MINERVA with Cryogenic Target

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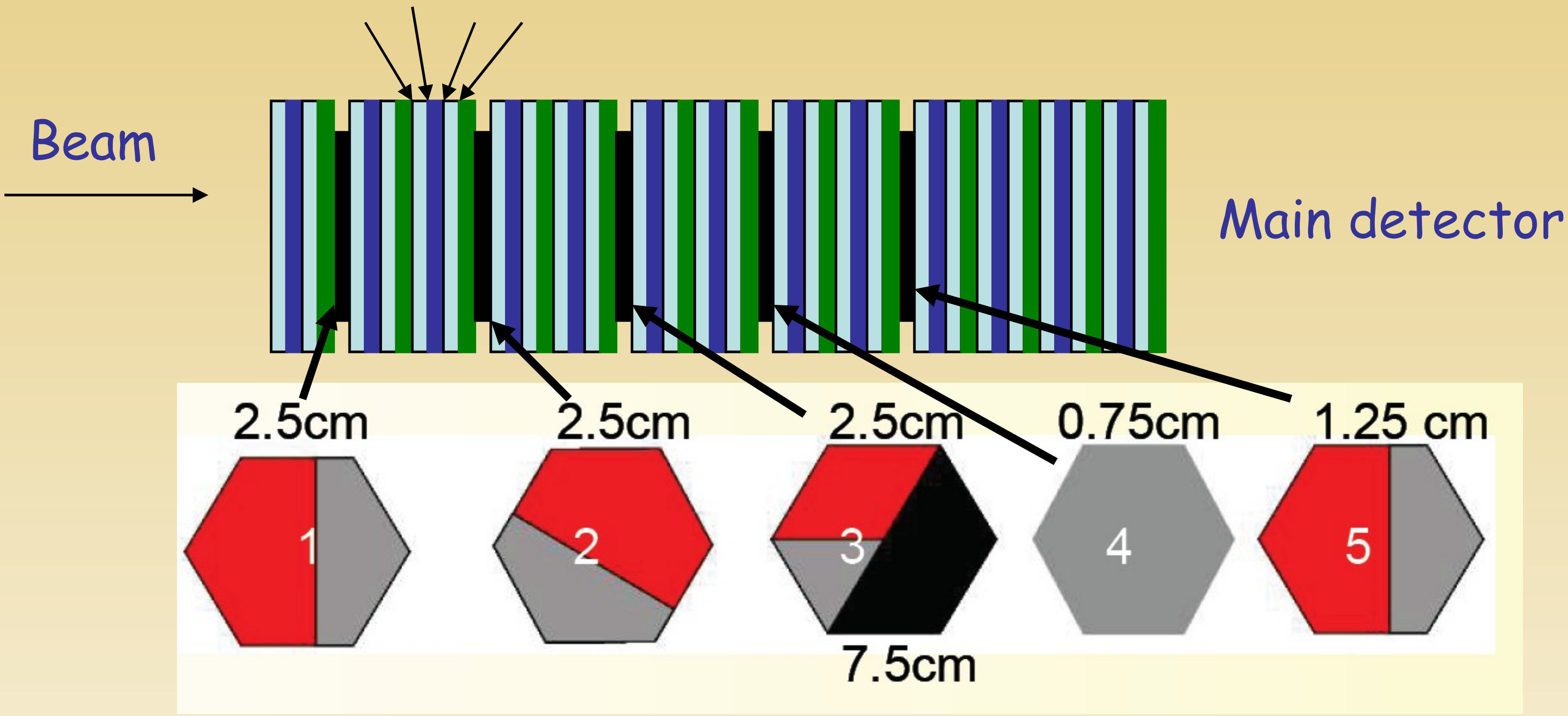
OUTLINE:

1. Addition of Helium Target Approved.
2. Working on the whitepaper to add Hydrogen Target
3. Current status on tracking and vertex reconstruction

