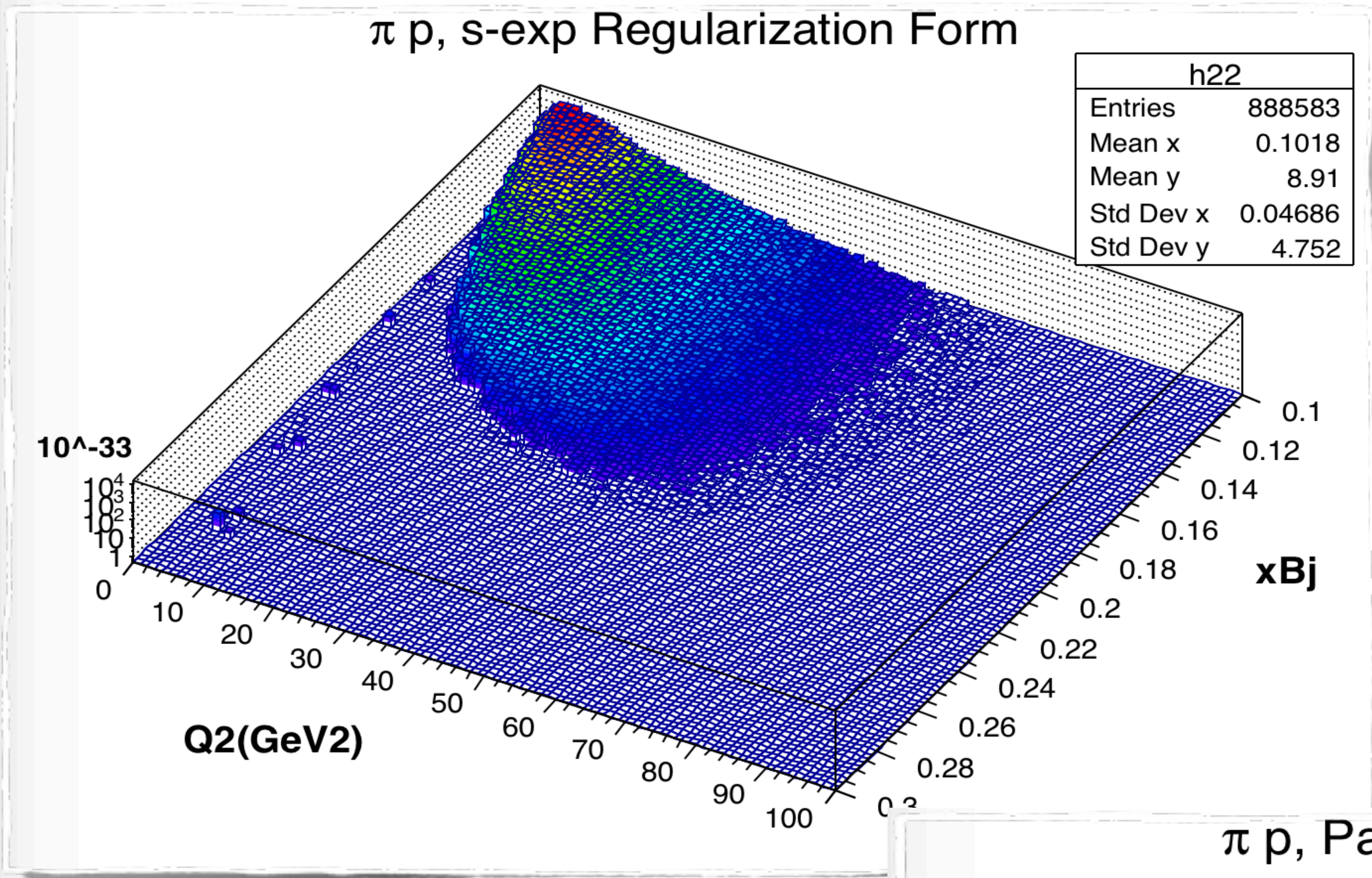
High Energy Physics – Phenomenology

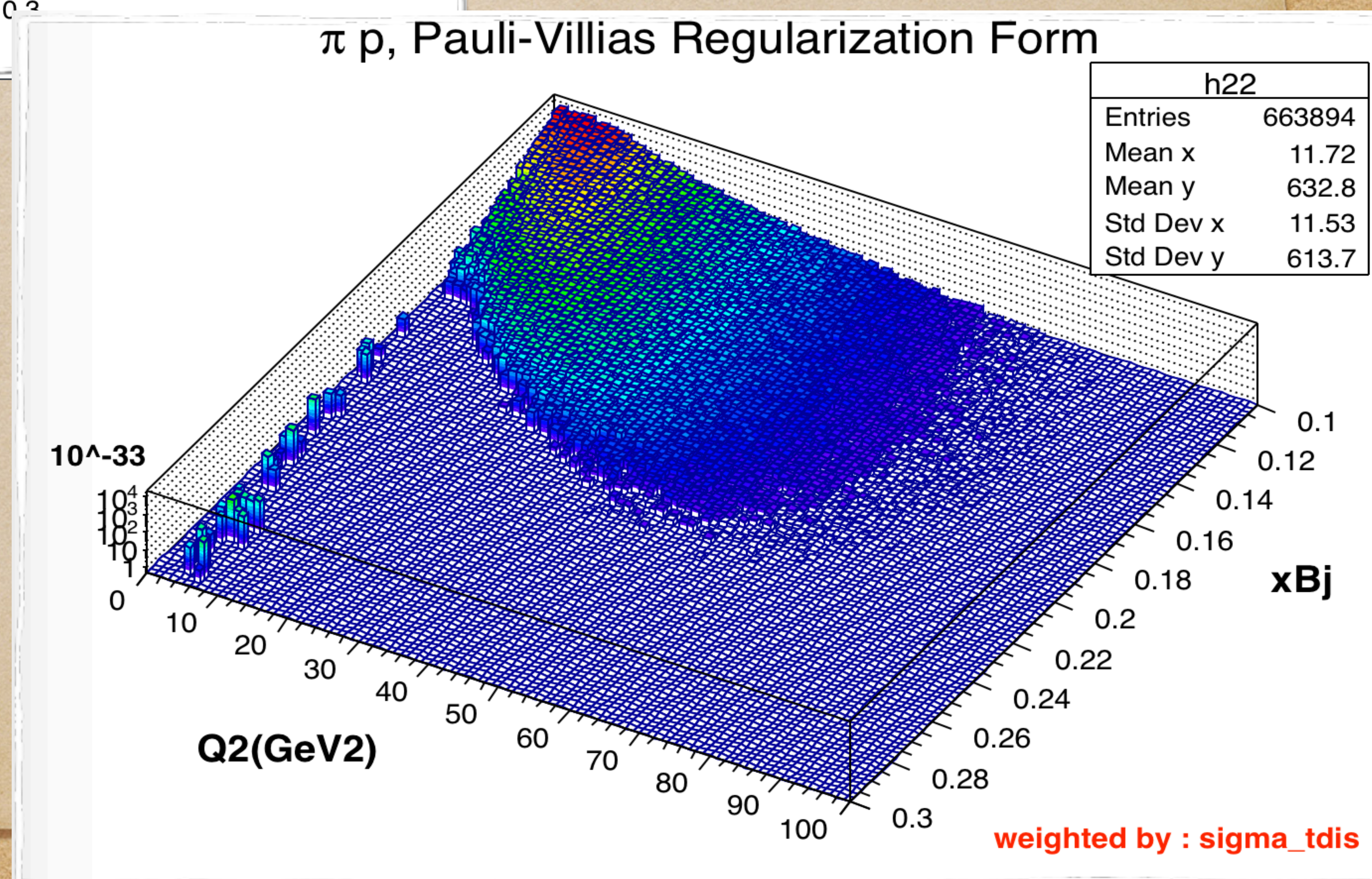
Strange quark asymmetry in the proton in chiral effective theory

X.G. Wang, Chueng-Ryong Ji, W. Melnitchouk, Y. Salamu, A.W. Thomas, P. Wang

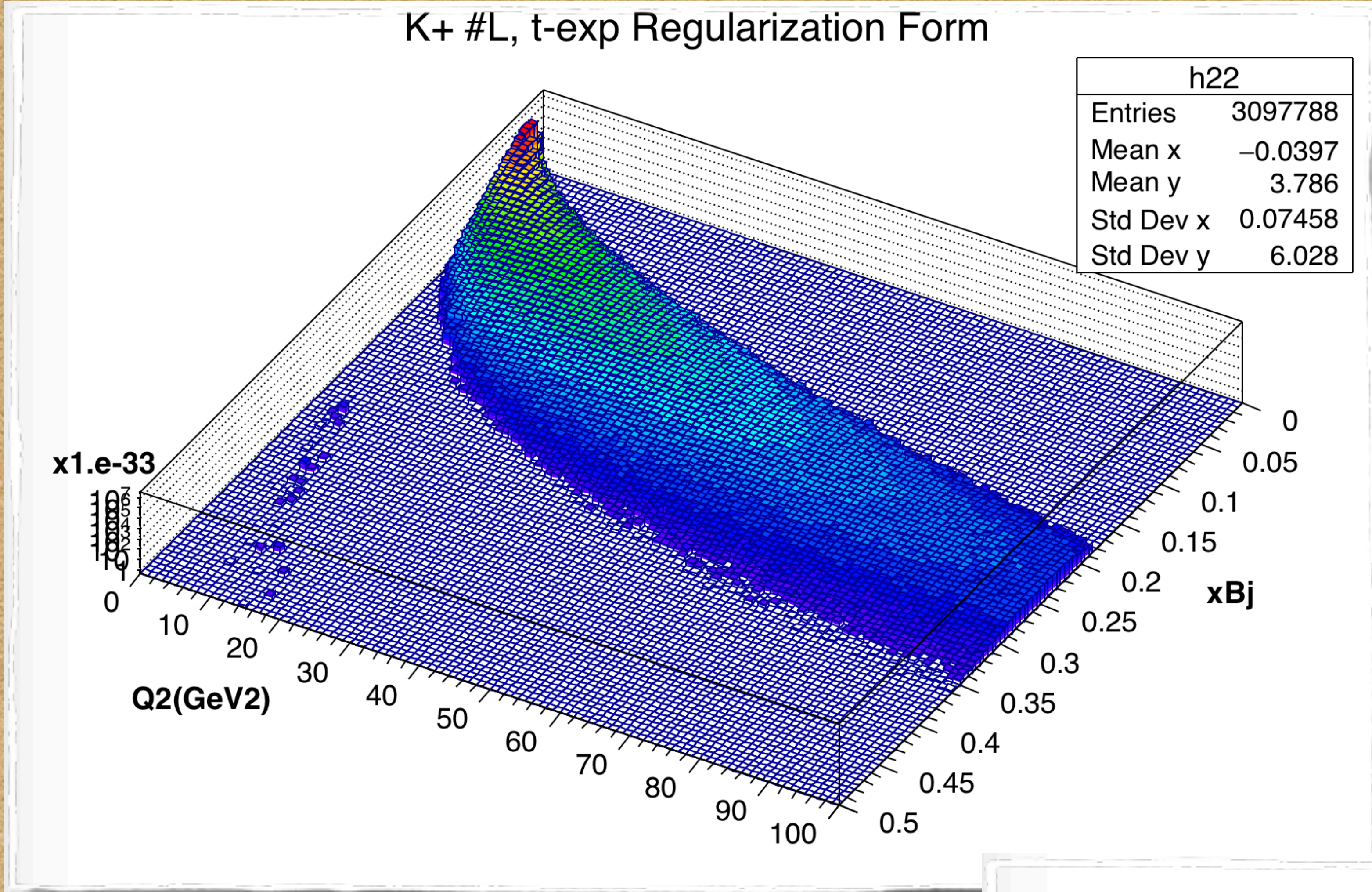
(Submitted on 11 Oct 2016)

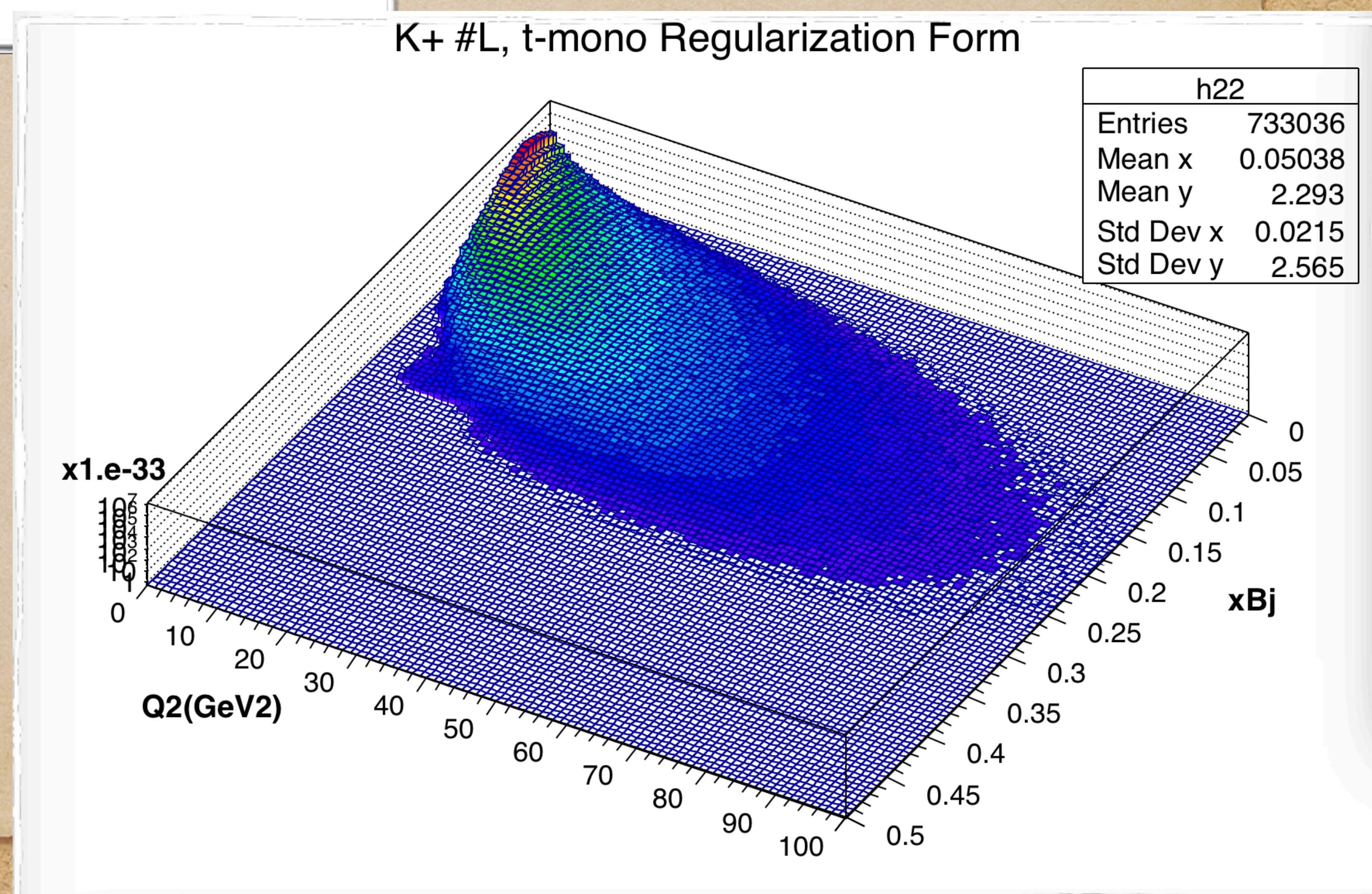
$ep \to e'p_sX$


π p, s-exp Regularization Form
h22
Entries 888583
Mean x 0.1018
Mean y 8.91
Std Dev x 0.04686
Std Dev y 4.752
10^-33
xBj
Q2(GeV2)

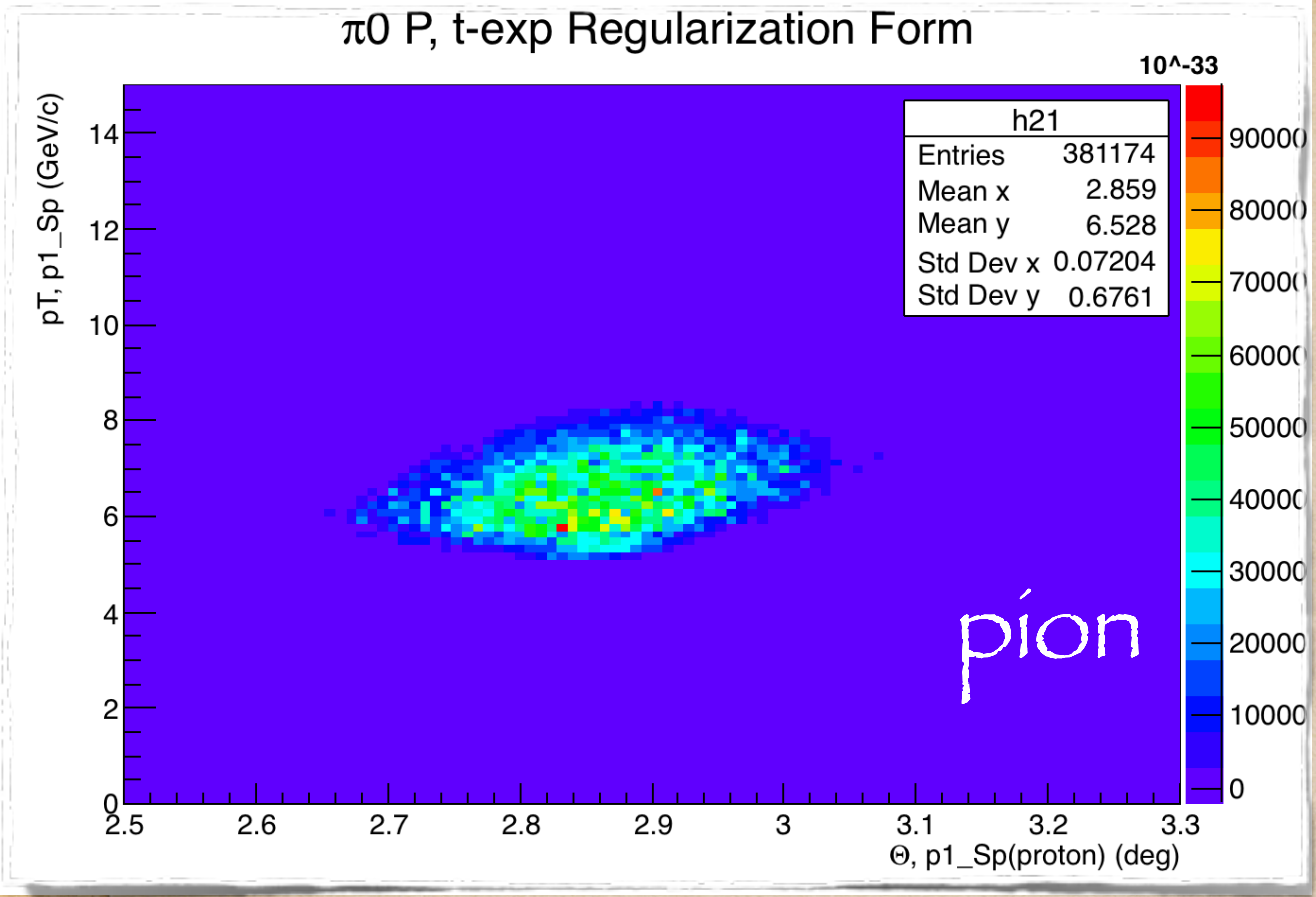

π p, Pauli-Villias Regularization Form
h22
Entries 663894
Mean x 11.72
Mean y 632.8
Std Dev x 11.53
Std Dev y 613.7
10^-33
xBj
Q2(GeV2)
weighted by : sigma_tdis