Minerva Nuclear Targets

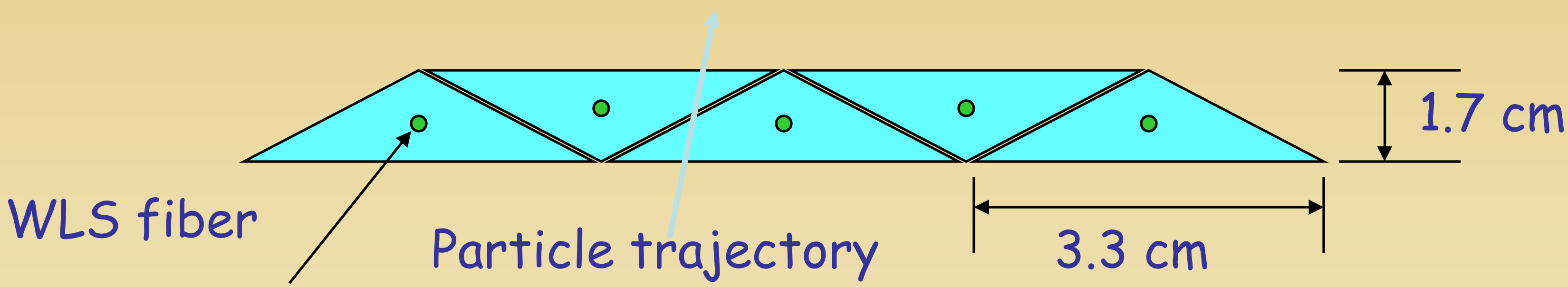
XUXVXUXV (4 tracking points) between each layer



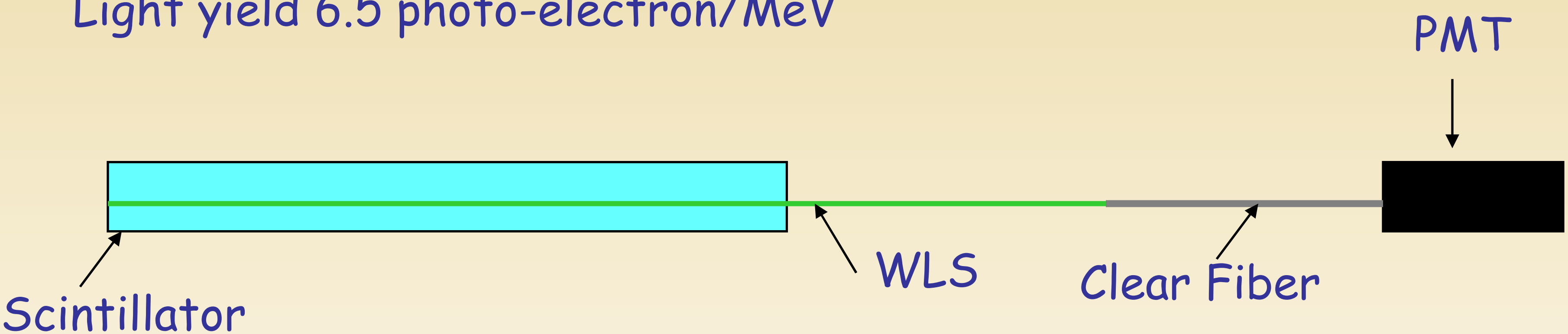
Carbon, Iron, Lead – mixed elements in layers to give same systematics

Active Scintillator Target

Triangular scintillators are arranged into planes – Wave length shifting fiber is read out by Multi-Anode PMT



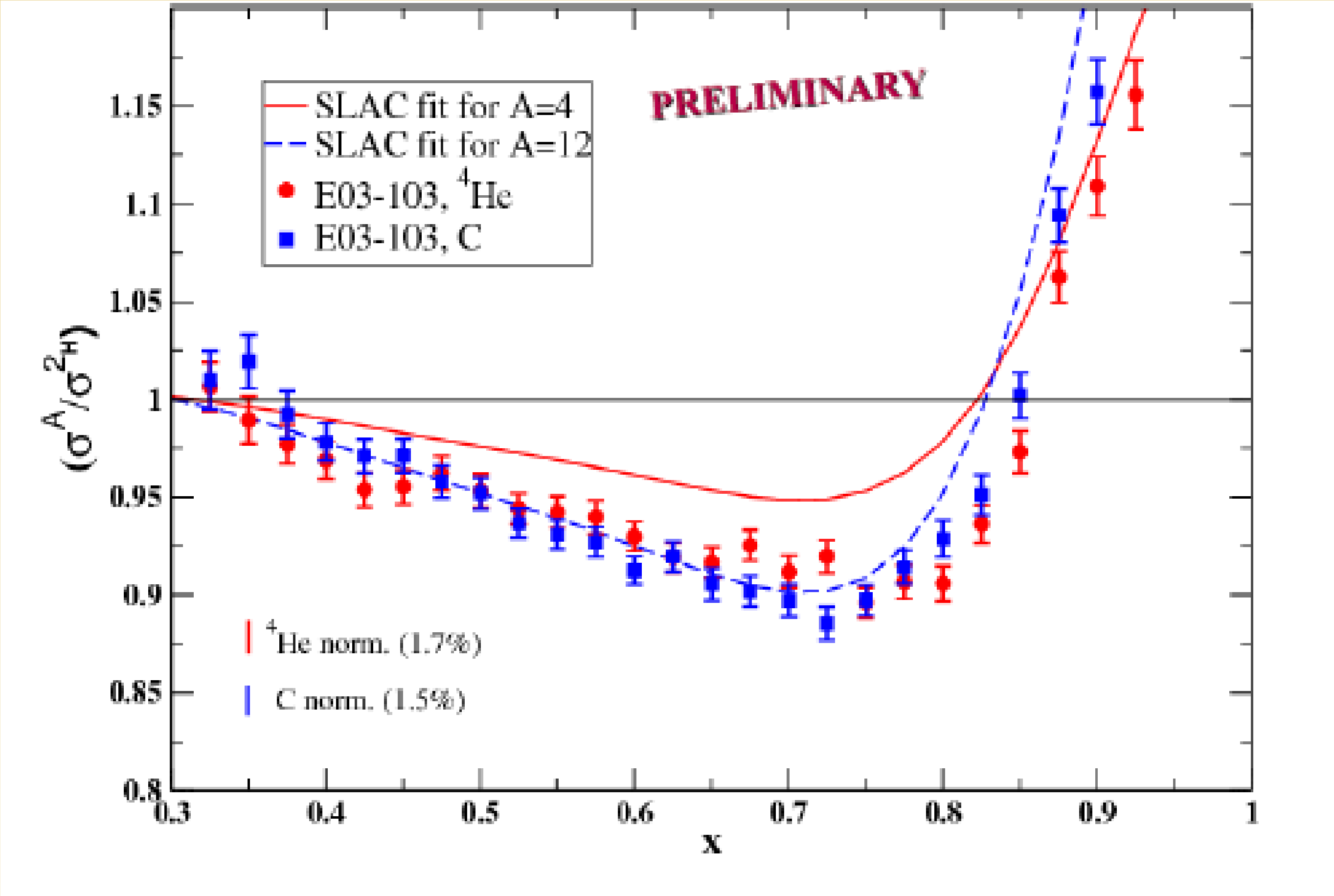
2.5 mm resolution with charge sharing
Light yield 6.5 photo-electron/MeV