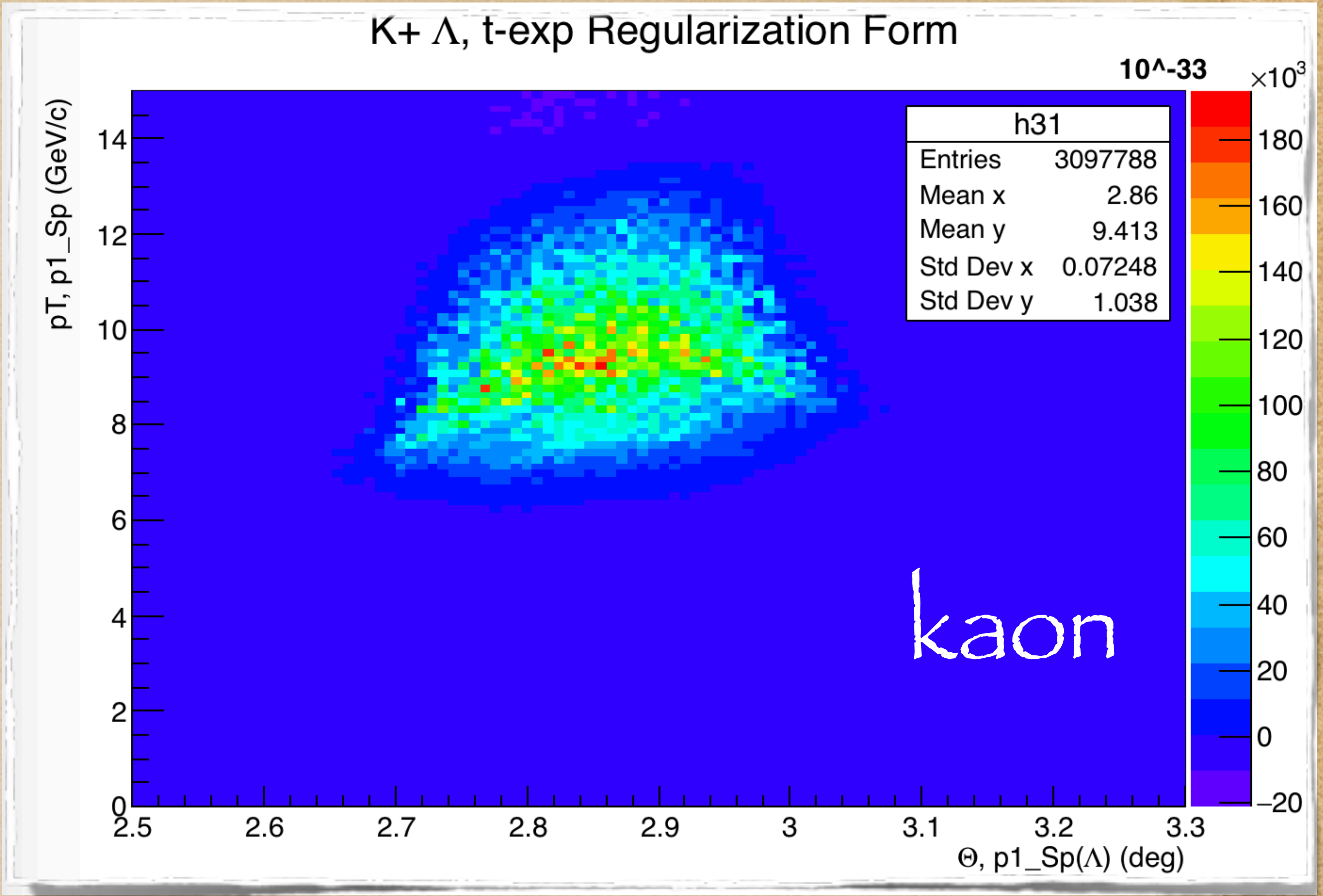
$ep \rightarrow e'\Lambda_s X$

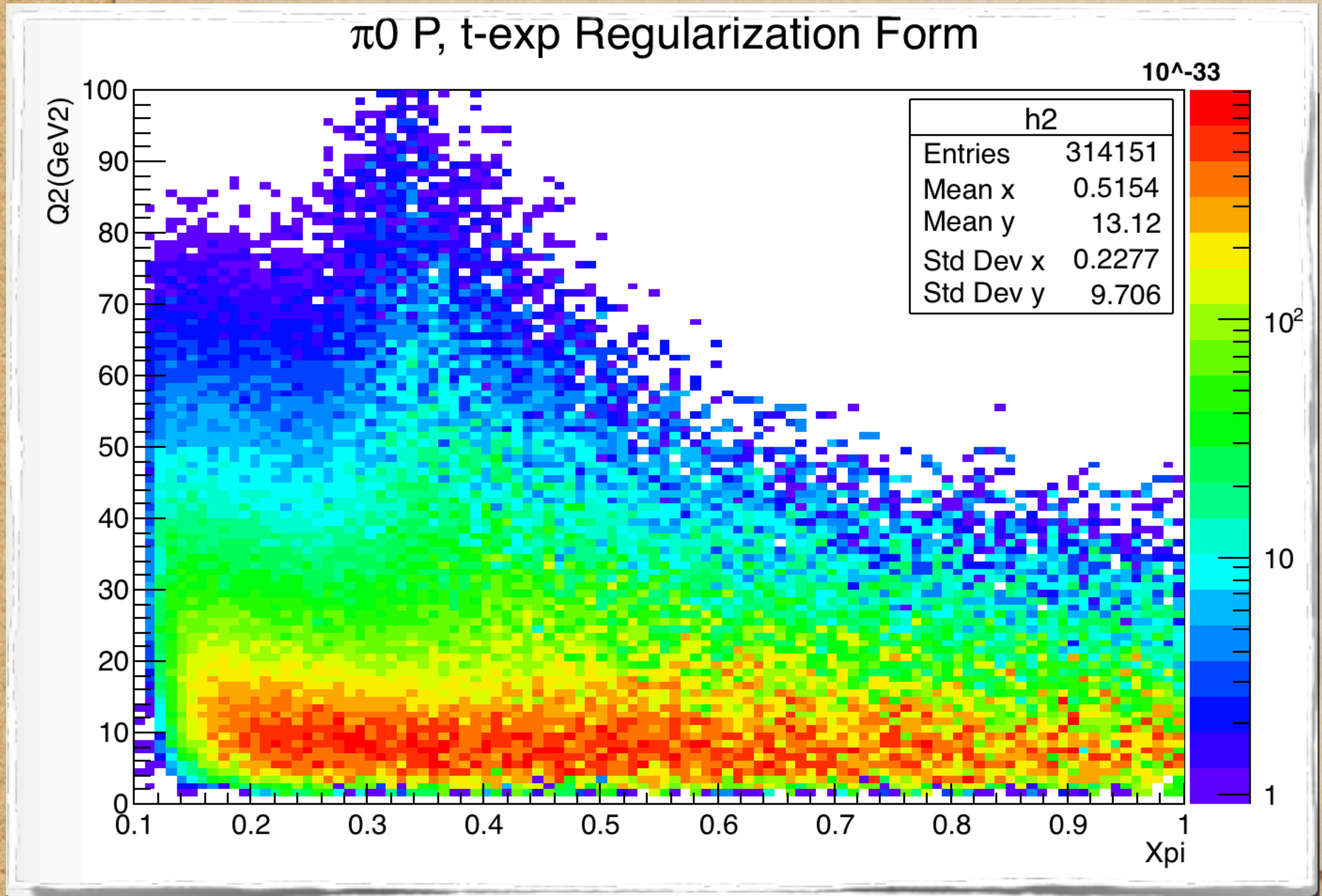


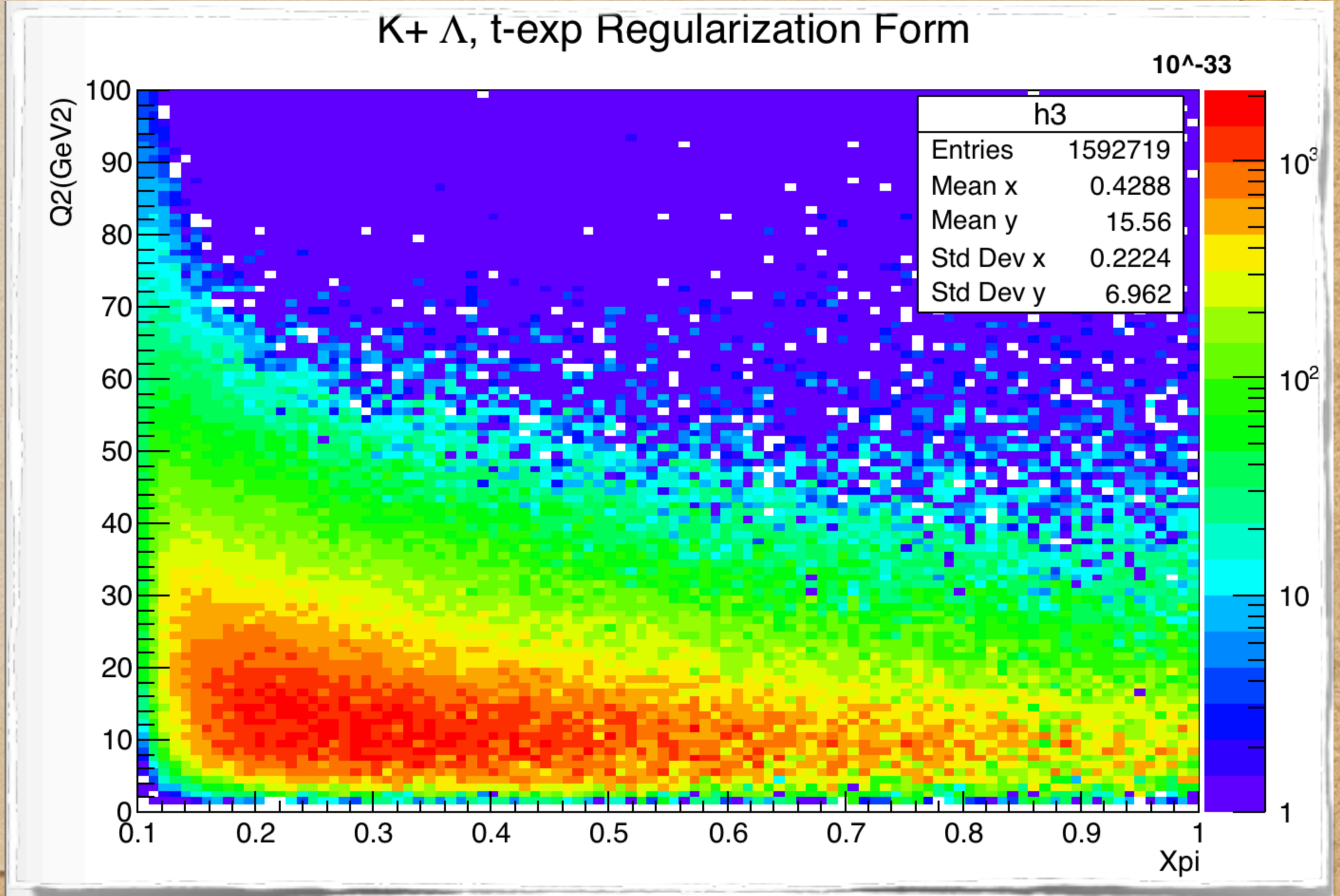


Kinematics for Pion and Kaon S.F. Simulations







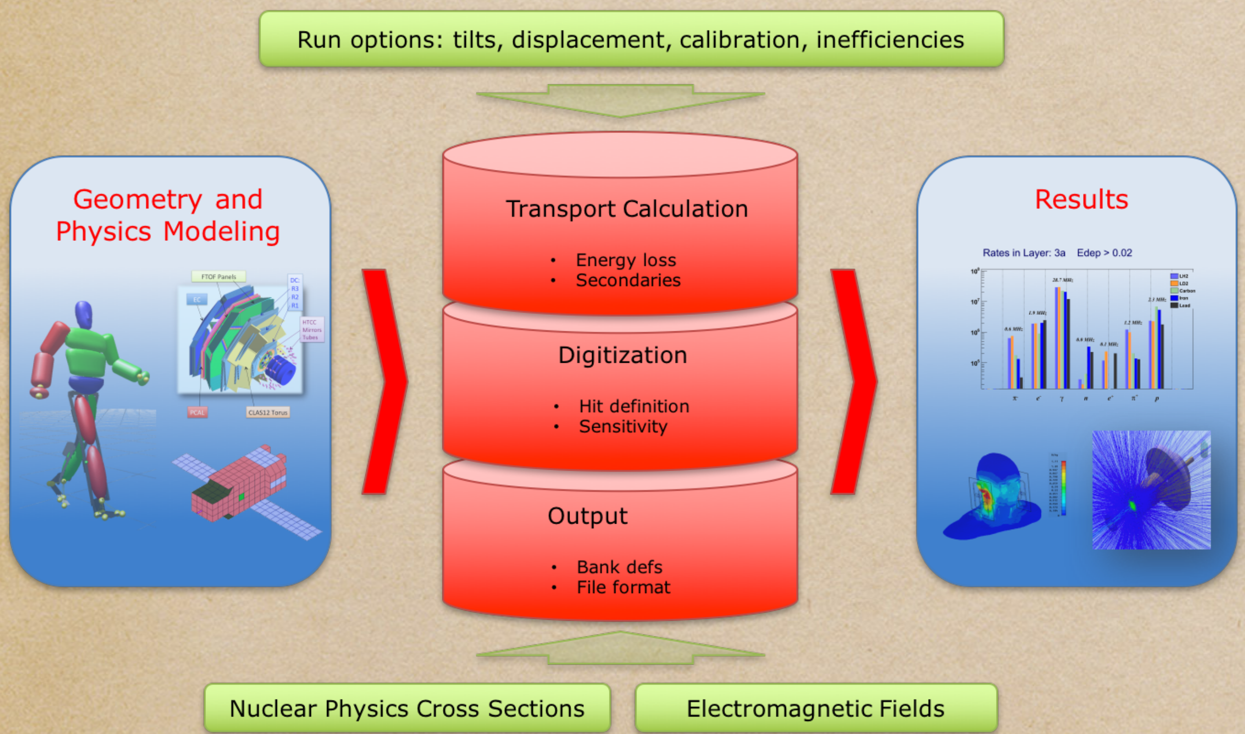


Detector Simulation for Acceptance

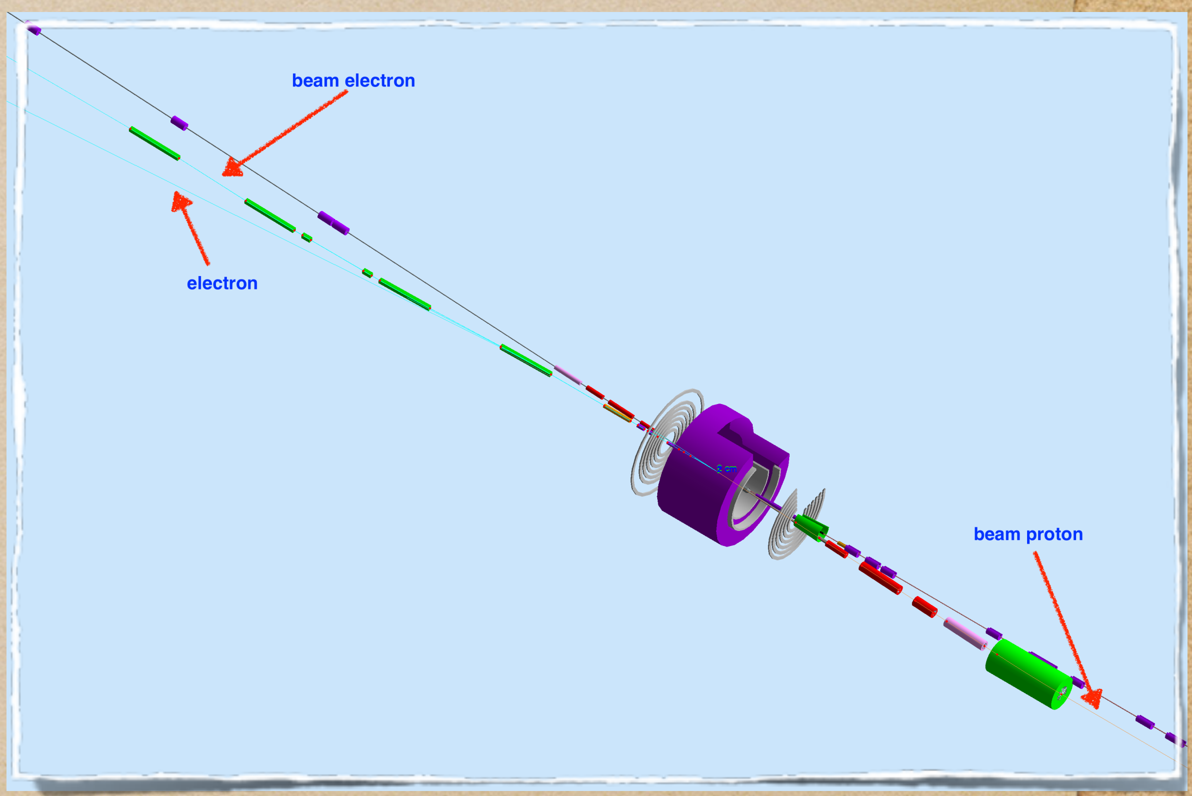
Plug event into GEMC: 5x100 GeV2, e/p beams

GEANT4MC

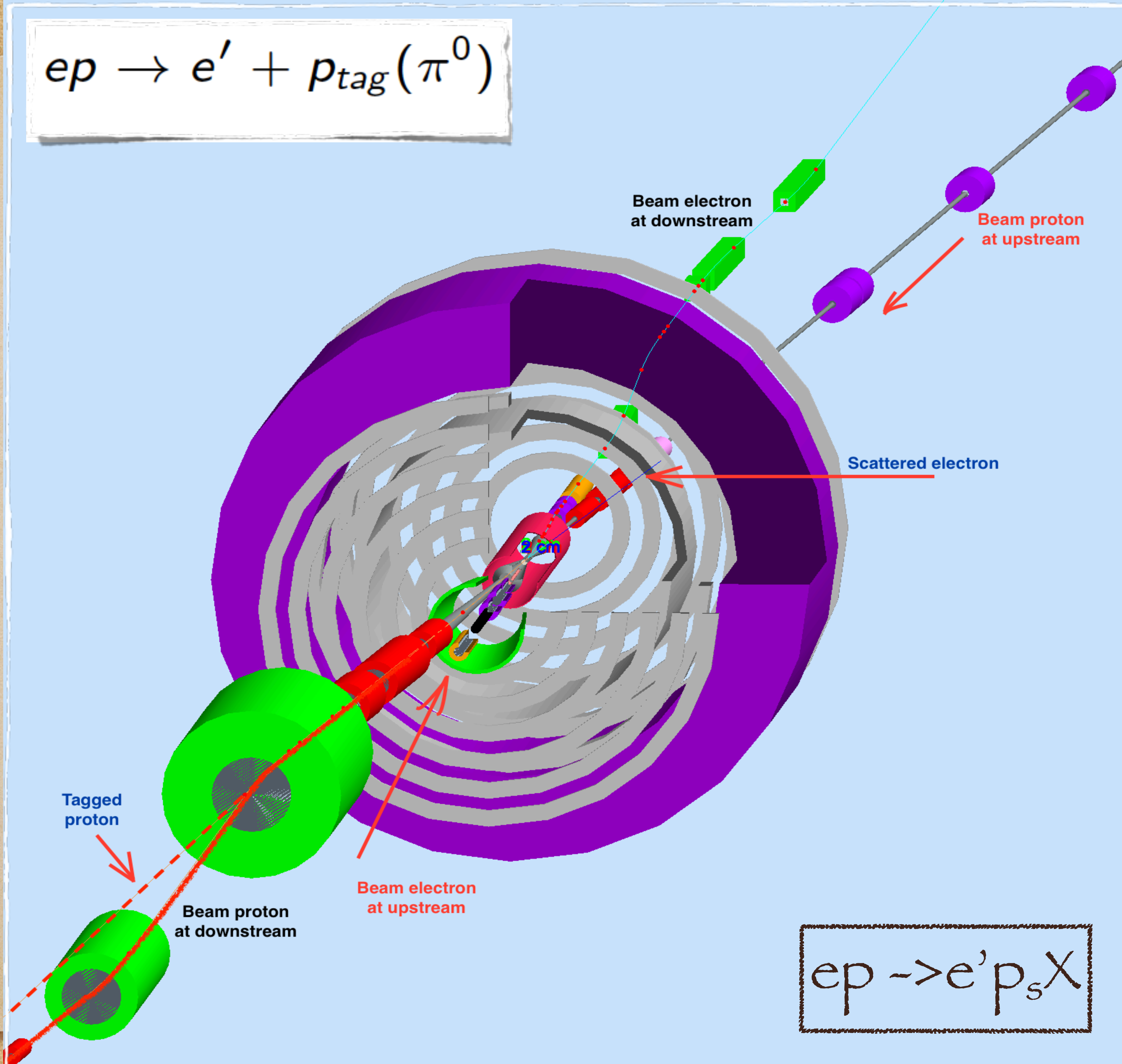
General EIC: see Rik's Talk



The architecture of gemc

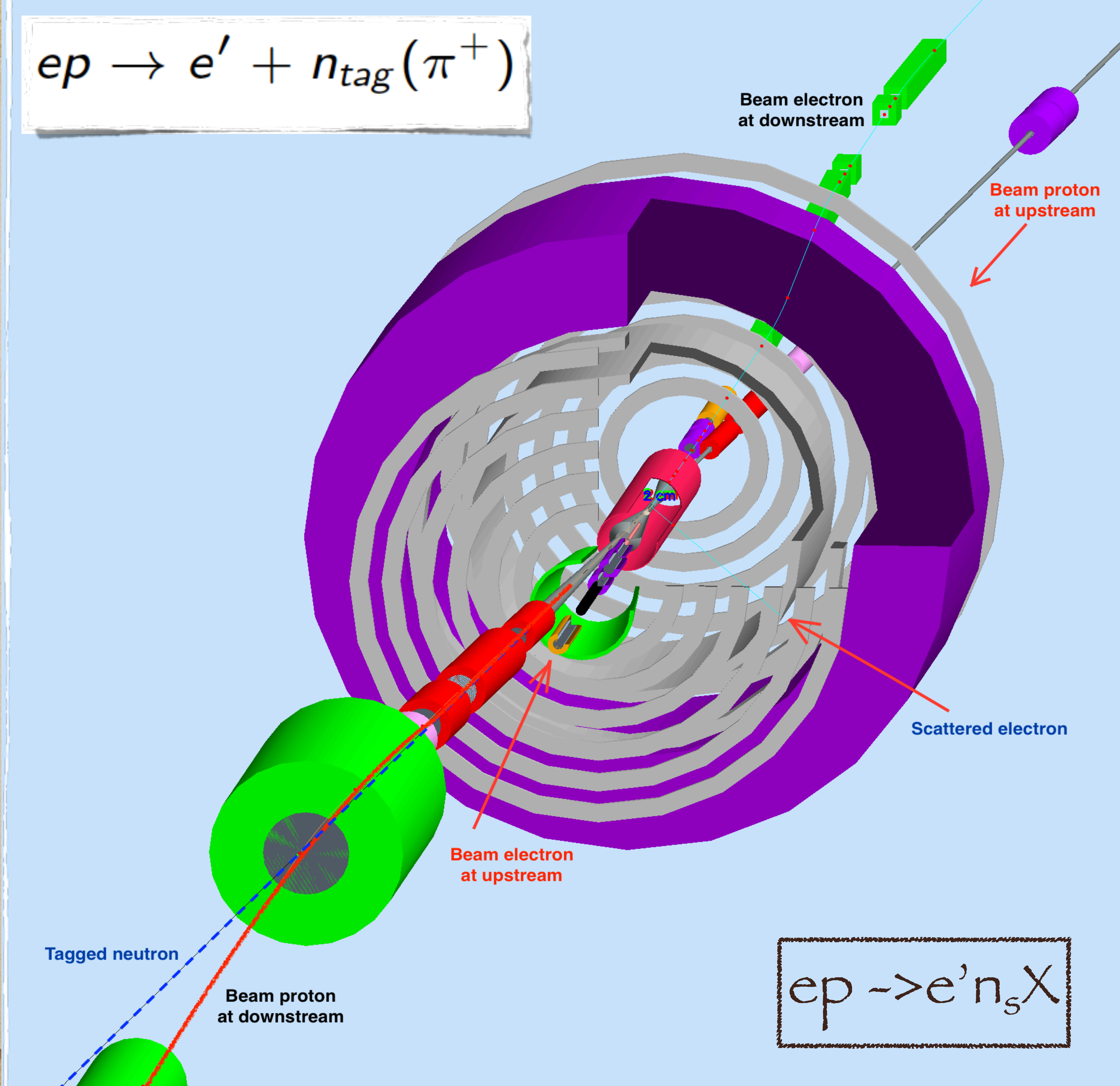


$$ep \to e' + p_{tag}(\pi^0)$$



$ep \to e' p_s X$

$$ep \rightarrow e' + n_{tag}(\pi^+)$$



$ep \rightarrow e' n_s X$

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****************************************************************************************
G4Track Information:   Particle = lambda,   Track ID = 4,   Parent ID = 0
****************************************************************************************

Step#    X(mm)    Y(mm)    Z(mm) KinE(MeV)  dE(MeV) StepLeng TrackLeng  NextVolume ProcName
    0        0        0        0  1.39e+05        0        0         0        root initStep
    1      -98     3.65 2.04e+03  1.39e+05        0 2.04e+03  2.04e+03 vac_det1_beamline_pipe_ionside_IonExtranceAperture Transportation
    2    -98.1     3.66 2.04e+03  1.39e+05        0        2  2.05e+03        root Transportation
    3     -240     8.94 4.99e+03  1.39e+05        0 2.95e+03     5e+03 det1_beamline_magnet_ion_downstream_dipole1_front Transportation
    4     -240     8.94 4.99e+03  1.39e+05        0    2e-07     5e+03 det1_beamline_magnet_ion_downstream_dipole1_inner Transportation
    5     -312     11.6 6.49e+03  1.39e+05        0  1.5e+03   6.5e+03 det1_beamline_magnet_ion_downstream_dipole1_back Transportation
    6     -312     11.6 6.49e+03  1.39e+05        0    2e-07   6.5e+03        root Transportation
    7     -336     12.5 6.99e+03  1.39e+05        0      500     7e+03 det1_beamline_magnet_ion_downstream_quadrupole1_front Transportation
    8     -336     12.5 6.99e+03  1.39e+05        0    2e-07     7e+03 det1_beamline_magnet_ion_downstream_quadrupole1_inner Transportation
    9     -393     14.7 8.19e+03  1.39e+05        0  1.2e+03   8.2e+03 det1_beamline_magnet_ion_downstream_quadrupole1_back Transportation
   10     -393     14.7 8.19e+03  1.39e+05        0    2e-07   8.2e+03        root Transportation
   11     -441     16.4 9.19e+03  1.39e+05        0    1e+03   9.2e+03 det1_beamline_magnet_ion_downstream_quadrupole2_front Transportation
   12     -441     16.4 9.19e+03  1.39e+05        0    2e-07   9.2e+03 det1_beamline_magnet_ion_downstream_quadrupole2_inner Transportation
   13     -556     20.7 1.16e+04  1.39e+05        0  2.4e+03  1.16e+04 det1_beamline_magnet_ion_downstream_quadrupole2_back Transportation
   14     -556     20.7 1.16e+04  1.39e+05        0    2e-07  1.16e+04        root Transportation
   15     -604     22.5 1.26e+04  1.39e+05        0    1e+03  1.26e+04 det1_beamline_magnet_ion_downstream_quadrupole3_front Transportation
   16     -604     22.5 1.26e+04  1.39e+05        0    2e-07  1.26e+04 det1_beamline_magnet_ion_downstream_quadrupole3_inner Transportation
   17     -662     24.7 1.38e+04  1.39e+05        0  1.2e+03  1.38e+04 det1_beamline_magnet_ion_downstream_quadrupole3_back Transportation
   18     -662     24.7 1.38e+04  1.39e+05        0    2e-07  1.38e+04        root Transportation
   19     -700     26.1 1.46e+04  1.39e+05        0      800  1.46e+04 det1_beamline_magnet_ion_downstream_solenoid1_front Transportation
   20     -700     26.1 1.46e+04  1.39e+05        0    2e-07  1.46e+04 det1_beamline_magnet_ion_downstream_solenoid1_inner Transportation
   21     -815     30.4   1.7e+04  1.39e+05        0  2.4e+03   1.7e+04 det1_beamline_magnet_ion_downstream_solenoid1_back Transportation
   22     -815     30.4   1.7e+04  1.39e+05        0    2e-07   1.7e+04        root Transportation
   23     -853     31.8 1.78e+04  1.39e+05        0      793  1.78e+04 det1_beamline_magnet_ion_downstream_dipole2_front Transportation
   24     -853     31.8 1.78e+04  1.39e+05        0    2e-07  1.78e+04 det1_beamline_magnet_ion_downstream_dipole2_inner Transportation
   25     -900     33.5 1.87e+04  1.39e+05        0      967  1.88e+04 det1_beamline_magnet_ion_downstream_dipole2_inner Decay

****************************************************************************************
G4Track Information:   Particle = proton,   Track ID = 6,   Parent ID = 4
****************************************************************************************

Step#    X(mm)    Y(mm)    Z(mm) KinE(MeV)  dE(MeV) StepLeng TrackLeng  NextVolume ProcName
    0     -900     33.5 1.87e+04  1.15e+05        0        0         0 det1_beamline_magnet_ion_downstream_dipole2_inner initStep
    1     -992     37.5 2.18e+04  1.15e+05 1.07e-22 3.04e+03  3.04e+03 det1_beamline_magnet_ion_downstream_dipole2_back Transportation
    2     -992     37.5 2.18e+04  1.15e+05 7.07e-33    2e-07  3.04e+03        root Transportation
    3 -1.16e+03     56.7 3.63e+04  1.15e+05 5.15e-22 1.45e+04  1.76e+04 det1_beamline_magnet_ion_downstream_dipole3_front Transportation
    4 -1.16e+03     56.7 3.63e+04  1.15e+05 7.07e-33    2e-07  1.76e+04 det1_beamline_magnet_ion_downstream_dipole3_inner Transportation
    5 -1.31e+03     61.9 4.03e+04  1.15e+05 1.42e-22    4e+03  2.16e+04 det1_beamline_magnet_ion_downstream_dipole3_back Transportation
    6 -1.31e+03     61.9 4.03e+04  1.15e+05 7.09e-33    2e-07  2.16e+04        root Transportation
    7 -1.7e+04      404     3e+05  1.15e+05  9.2e-21  2.6e+05  2.82e+05  OutOfWorld Transportation

****************************************************************************************
G4Track Information:   Particle = pi-,   Track ID = 5,   Parent ID = 4
****************************************************************************************

Step#    X(mm)    Y(mm)    Z(mm) KinE(MeV)  dE(MeV) StepLeng TrackLeng  NextVolume ProcName
    0     -900     33.5 1.87e+04  2.41e+04        0        0         0 det1_beamline_magnet_ion_downstream_dipole2_inner initStep
    1 -1.31e+03     45.9 2.18e+04  2.41e+04 1.11e-22 3.06e+03  3.06e+03 det1_beamline_magnet_ion_downstream_dipole2_back Transportation
    2 -1.31e+03     45.9 2.18e+04  2.41e+04 7.45e-33 2.05e-07  3.06e+03        root Transportation
    3 -6.39e+04   1.2e+03     3e+05  2.41e+04 1.04e-20 2.85e+05  2.88e+05  OutOfWorld Transportation

****************************************************************************************
* G4Track Information:   Particle = e-,   Track ID = 3,   Parent ID = 0
****************************************************************************************

Step#    X(mm)    Y(mm)    Z(mm) KinE(MeV)  dE(MeV) StepLeng TrackLeng  NextVolume ProcName
    0        0        0        0  6.89e+03        0        0         0        root initStep
    1     4.48     31.9    -5.87  6.89e+03 1.63e-24     32.8      32.8 vac_det1_beamline_pipe_eleside_VertexChamber Transportation
    2     4.62     32.9    -6.05  6.89e+03    0.298     1.02      33.8 vac_det1_beamline_pipe_ionside_VertexChamber Transportation
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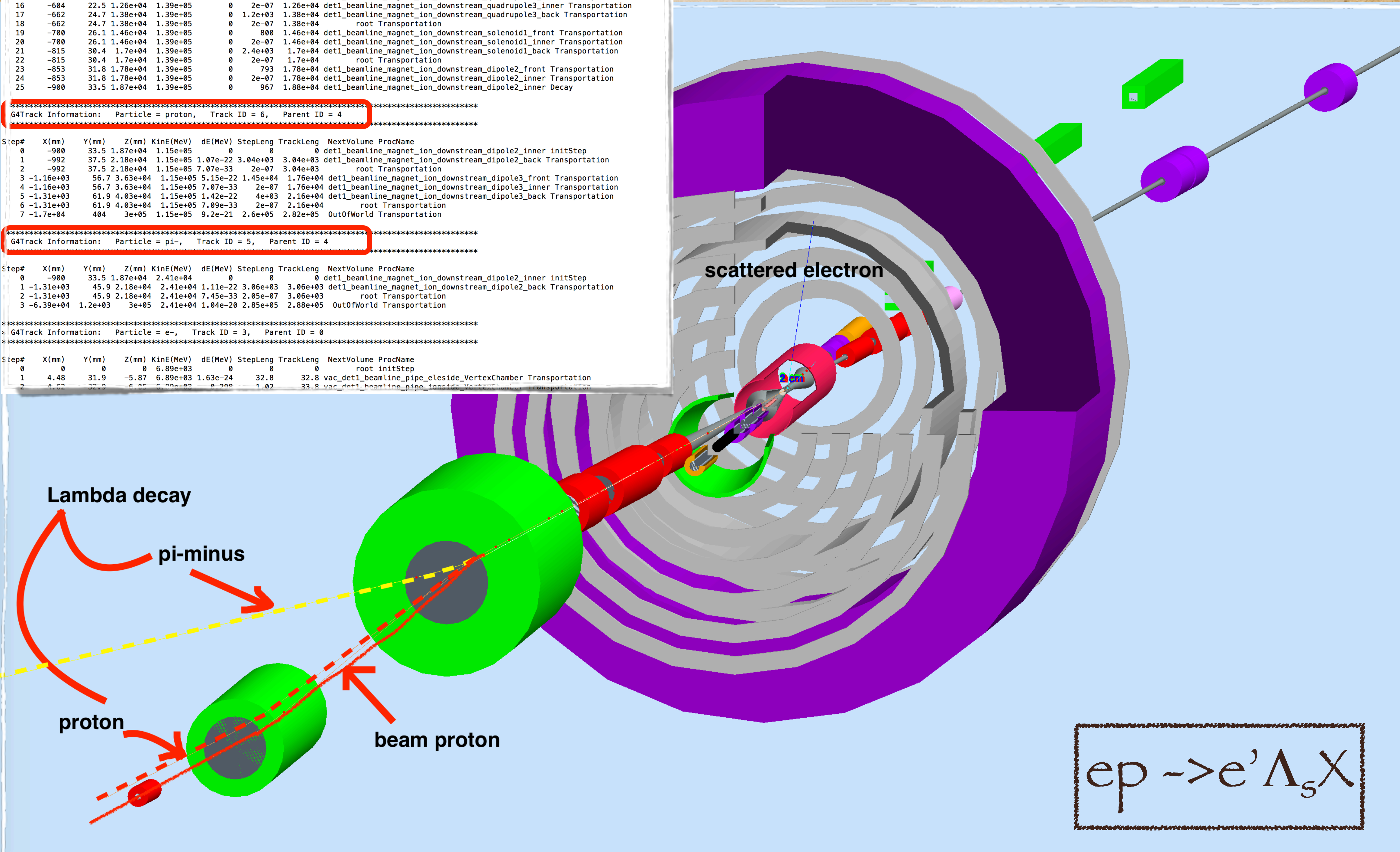
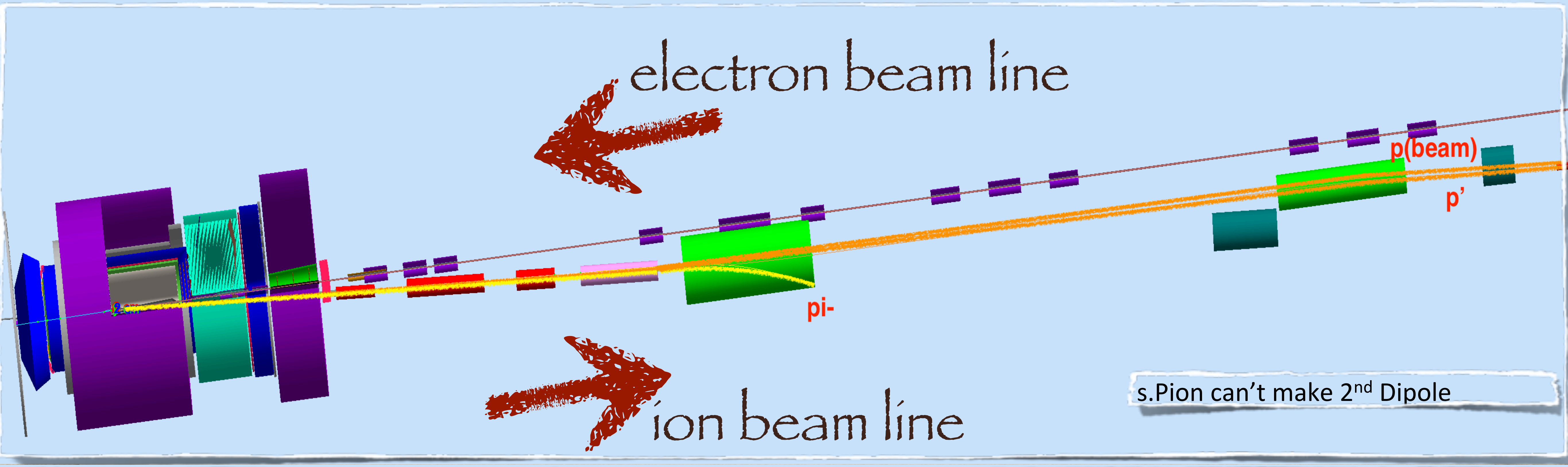
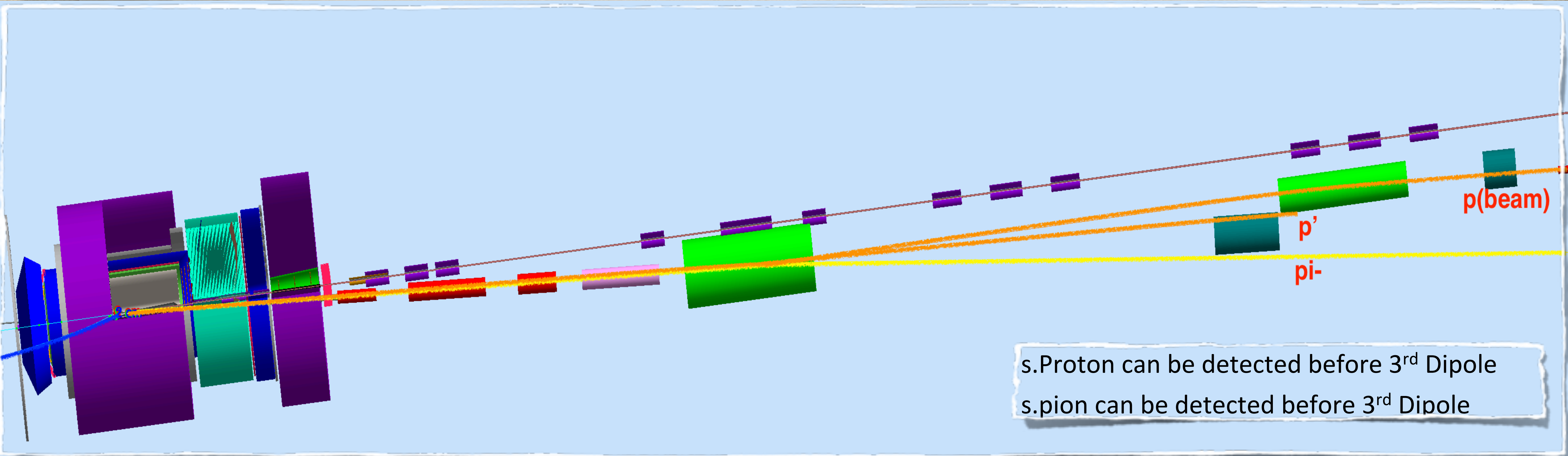
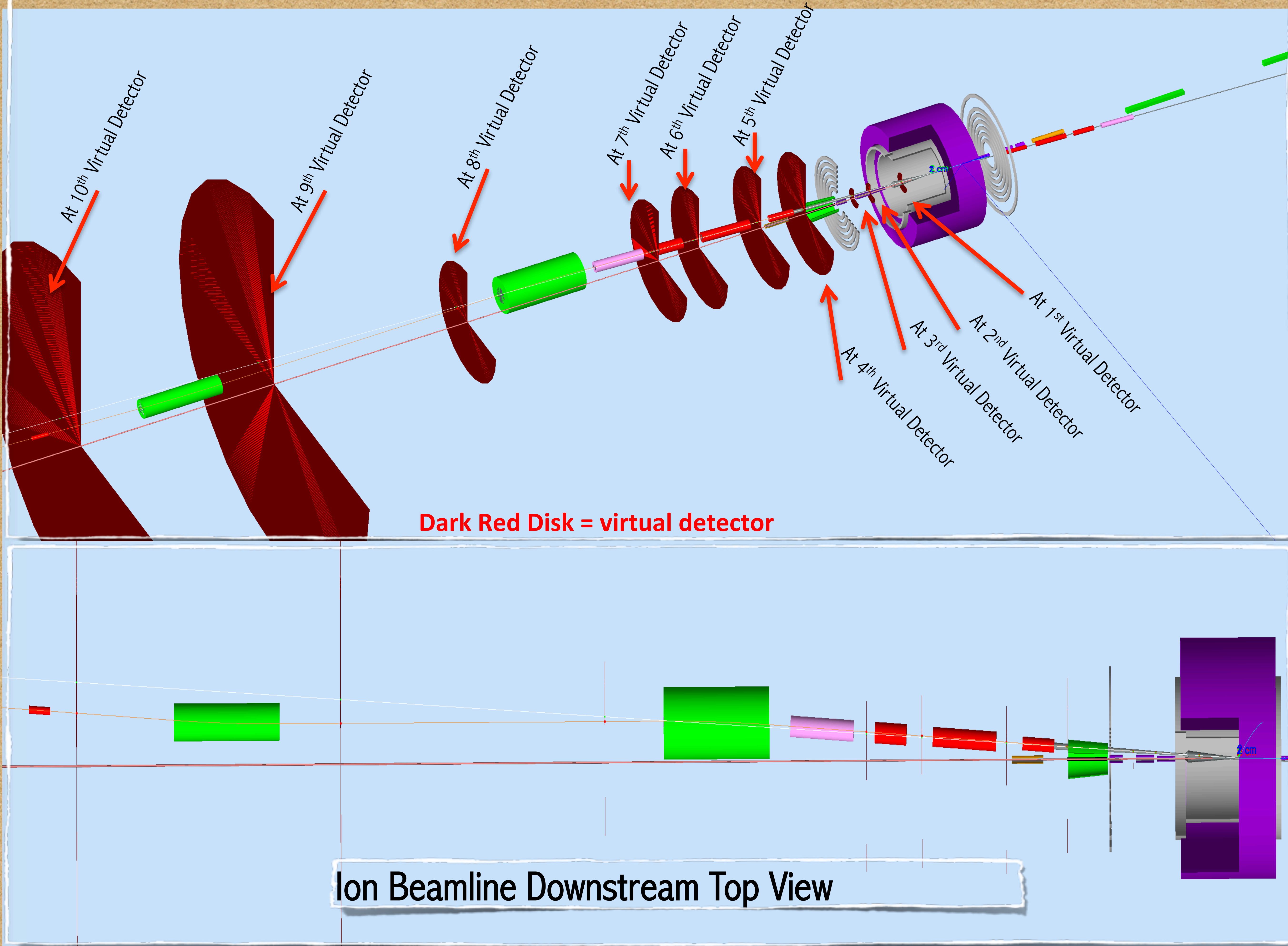