EMC Effect between Helium and Carbon

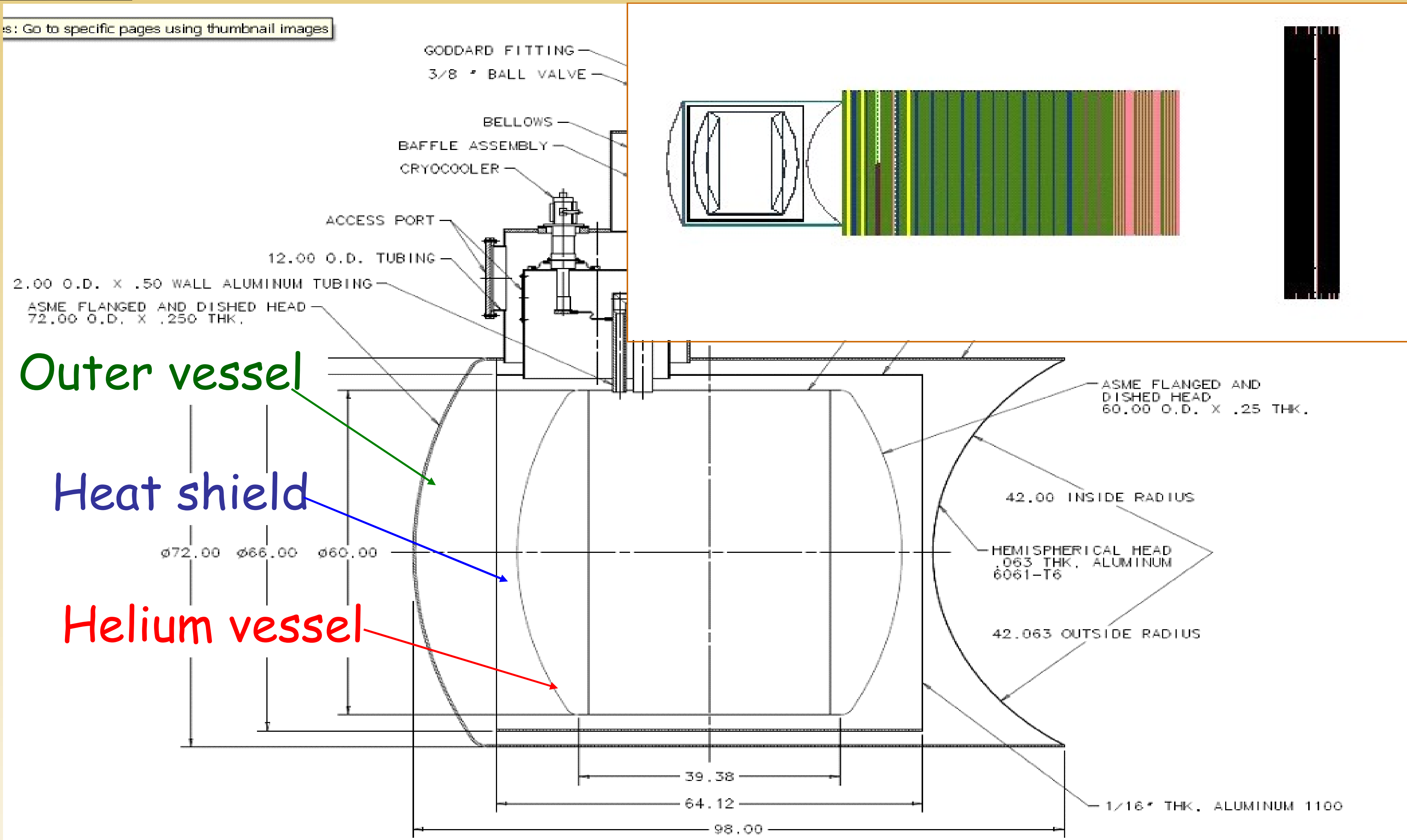
From Aji Daniel, JLab E03-103

Ref: John Arrington, nucl-ex/0701017

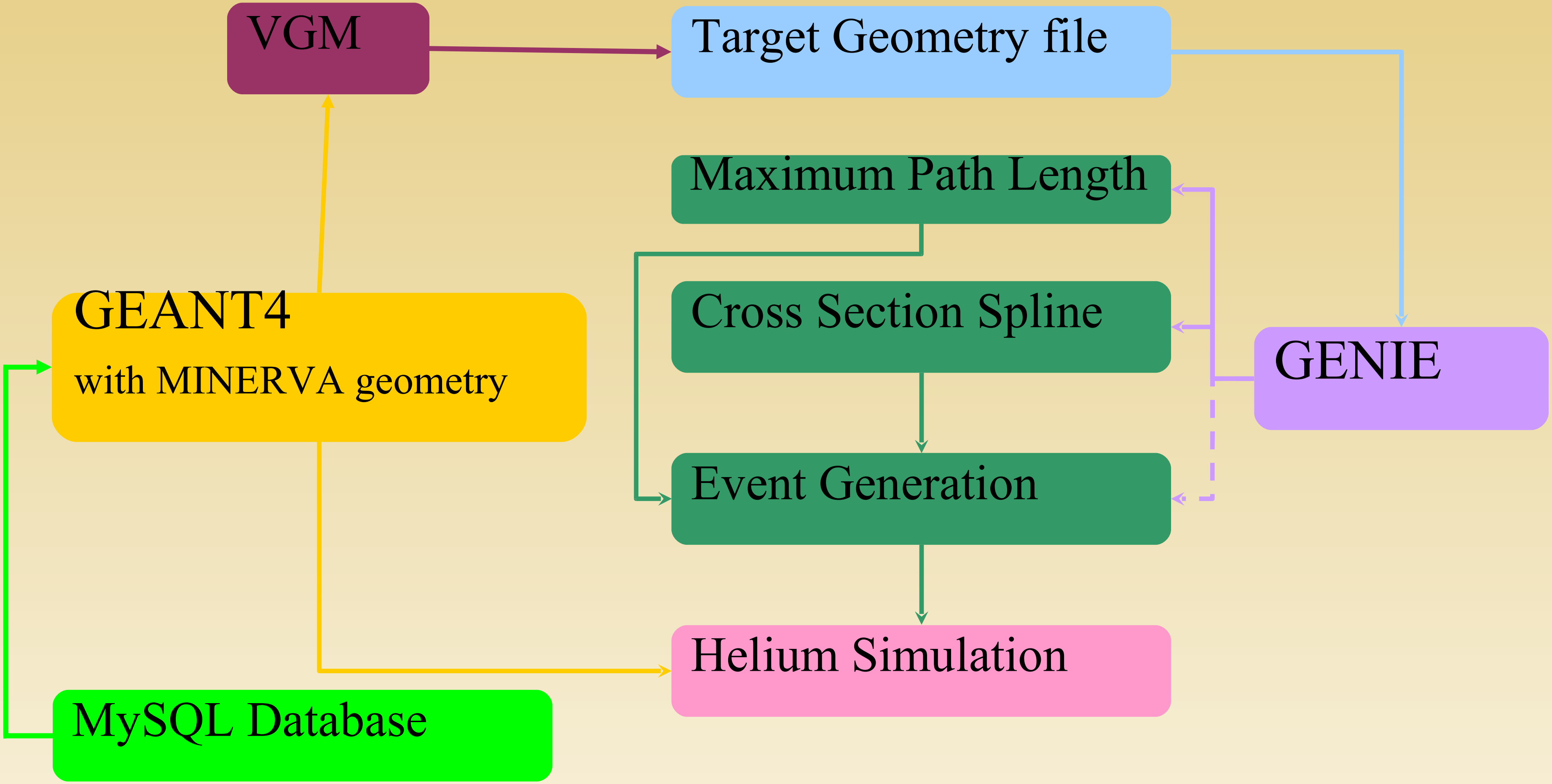


Helium is like Carbon