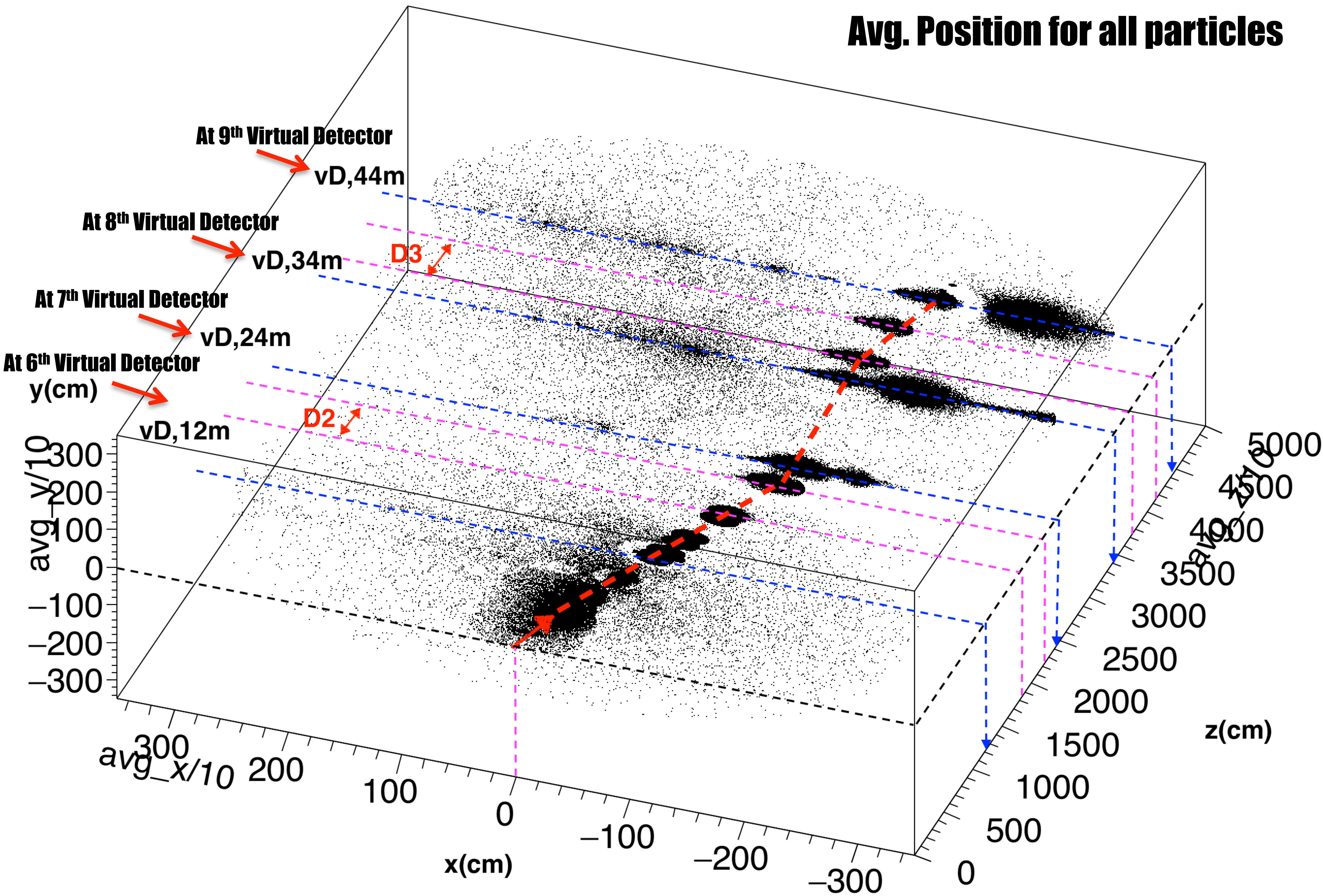
$ep \to e' \Lambda_s X$

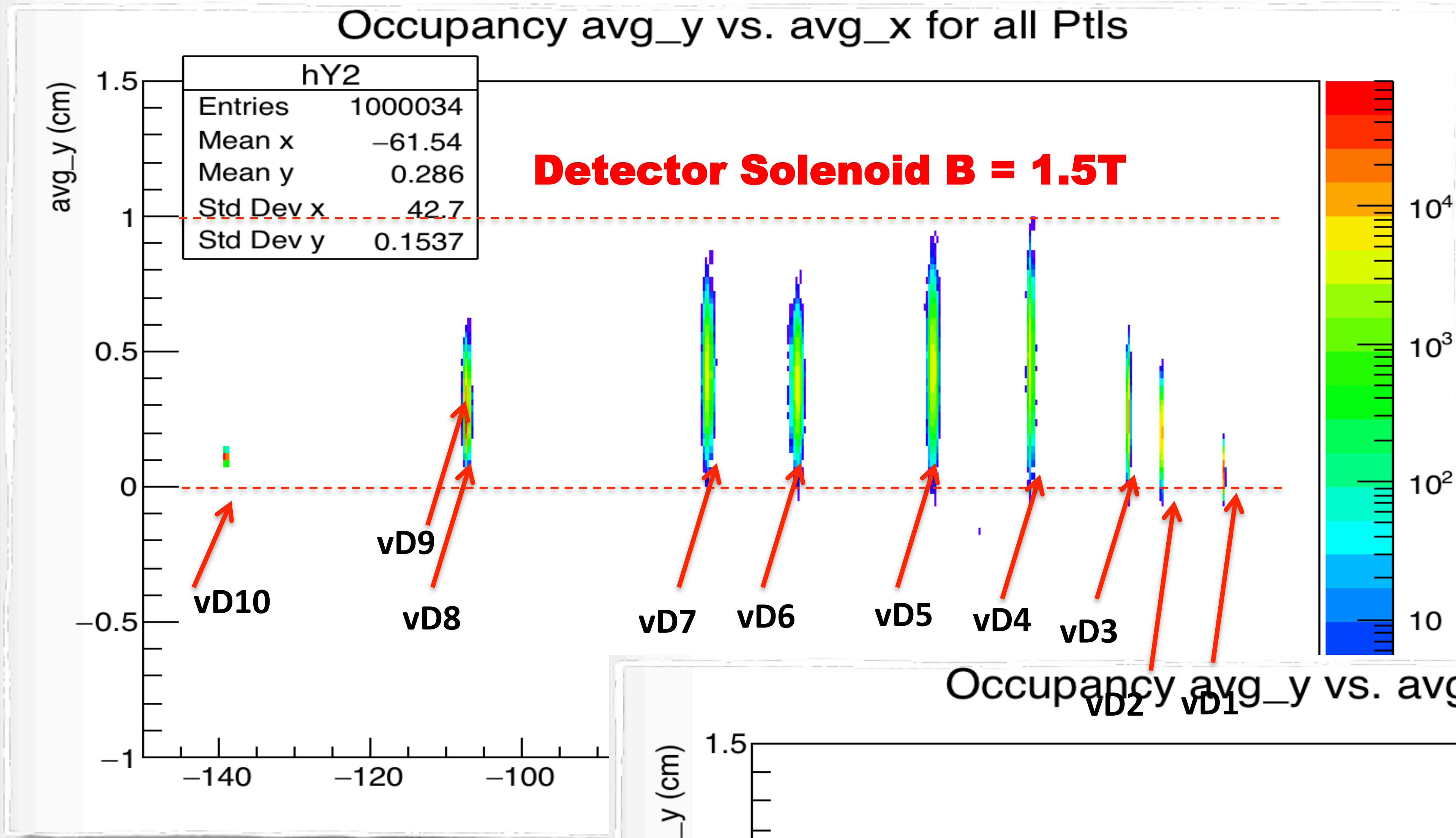
Particle Trajectory

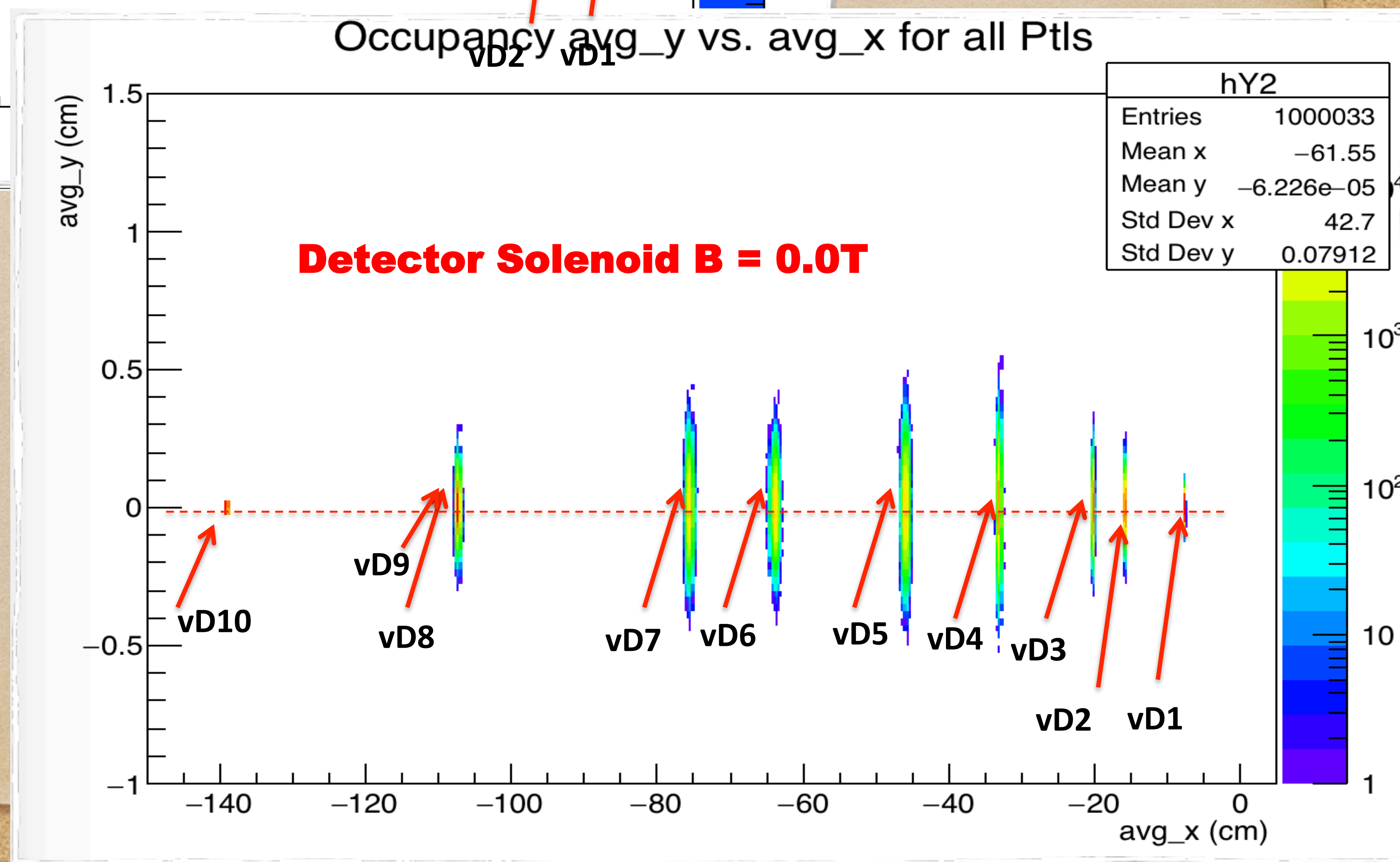


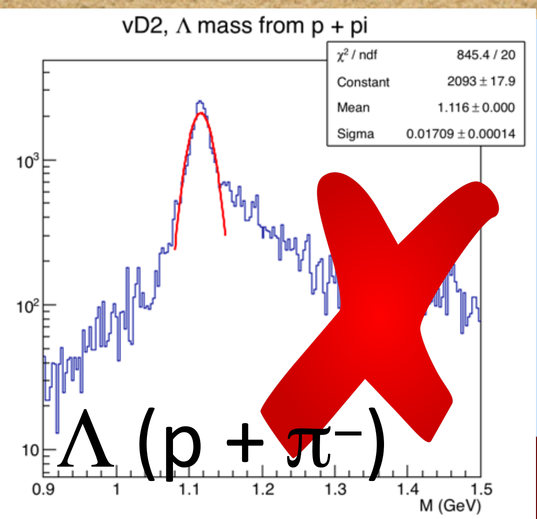


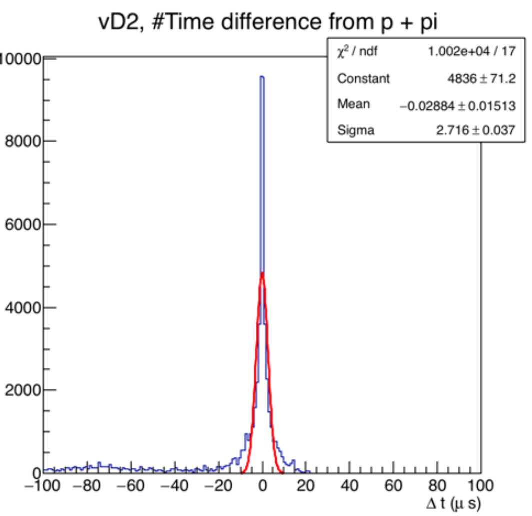

At 10th Virtual Detector
At 9th Virtual Detector
At 8th Virtual Detector
At 7th Virtual Detector
At 6th Virtual Detector
At 5th Virtual Detector
At 4th Virtual Detector
At 3rd Virtual Detector
At 2nd Virtual Detector
At 1st Virtual Detector
2 cm
Dark Red Disk = virtual detector
2 cm
Ion Beamline Downstream Top View

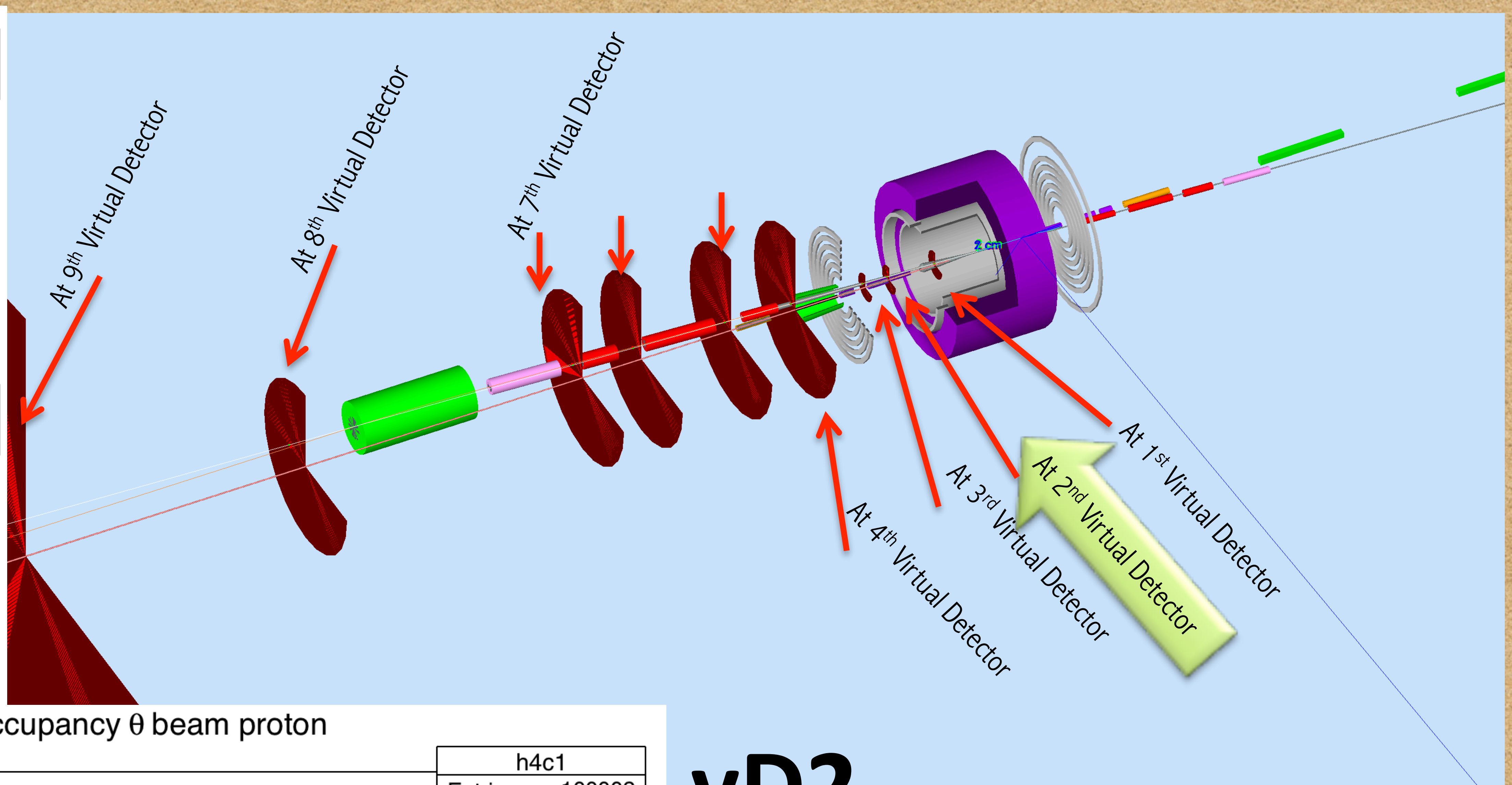

Avg. Position for all particles
At 9th Virtual Detector
vD,44m
At 8th Virtual Detector
vD,34m
At 7th Virtual Detector
vD,24m
At 6th Virtual Detector
y(cm)
vD,12m
D3
D2
avg_y/10
300
200
100
0
−100
−200
−300
avg_x/10
300
200
100
0
−100
−200
−300
x(cm)
avg_z/10
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
z(cm)


Occupancy avg_y vs. avg_x for all Ptls
hY2
Entries 1000034
Mean x −61.54
Mean y 0.286
Std Dev x 42.7
Std Dev y 0.1537
Detector Solenoid B = 1.5T
avg_y (cm)
vD10
vD9
vD8
vD7
vD6
vD5
vD4
vD3
vD2
vD1

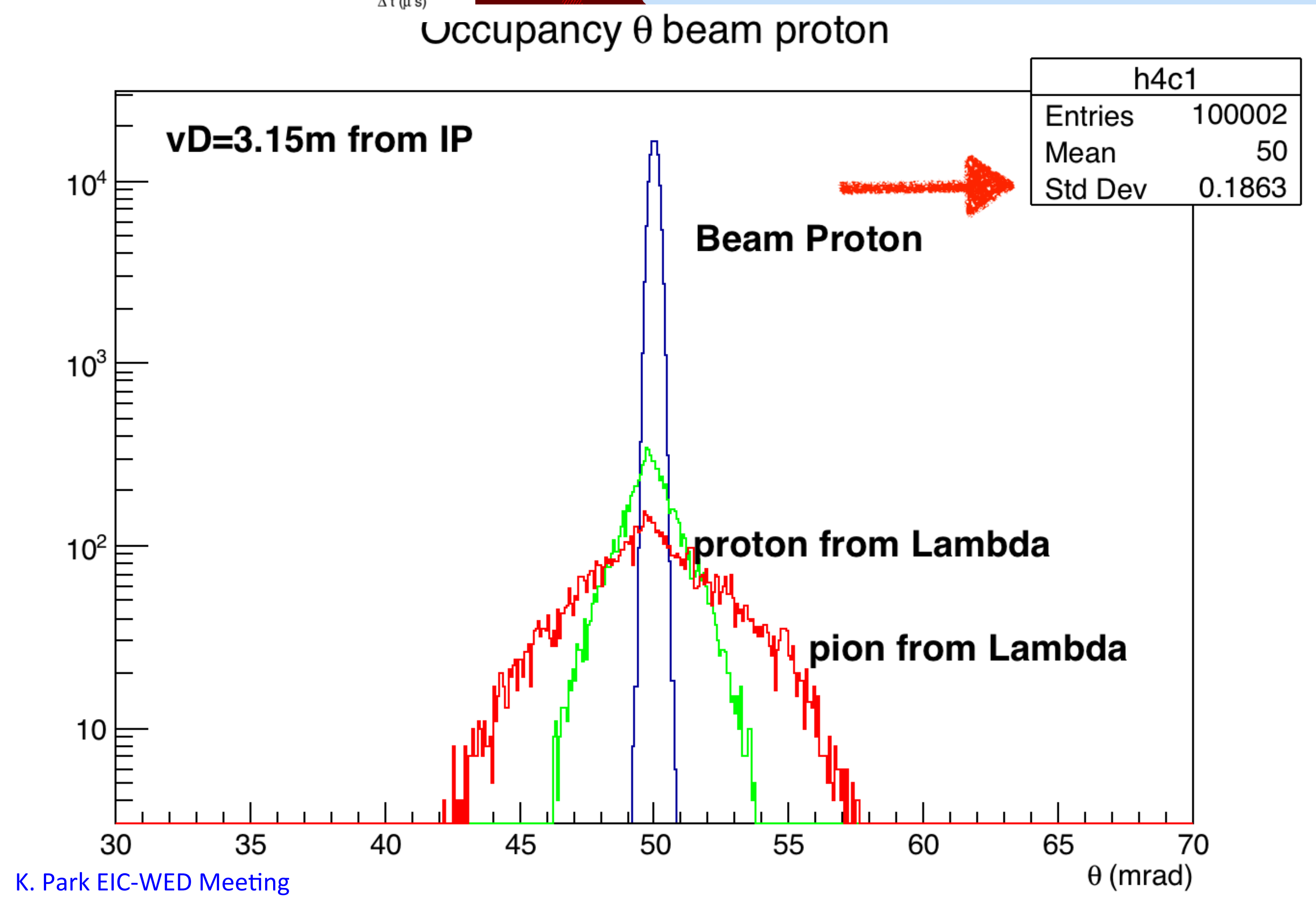

Occupancy avg_y vs. avg_x for all Ptls
hY2
Entries 1000033
Mean x −61.55
Mean y −6.226e−05
Std Dev x 42.7
Std Dev y 0.07912
Detector Solenoid B = 0.0T
avg_y (cm)
avg_x (cm)
vD10
vD9
vD8
vD7
vD6
vD5
vD4
vD3
vD2
vD1

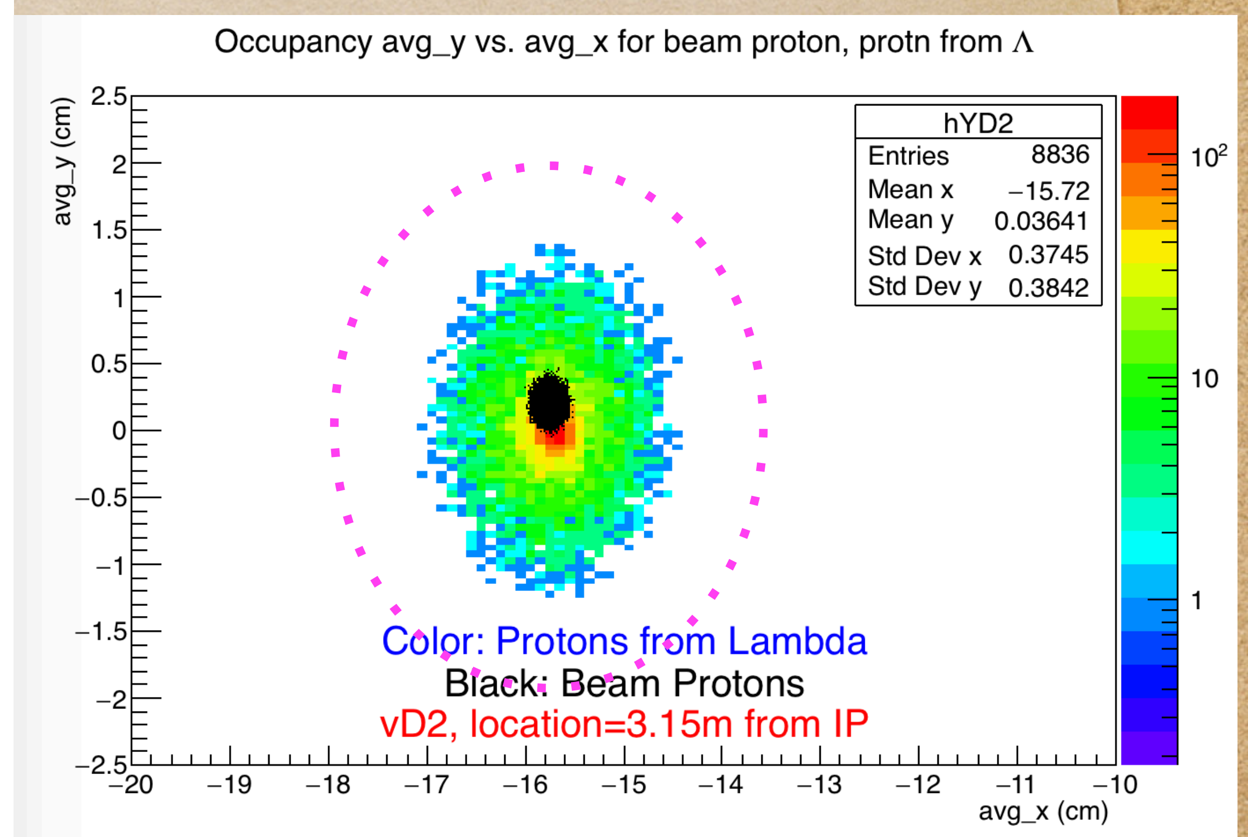

vD2, Λ mass from p + pi
χ² / ndf 845.4 / 20
Constant 2093 ± 17.9
Mean 1.116 ± 0.000
Sigma 0.01709 ± 0.00014
Λ (p + π⁻)
M (GeV)

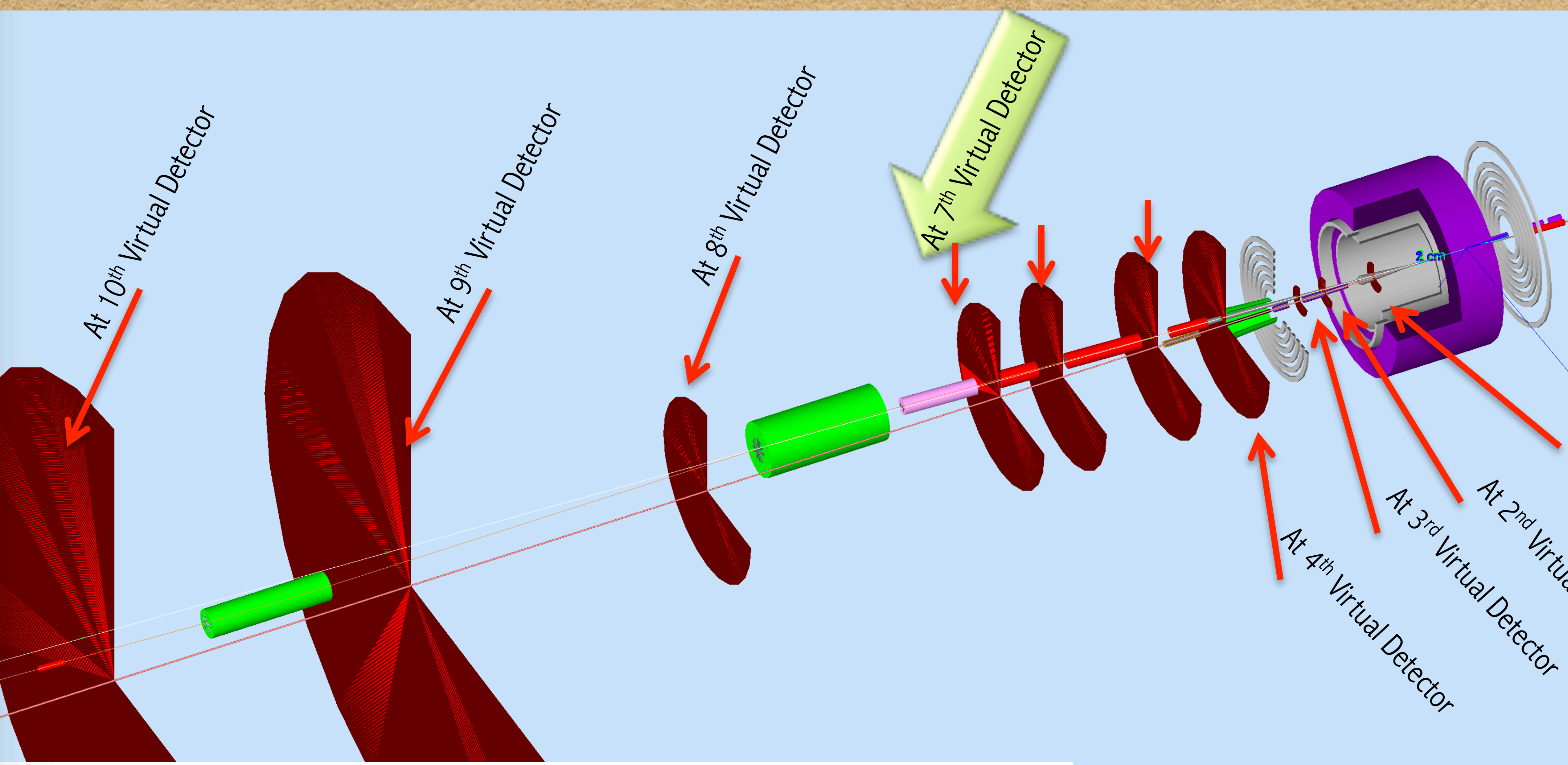

vD2, #Time difference from p + pi
χ² / ndf 1.002e+04 / 17
Constant 4836 ± 71.2
Mean −0.02884 ± 0.01513
Sigma 2.716 ± 0.037
Δ t (μ s)

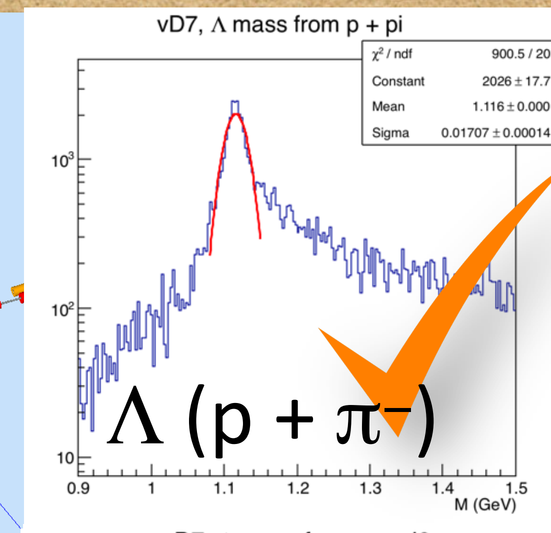

At 9th Virtual Detector
At 8th Virtual Detector
At 7th Virtual Detector
At 1st Virtual Detector
At 2nd Virtual Detector
At 3rd Virtual Detector
At 4th Virtual Detector

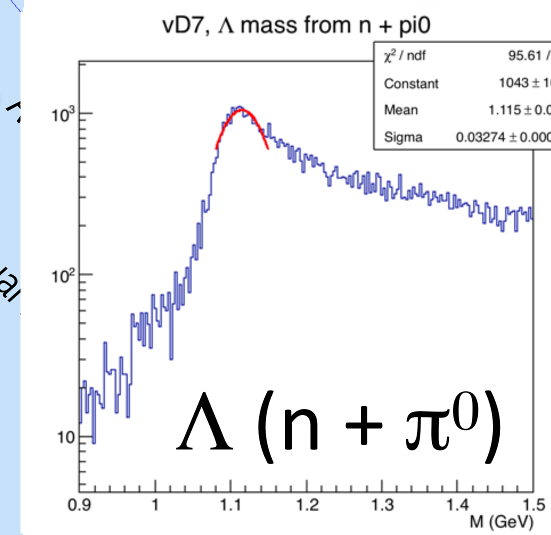
vD2


Occupancy θ beam proton
h4c1
Entries 100002
Mean 50
Std Dev 0.1863
vD=3.15m from IP
Beam Proton
proton from Lambda
pion from Lambda
θ (mrad)

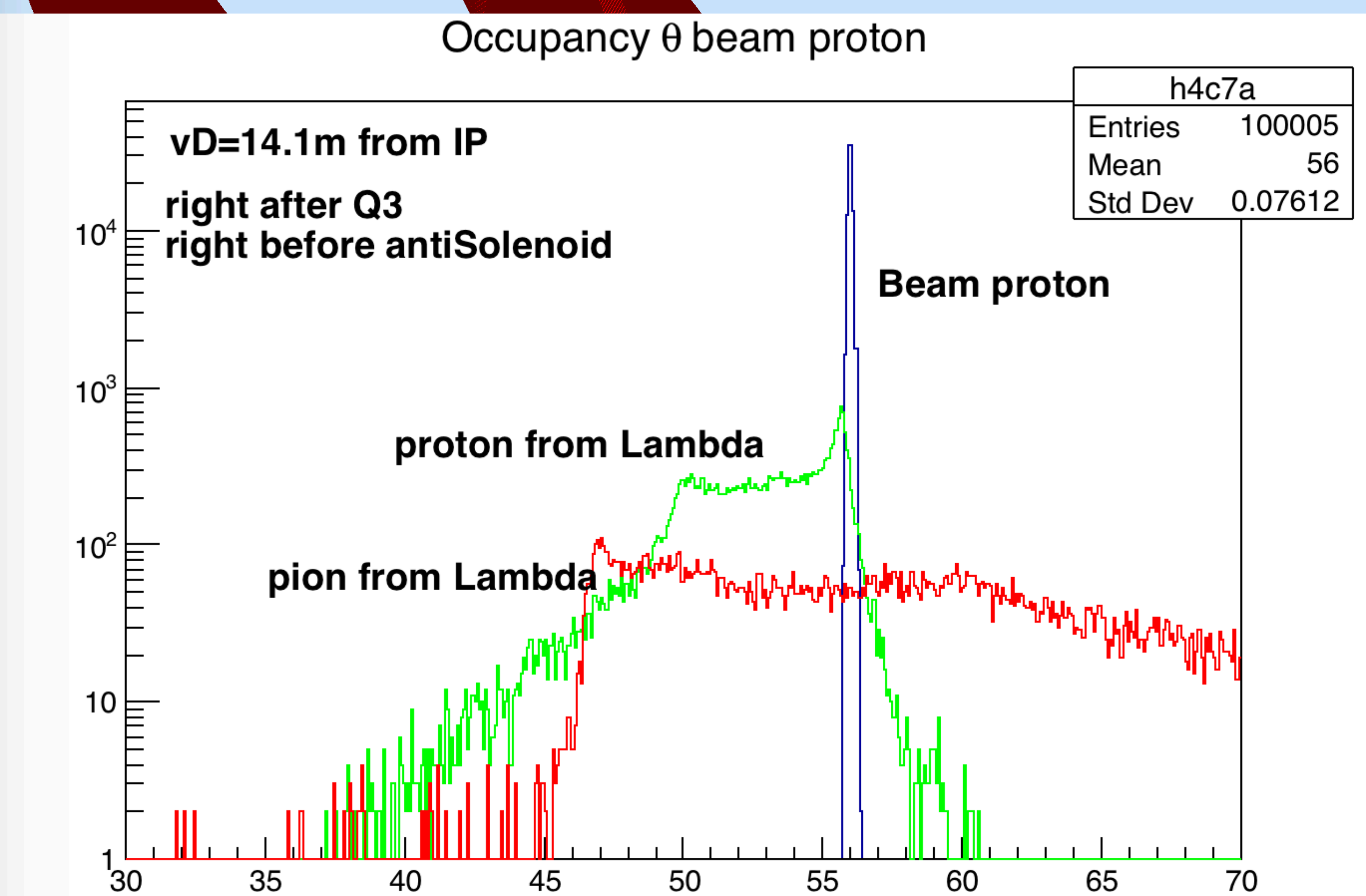

Occupancy avg_y vs. avg_x for beam proton, protn from Λ
hYD2
Entries 8836
Mean x −15.72
Mean y 0.03641
Std Dev x 0.3745
Std Dev y 0.3842
Color: Protons from Lambda
Black: Beam Protons
vD2, location=3.15m from IP
avg_y (cm)
avg_x (cm)

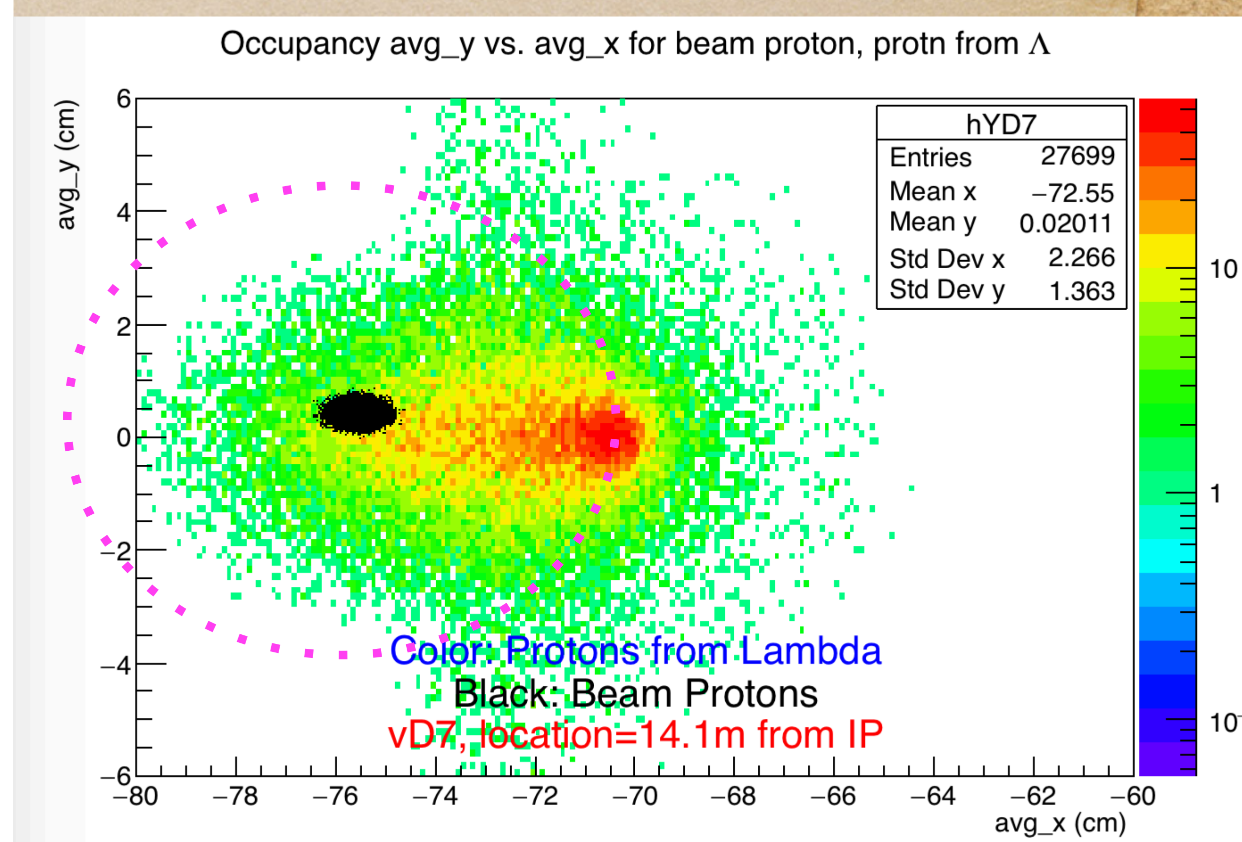

At 10th Virtual Detector
At 9th Virtual Detector
At 8th Virtual Detector
At 7th Virtual Detector
At 4th Virtual Detector
At 3rd Virtual Detector
At 2nd Virtual
2 cm

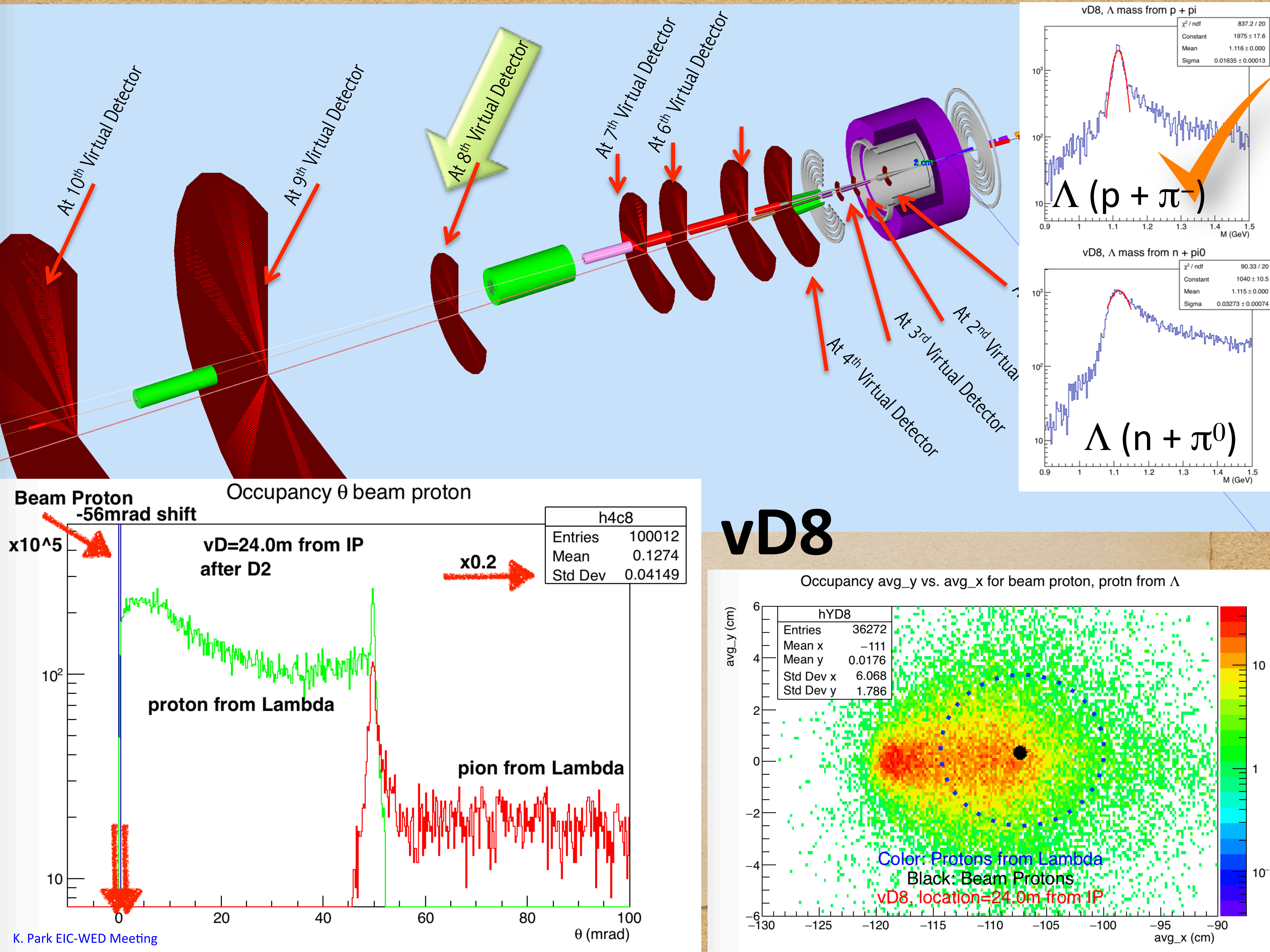

vD7, Λ mass from p + pi
χ² / ndf 900.5 / 20
Constant 2026 ± 17.7
Mean 1.116 ± 0.000
Sigma 0.01707 ± 0.00014
Λ (p + π⁻)
M (GeV)


vD7, Λ mass from n + pi0
χ² / ndf 95.61 / 20
Constant 1043 ± 10.5
Mean 1.115 ± 0.000
Sigma 0.03274 ± 0.00074
Λ (n + π⁰)
M (GeV)

vD7


Occupancy θ beam proton
h4c7a
Entries 100005
Mean 56
Std Dev 0.07612
vD=14.1m from IP
right after Q3
right before antiSolenoid
Beam proton
proton from Lambda
pion from Lambda
θ (mrad)


Occupancy avg_y vs. avg_x for beam proton, protn from Λ
hYD7
Entries 27699
Mean x −72.55
Mean y 0.02011
Std Dev x 2.266
Std Dev y 1.363
avg_y (cm)
avg_x (cm)
Color: Protons from Lambda
Black: Beam Protons
vD7, location=14.1m from IP

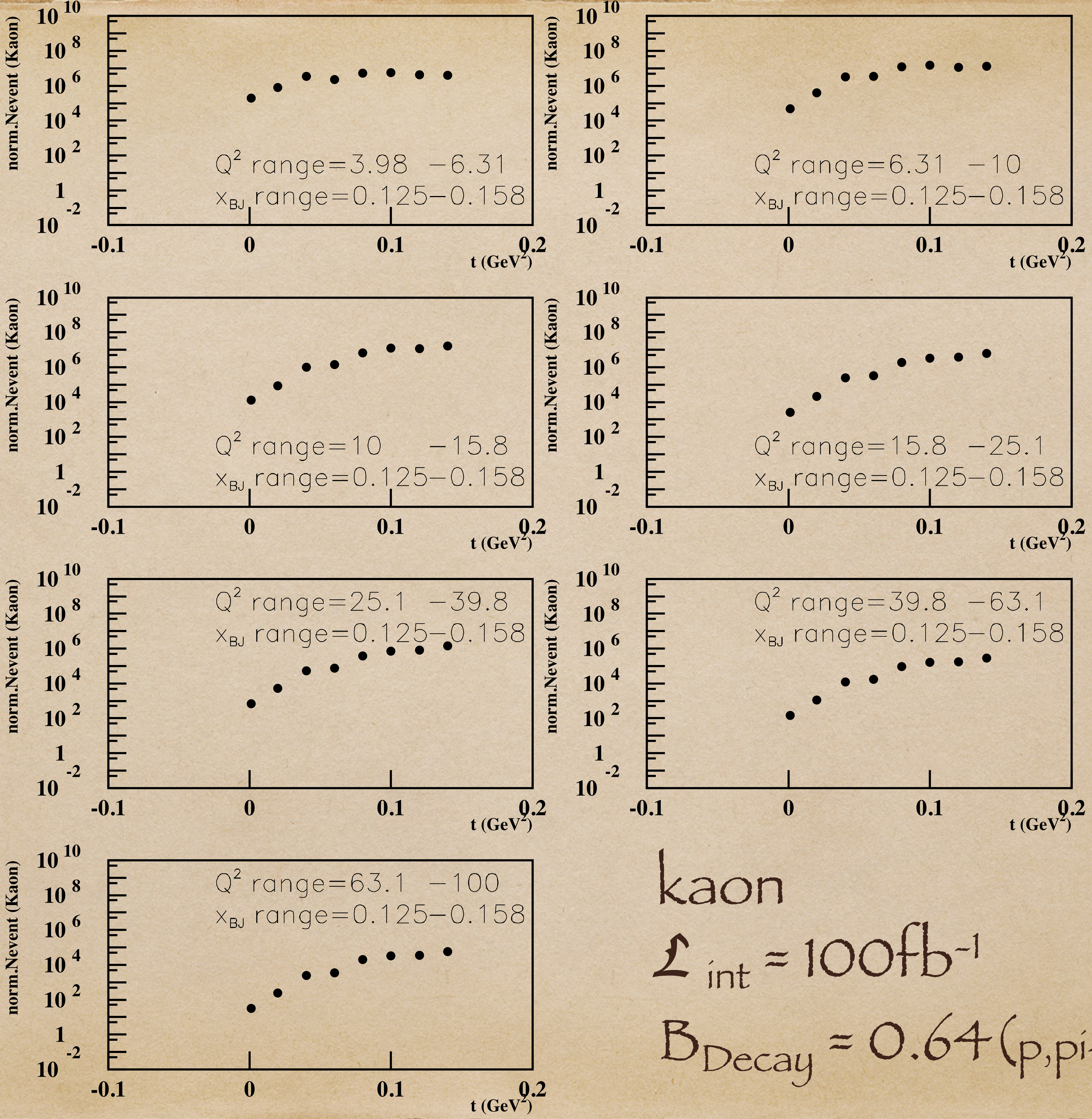


At 10th Virtual Detector
At 9th Virtual Detector
At 8th Virtual Detector
At 7th Virtual Detector
At 6th Virtual Detector
At 4th Virtual Detector
At 3rd Virtual Detector
At 2nd Virtual
2 cm
vD8, Λ mass from p + pi
χ² / ndf 837.2 / 20
Constant 1975 ± 17.6
Mean 1.116 ± 0.000
Sigma 0.01635 ± 0.00013
Λ (p + π⁻)
M (GeV)
vD8, Λ mass from n + pi0
χ² / ndf 90.33 / 20
Constant 1040 ± 10.5
Mean 1.115 ± 0.000
Sigma 0.03273 ± 0.00074
Λ (n + π⁰)
M (GeV)
Beam Proton
-56mrad shift
Occupancy θ beam proton
x10^5
vD=24.0m from IP
after D2
x0.2
h4c8
Entries 100012
Mean 0.1274
Std Dev 0.04149
proton from Lambda
pion from Lambda
θ (mrad)
vD8
Occupancy avg_y vs. avg_x for beam proton, protn from Λ
hYD8
Entries 36272
Mean x −111
Mean y 0.0176
Std Dev x 6.068
Std Dev y 1.786
avg_y (cm)
avg_x (cm)
Color: Protons from Lambda
Black: Beam Protons
vD8, location=24.0m from IP
K. Park EIC-WED Meeting