Design for the Cryogenic Target



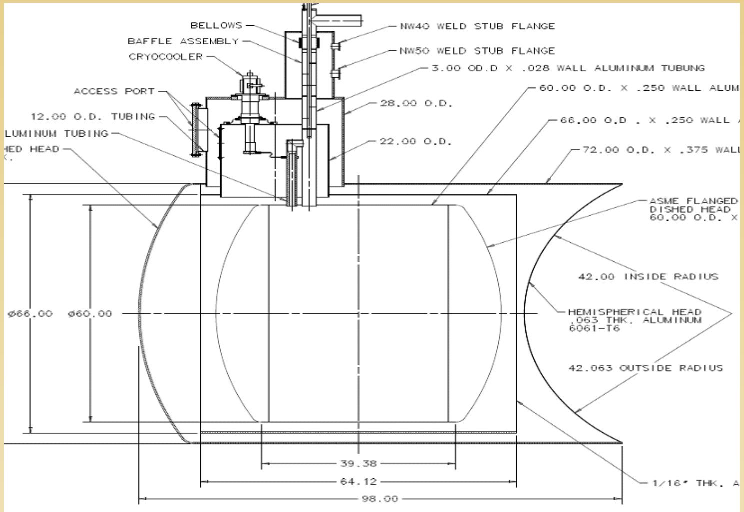
Flow chart for Helium Simulation

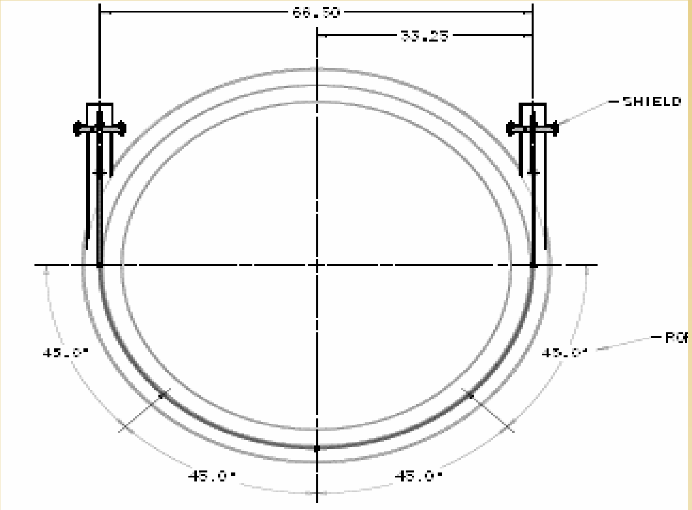


GENIE and GEANT4 simulation are separate steps.