Summary

* Tagged DIS (TDIS) technique optimized to probe the partonic components of the meson cloud of the nucleon
  - Limited (pion) / no (kaon) experiment at all
  - Address what part of the nucleon pdf comes from the mesonic component
  - Help to understand flavor asymmetry of the nucleon sea

* Facilitates extraction of the pion and kaon structure functions
  - Fundamental QCD
  - The result of the studies is that one can use the Sullivan process to probe pion/kaon structure.
  - Important to verify xBj shape

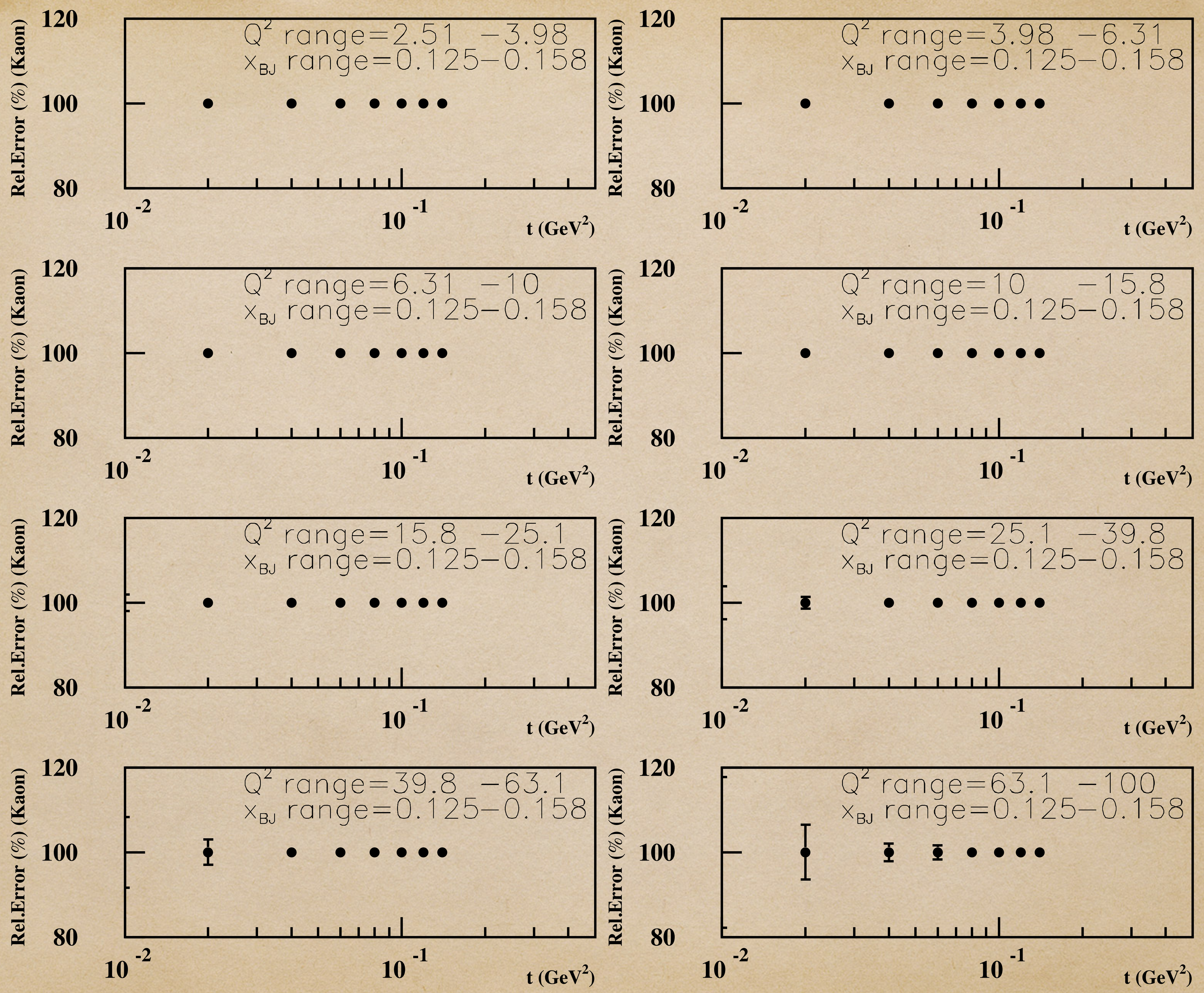


kaon

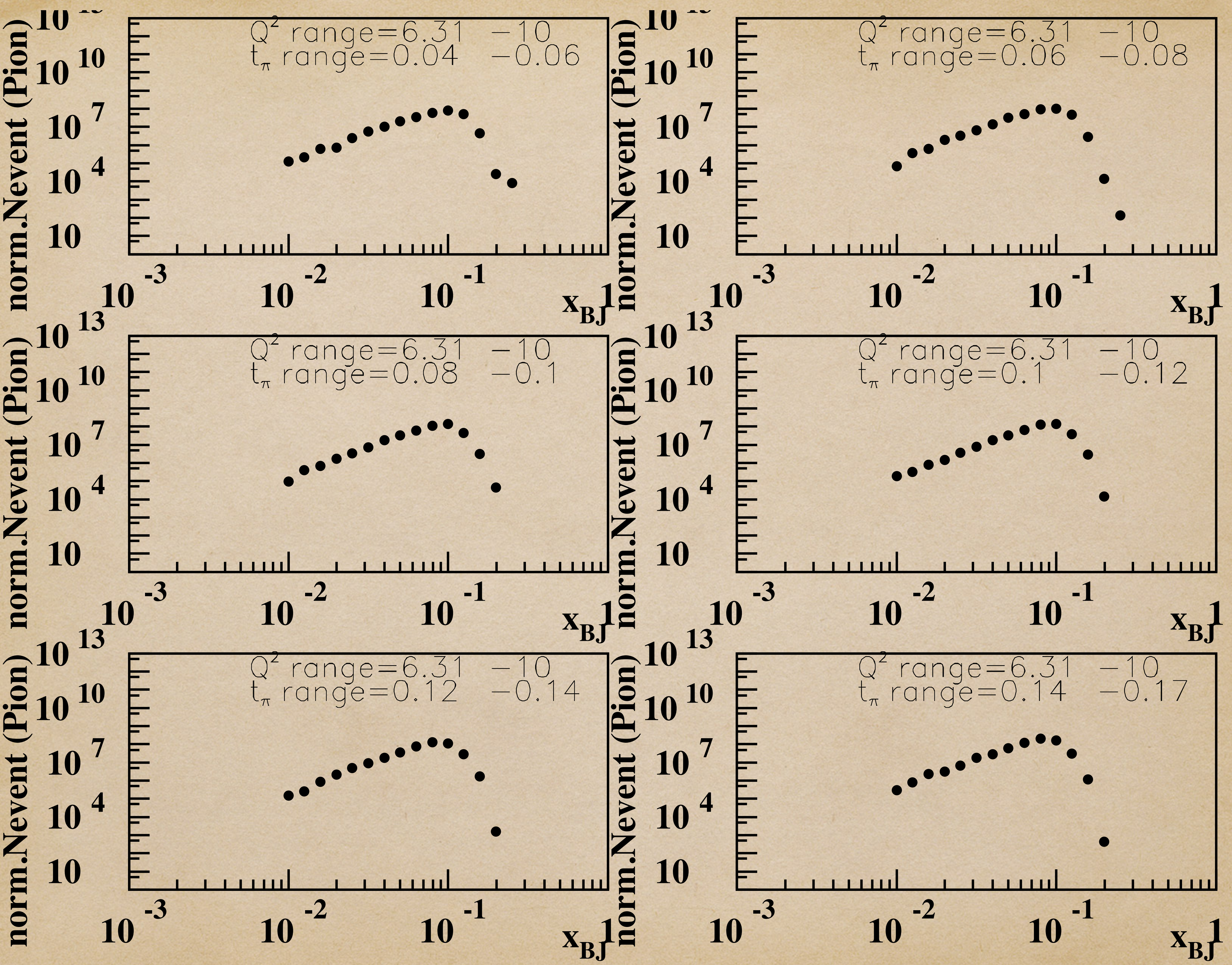
$\mathcal{L}_{int} = 100fb^{-1}$

$B_{Decay} = 0.64$ (p,pi-)

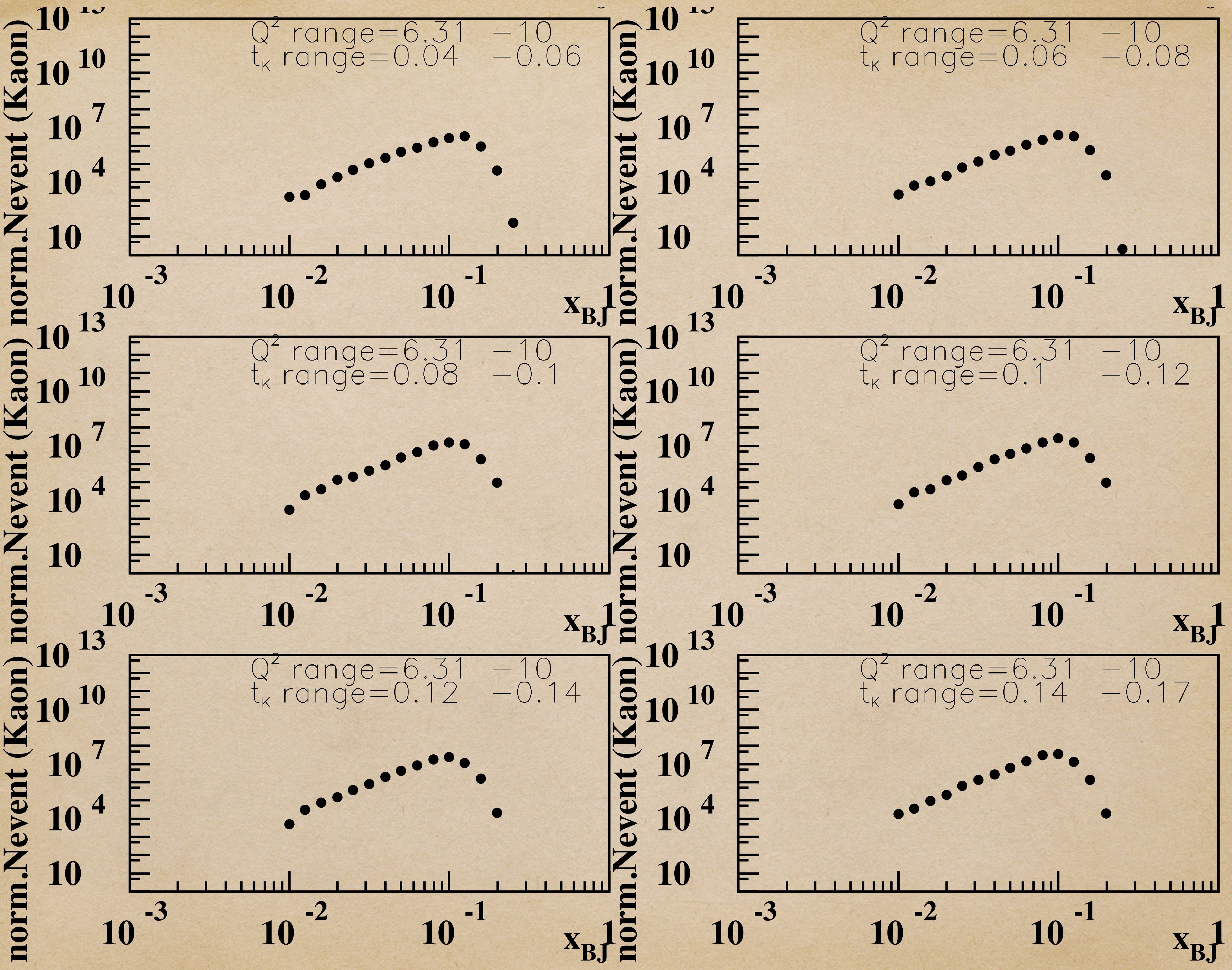
1/sqrt(N)

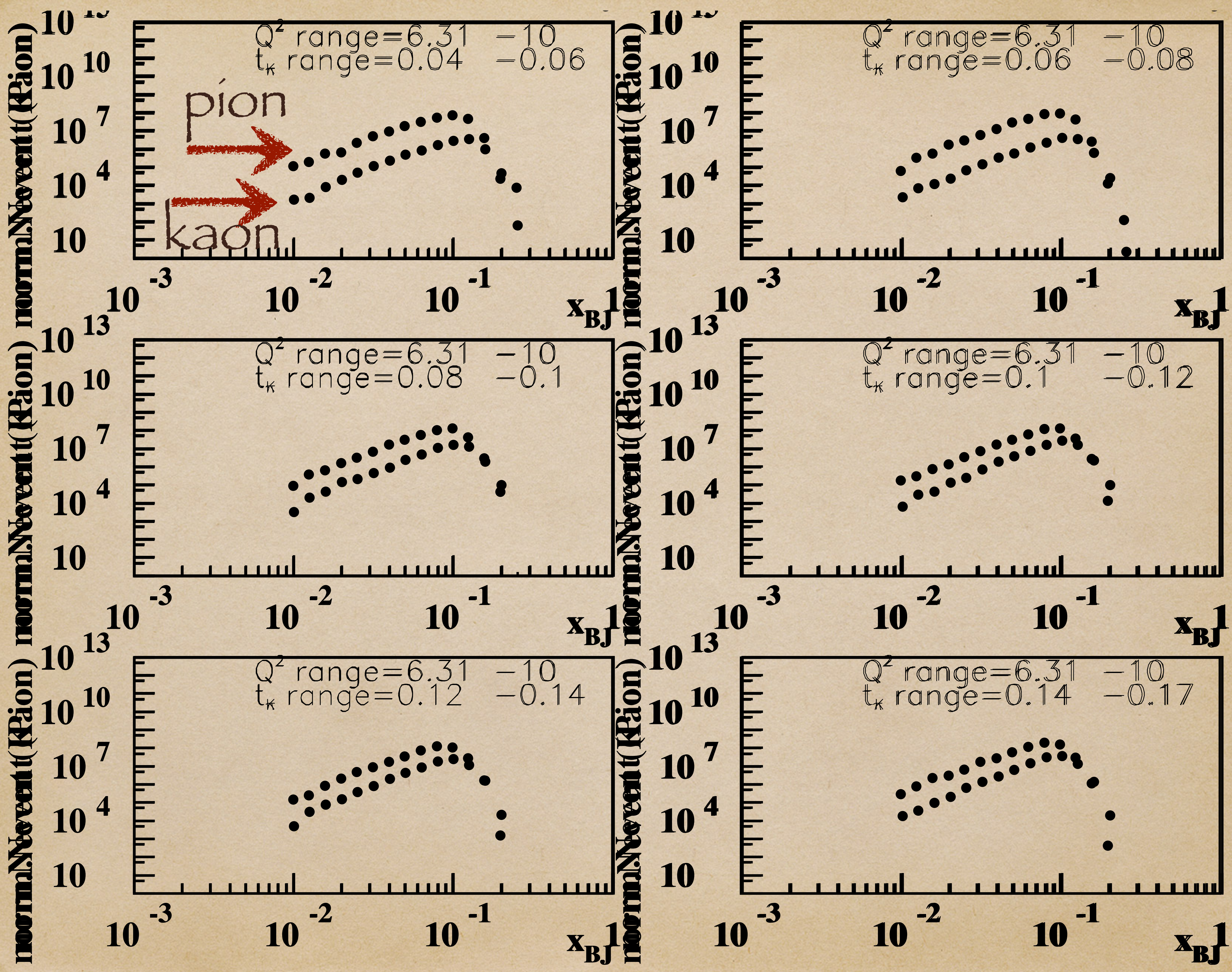


Q² range=2.51 −3.98
x_BJ range=0.125−0.158
Q² range=3.98 −6.31
x_BJ range=0.125−0.158
Q² range=6.31 −10
x_BJ range=0.125−0.158
Q² range=10 −15.8
x_BJ range=0.125−0.158
Q² range=15.8 −25.1
x_BJ range=0.125−0.158
Q² range=25.1 −39.8
x_BJ range=0.125−0.158
Q² range=39.8 −63.1
x_BJ range=0.125−0.158
Q² range=63.1 −100
x_BJ range=0.125−0.158
Rel.Error (%) (Kaon)
t (GeV²)
120
100
80
10⁻²
10⁻¹

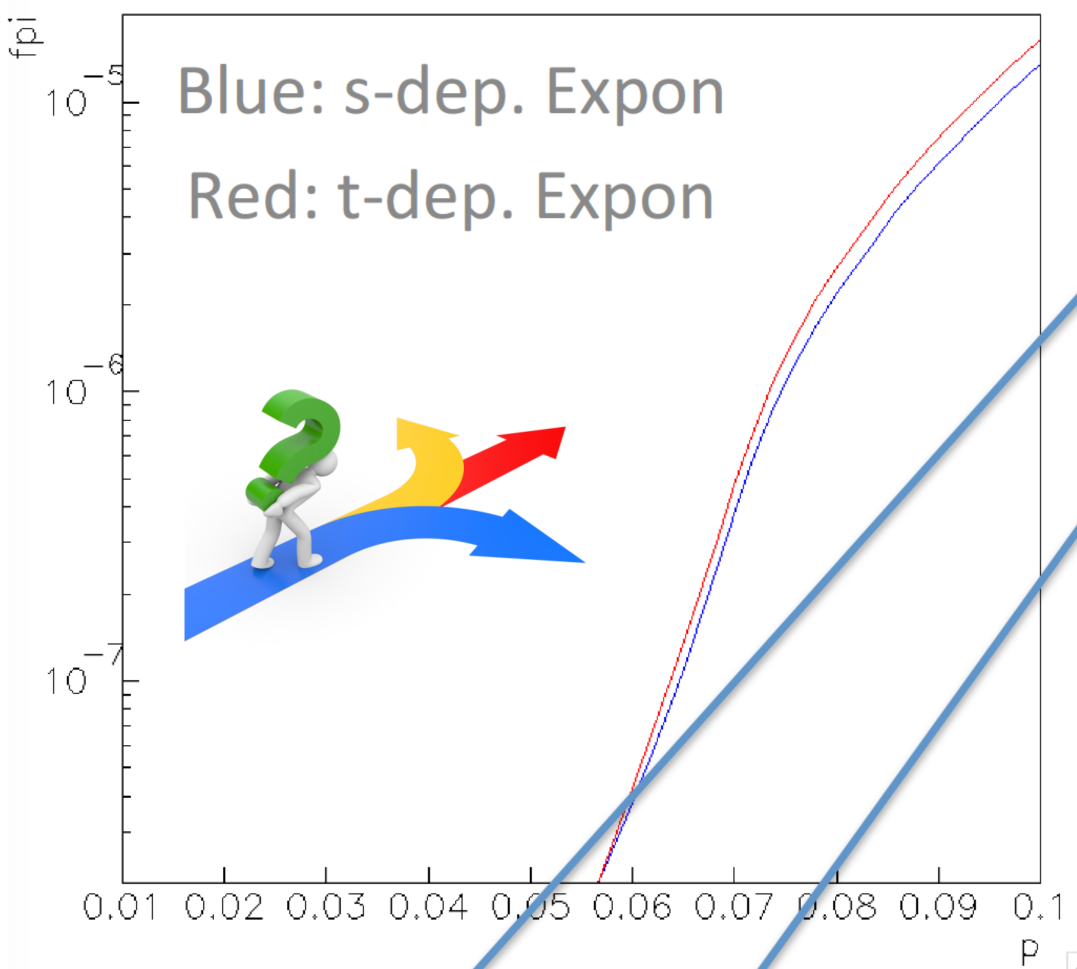


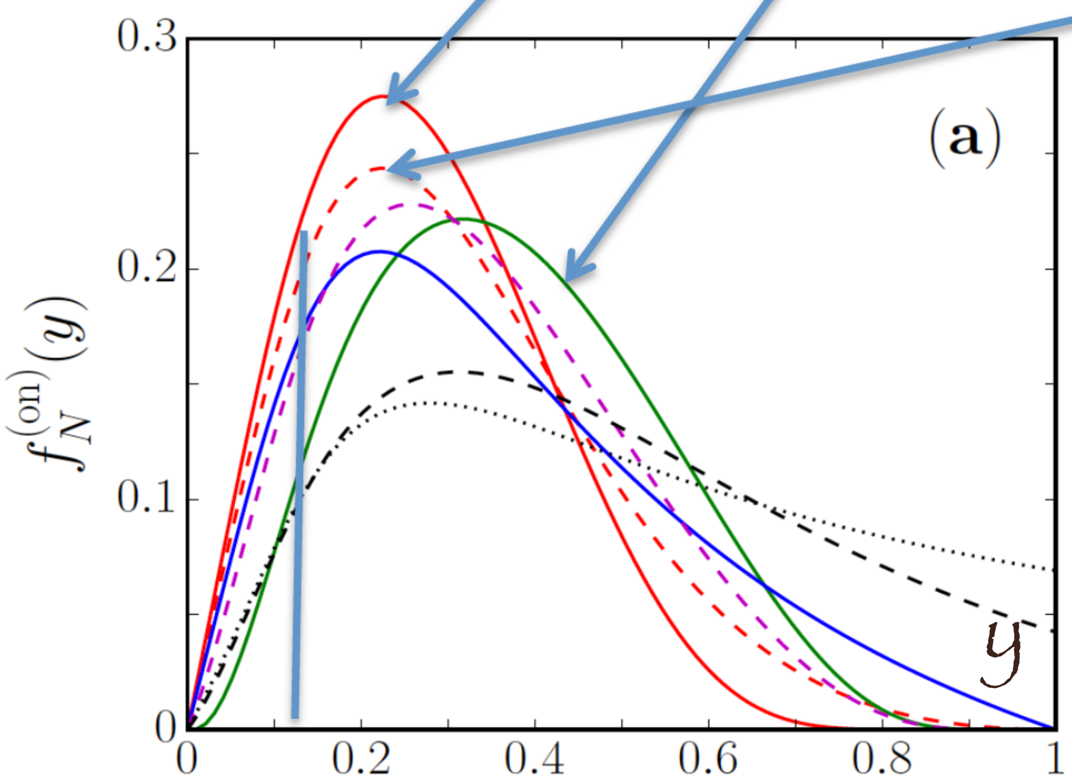
Q² range=6.31 −10
tπ range=0.04 −0.06
Q² range=6.31 −10
tπ range=0.06 −0.08
Q² range=6.31 −10
tπ range=0.08 −0.1
Q² range=6.31 −10
tπ range=0.1 −0.12
Q² range=6.31 −10
tπ range=0.12 −0.14
Q² range=6.31 −10
tπ range=0.14 −0.17
norm.Nevent (Pion)
xBJ


Q² range=6.31 −10
tκ range=0.04 −0.06
Q² range=6.31 −10
tκ range=0.06 −0.08
Q² range=6.31 −10
tκ range=0.08 −0.1
Q² range=6.31 −10
tκ range=0.1 −0.12
Q² range=6.31 −10
tκ range=0.12 −0.14
Q² range=6.31 −10
tκ range=0.14 −0.17
norm.Nevent (Kaon)
x_BJ
10^-3
10^-2
10^-1
1
10
10^4
10^7
10^10
10^13


Q² range=6.31 −10
t_K range=0.04 −0.06
pion
kaon
Q² range=6.31 −10
t_K range=0.06 −0.08
Q² range=6.31 −10
t_K range=0.08 −0.1
Q² range=6.31 −10
t_K range=0.1 −0.12
Q² range=6.31 −10
t_K range=0.12 −0.14
Q² range=6.31 −10
t_K range=0.14 −0.17
x_BJ
norm.Nevent(Kaon)

Model dependent Regularization Form





Pion exchange model

$$F = \exp\left[(t - m_\pi^2)/\Lambda^2\right]$$ [t-dependent exponential],

$$F = \exp\left[(M^2 - s)/\Lambda^2\right]$$ [s-dependent exponential],

$$F = \left[1 - \frac{(t - m_\pi^2)^2}{(t - \Lambda^2)^2}\right]^{1/2}$$ [Pauli-Villars].

$$F = y^{-\alpha_\pi(t)} \exp\left[(t - m_\pi^2)/\Lambda^2\right]$$ [Regge exponential],

$$F = \left(\frac{\Lambda^2 - m_\pi^2}{\Lambda^2 - t}\right)$$ [t-dependent monopole].

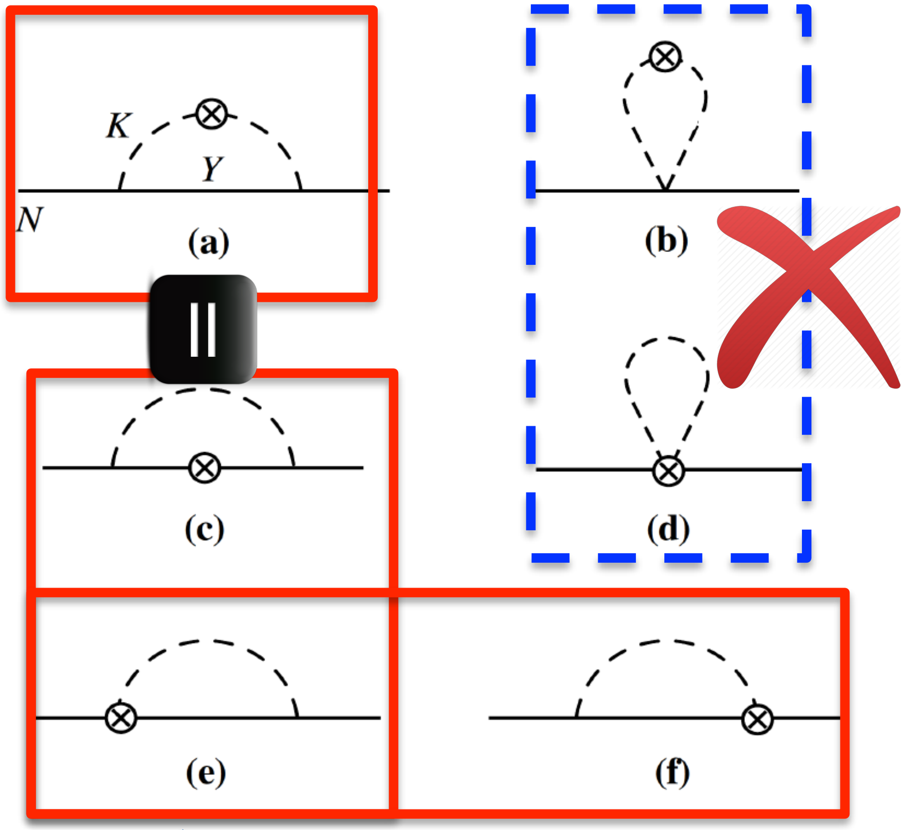
This F.F. is also in the code

$$F = y^{-\alpha_\pi(t)}$$ [Bishari],

On-shell πN splitting functions **(a)** $f_N^{(on)}(y)$

$y=z$, $x_F = 1-z$, $x_\pi = xBj/(1-z)$

Feynman Diagrams for KY



- (a) kaon rainbow
  $f_{KY}^{(rbw)}(y) = \kappa \left[f_Y^{(on)}(y) + f_K^{(\delta)}(y) \right]$
- (b) kaon buble diagram ($\bar{s}$ PDFs)
  $= f_K^{(bub)}(y)$
- (c) Hyperon rainbow
  $= f_{YK}^{(rbw)}(y)$
- (d) kaon tadpole (s PDFs)
  $= f_K^{(tad)}(y)$
- (e), (f) Kroll-Ruderman diagrams
  $= f_{YK}^{(KR)}(y)$

Fact:

$$f_K^{(tad)}(y) + f_K^{(bub)}(y) = 0$$

$$f_{YK}^{(rbw)}(y) + f_{YK}^{(KR)}(y) = f_{KY}^{(rbw)}(y)$$

Splitting Function for Lambda Hyperon

$$f_Y^{(on)}(y) = y \int dk_\perp^2 \frac{k_\perp^2 + (My + \Delta)^2}{(1-y)^2 D_{KY}^2} F$$

- D_{KY}: kaon virtuality for an on-shell hyperon intermediate state

$= -\frac{1}{1-y}\left(k_\perp^2 - y(1-y)M^2 + yM_Y^2 + (1-y)m_K^2\right)$

P. Kroll and S. Goloskov, Eur. Phys. J **A47** 112 (2011).

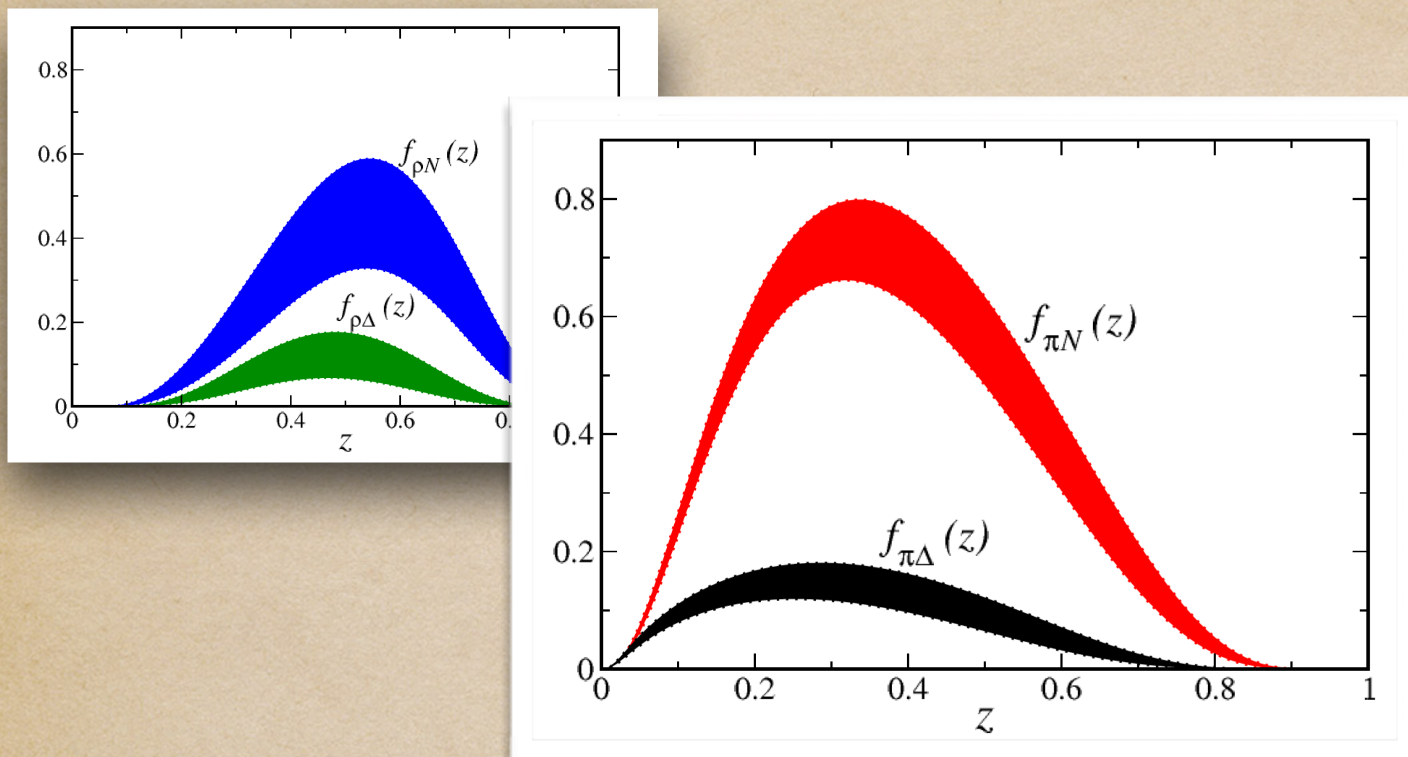
Model dependence: coupling constant

$g_{\pi NN} = 13.1$	$g_{K^+ p\Lambda} = -13.3$	$g_{K^+ p\Sigma} = -3.5$

Model dependence: various regularization form

$F = \left(\frac{\Lambda_t^2 - m_K^2}{\Lambda_t^2 - t}\right)$	t-dependent monopole	In Code
$F = exp[(M^2 - s)/\Lambda_s^2]$	s-dependent exponential	In Code

Optimized the kinematics kaon / pion



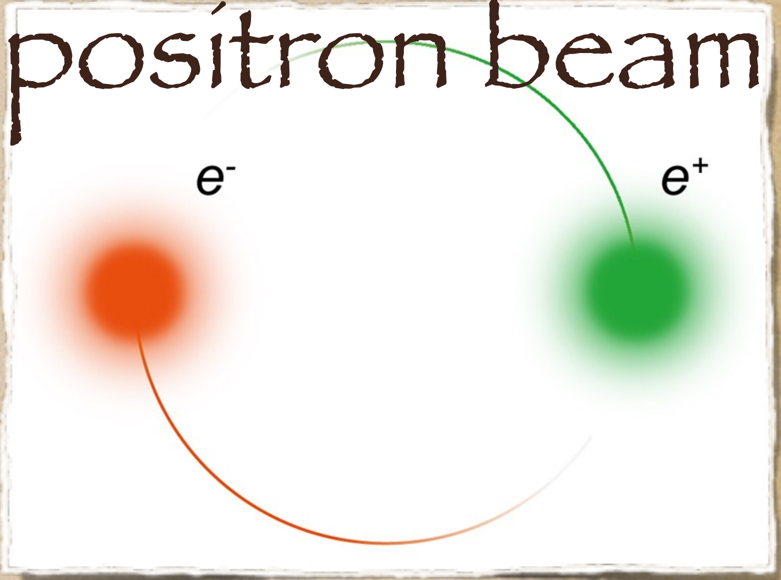
T. J. Hobbs et al.
arXiv:14038.5463v1 (2014)
H. Holtmann, A. Szczurek and J. Speth,
Nucl. Phys. A 596, 631 (1996)
W. Melnitchouk and A. W. Thomas,
Z. Phys. A 353, 311 (1995)

Kinematic Limits

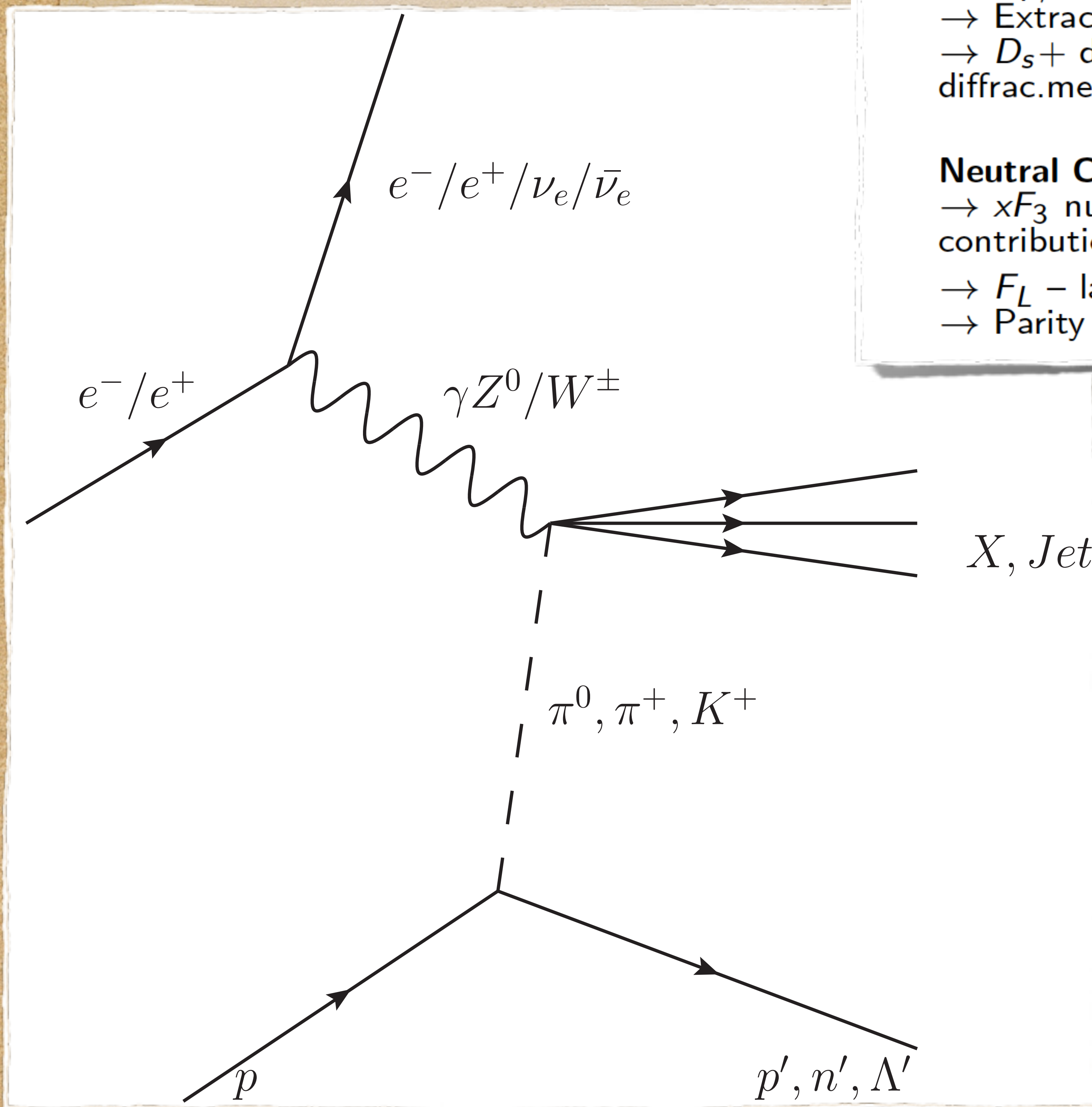
1) z~ |k|/M, where k is the meson momentum = -p'
2) k =60-400MeV/c, which corresponds to z<0.2
3) x <z
4) Low xBj, high W at 11GeV, Q2~2GeV2

$x_{pi} = x_{Bj}/(1-z_{pi})$ $\quad$ $x_K = x_{Bj}/(1-z_K)$

pi/K Structure Function with positron beam



Reaction Process



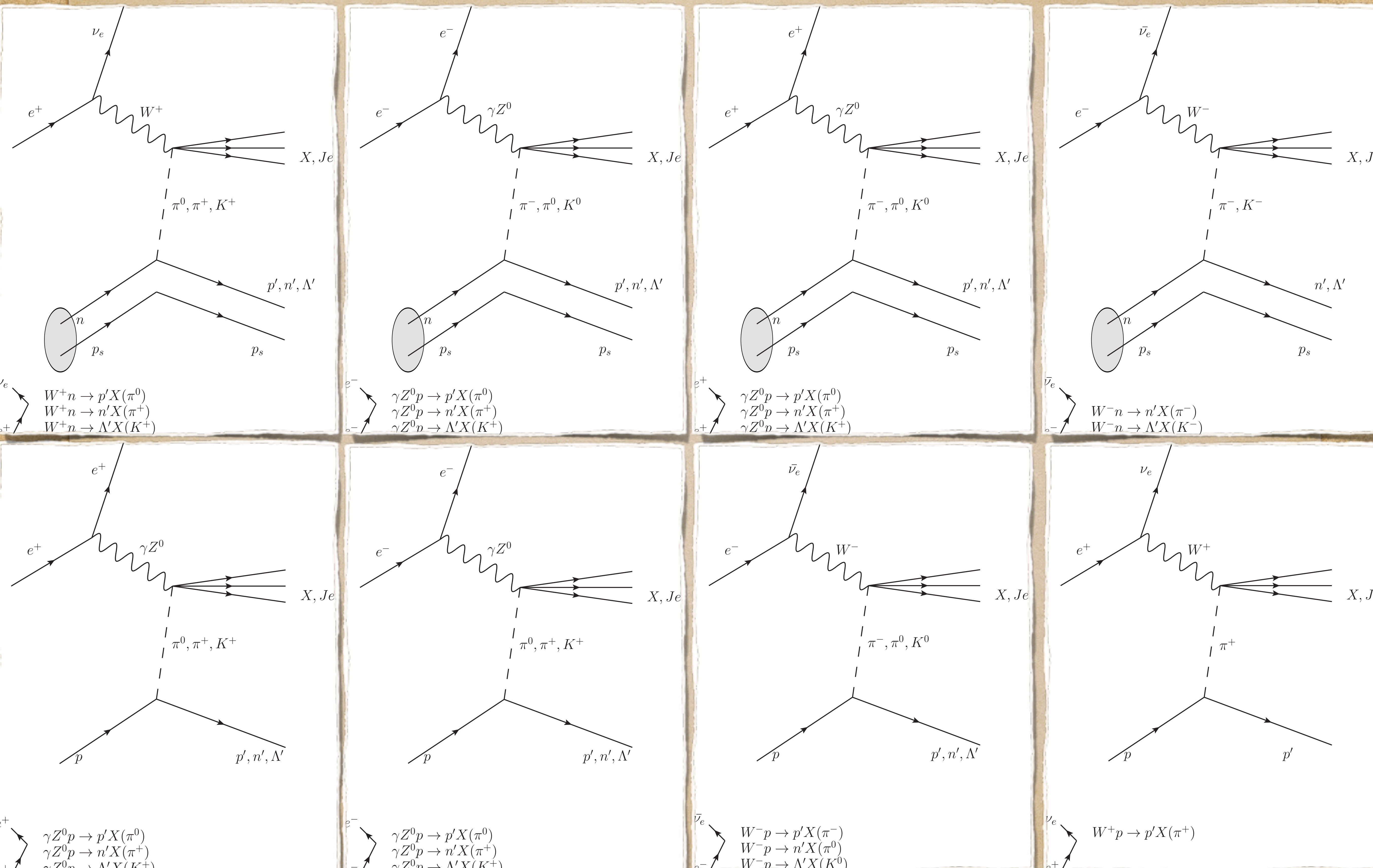
- Neutral/Charged Current Probe

Charged Current
→ Up/Down flavors dependence
→ Extract $s\bar{s}$ distribution in CC DIS charm production
→ D_s+ diffractive CC DIS production → gluon structure of diffrac.mech. in QCD