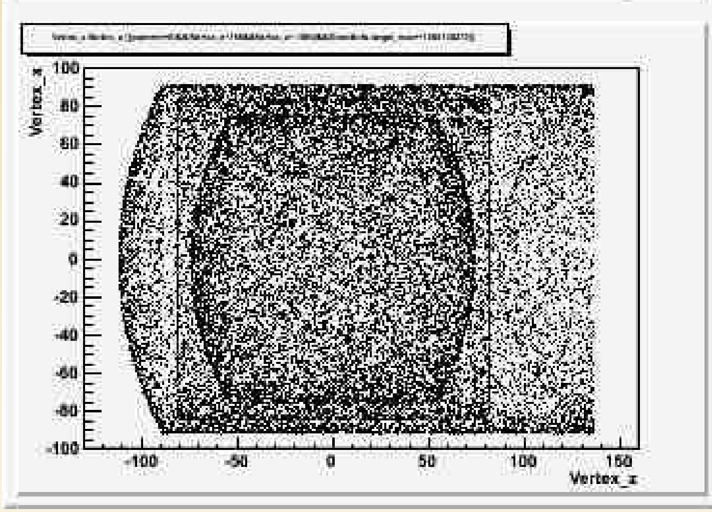
True Vertex Distribution from Aluminum

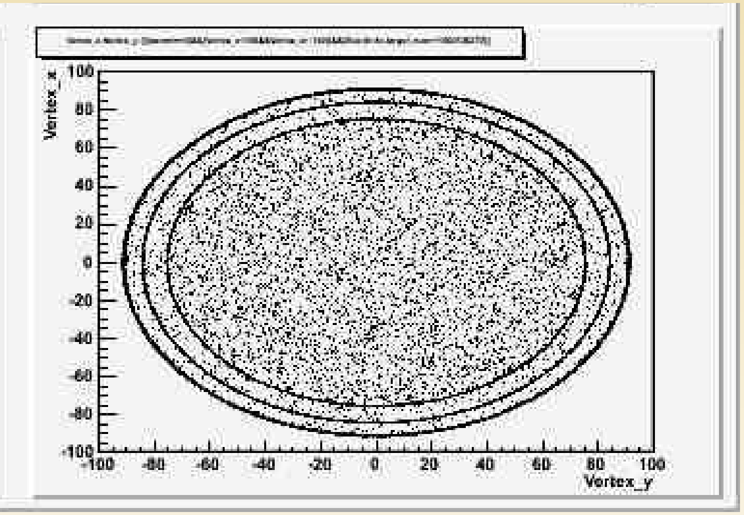
Design



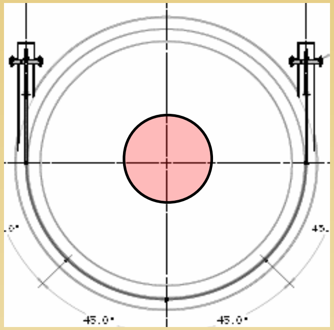


AL simulation



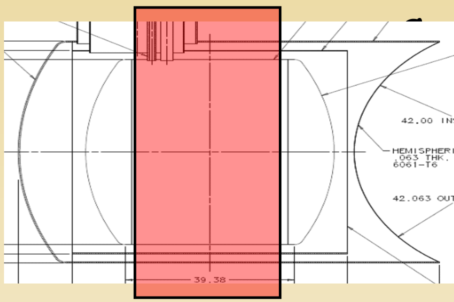


Al/He Ratio



Calculation Al/He=0.39 for vertex_radius<20

50k DIS Simulation:
Everything(no acceptance cut): Al/He=302/727=0.42
- With a muon hit on plane>100: Al/He=82/195=0.42