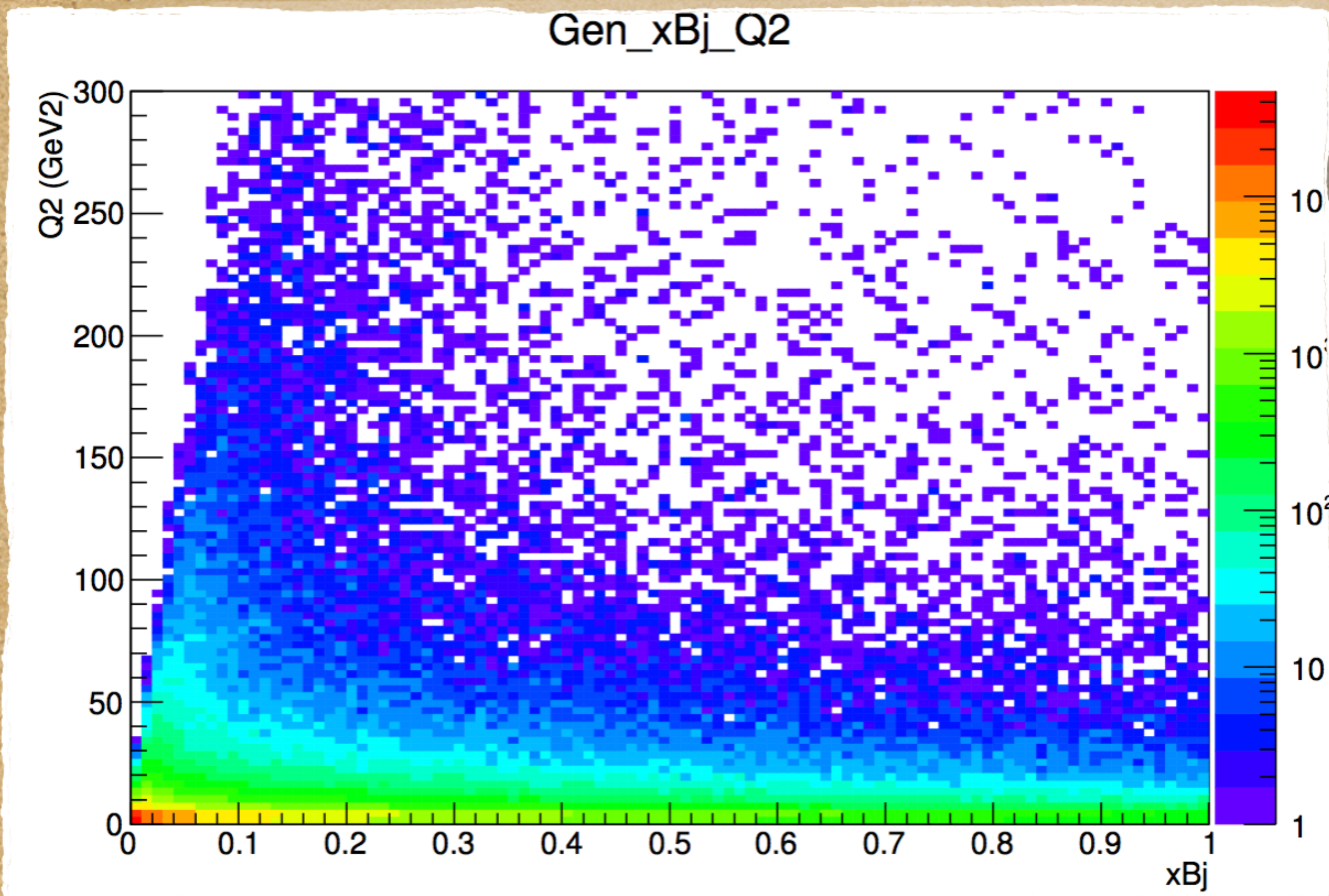
Neutral Current
→ xF_3 nucleon structure function (γZ interference contribution)
→ F_L – large background at high y (e^+ help for subtraction)
→ Parity violation in weak neutral current

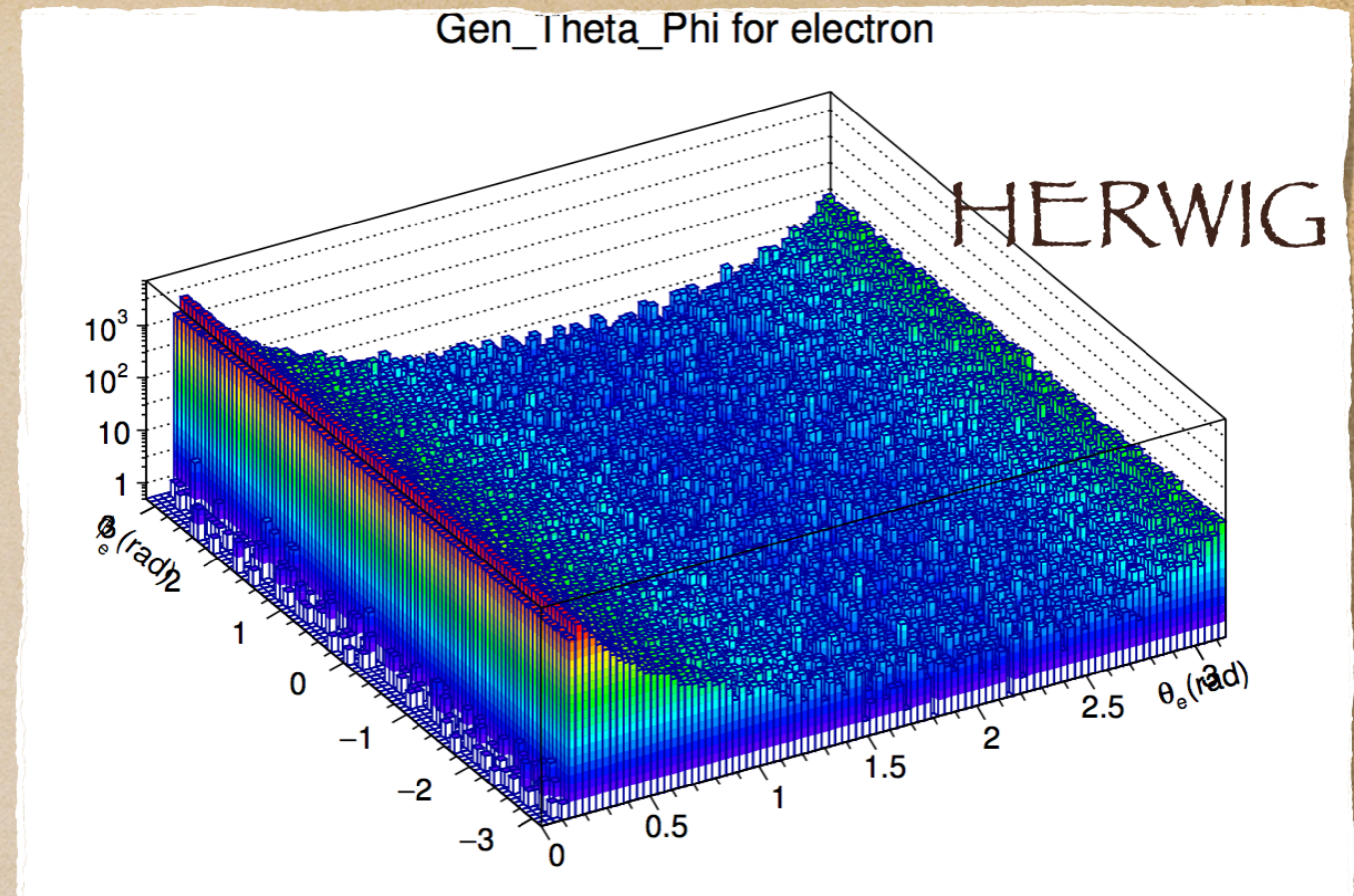
see Rik's Talk

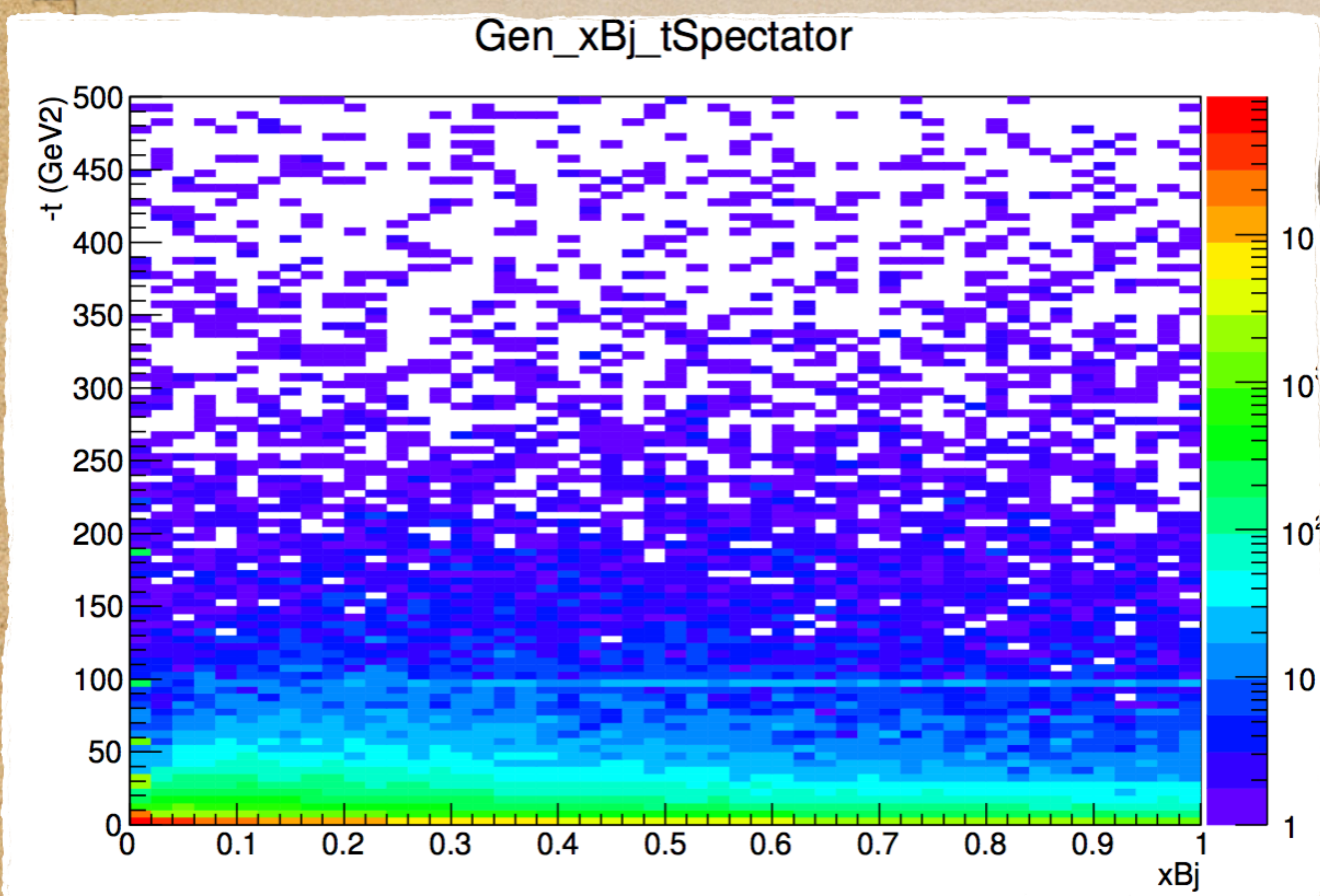
Dissociation Mode

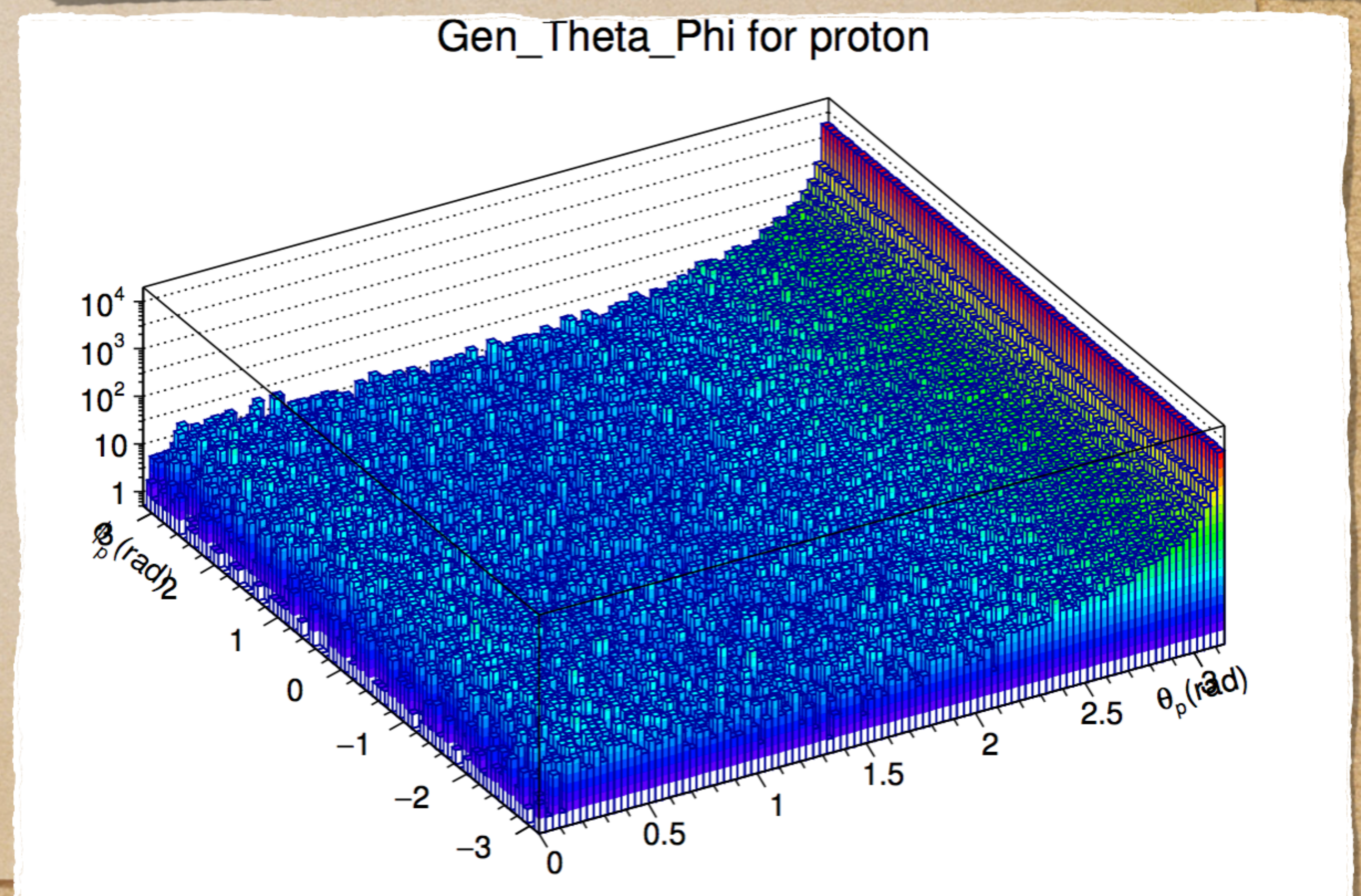


NC, e⁺p = 10x100 GeV²

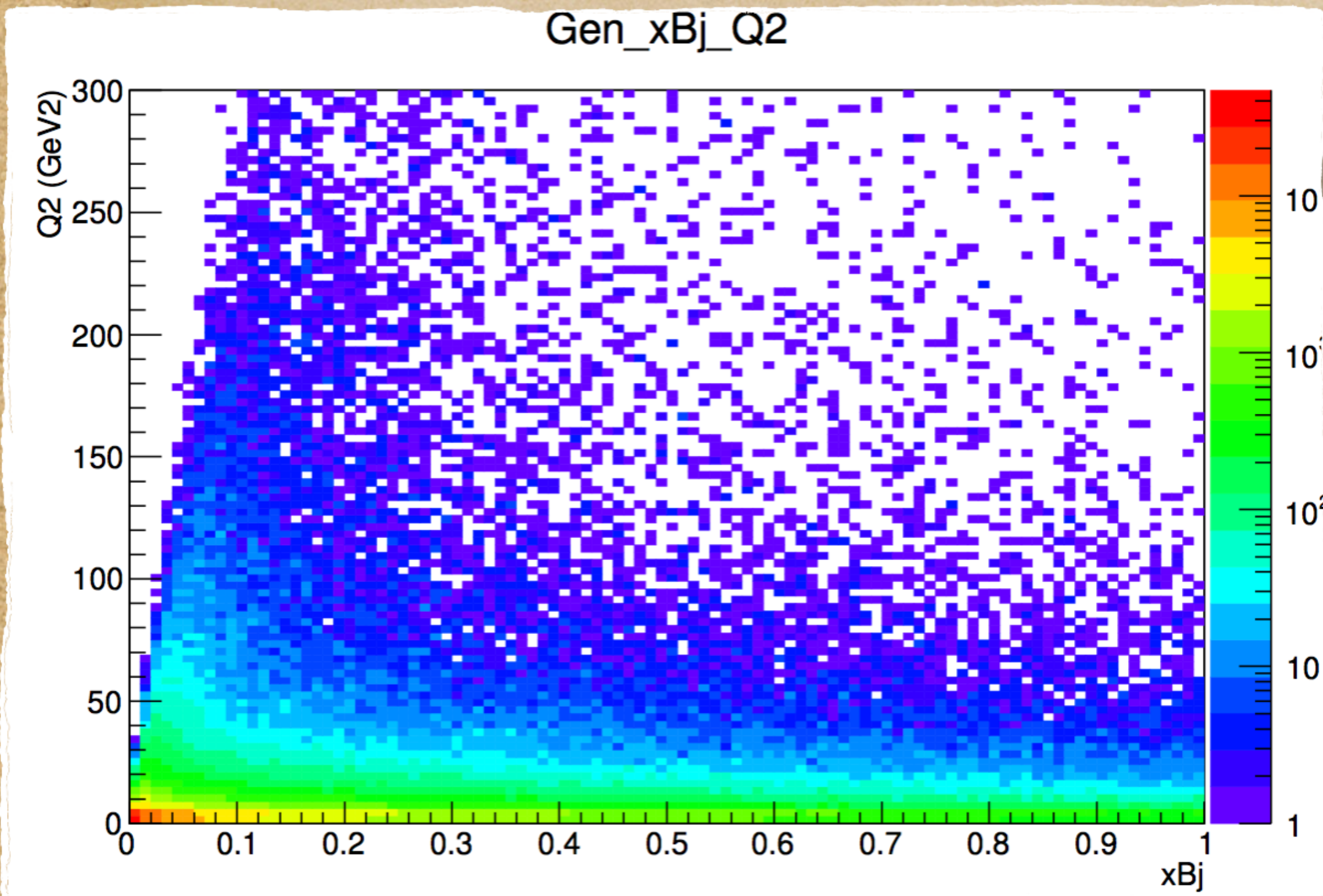


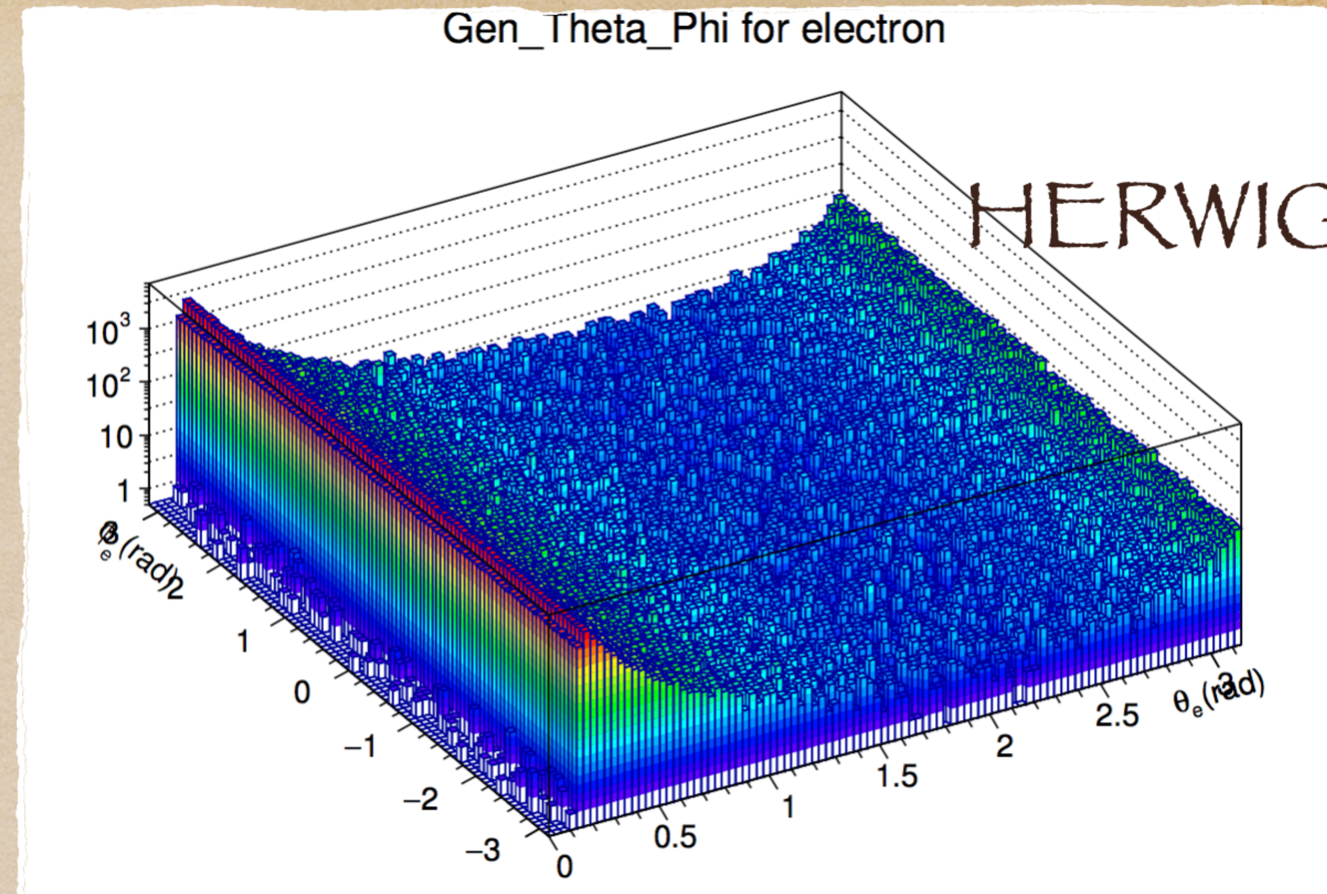






NC, e⁻p = 10x100 GeV^2





HERWIG