Calculation: Al/He=1.54 for |Vertex_z|<50

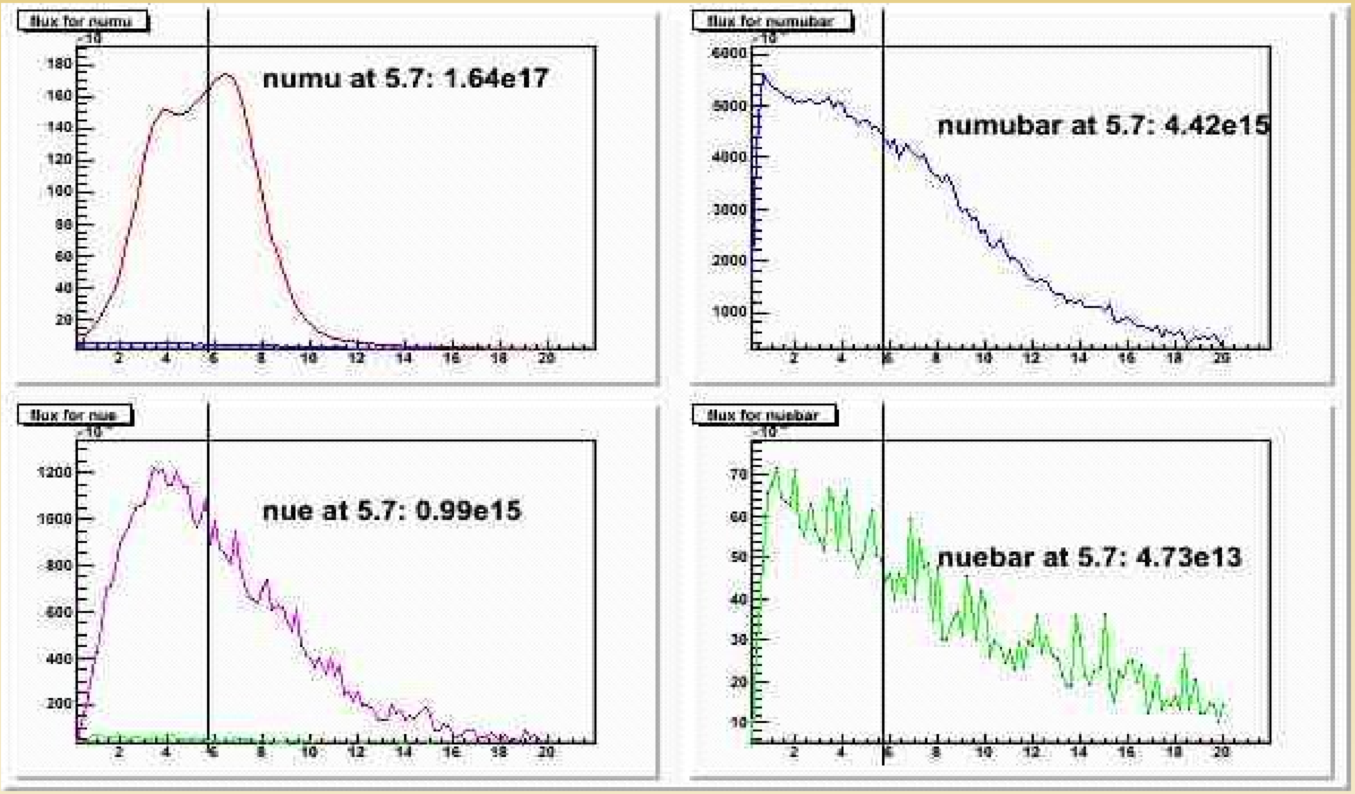
50k DIS Simulation:
Everything (no acceptance cut): Al/He=12012/7339=1.64
With a muon hit on plane >100: Al/He=2496/1864=1.34

- Calculation: Al/He~2.9 for the whole helium target.

- 50k DIS Simulation:
- Everything(no acceptance cut): Al/He=26692/9340=2.86
- With a muon hit on plane>100: Al/He=5946/2419=2.46

Al/He from Simulation is consistent with the calculation.

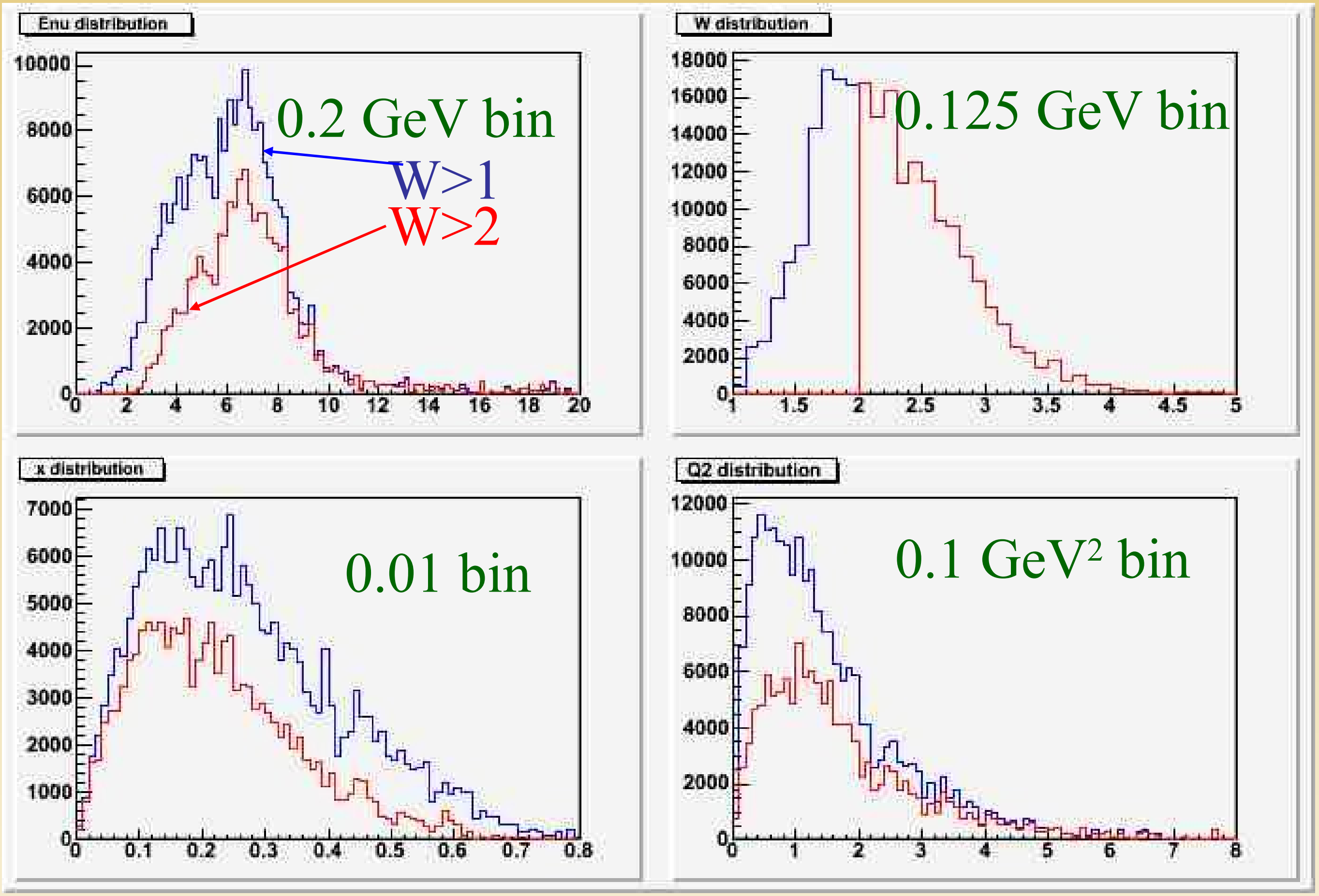
NUMICombo Neutrino Flux



Referring to doc2004-v3 by Jorge Morfin, revised on Nov 2007:
4 years' neutrino beam in the units of Neutrino/GeV/m^2

At 5.7 GeV: numu: numubar: nue: nuebar=3467:93:21:1

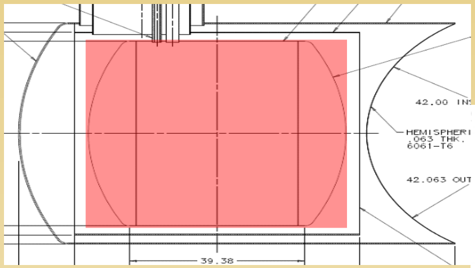
CC events with 4-year combo neutrino flux on He

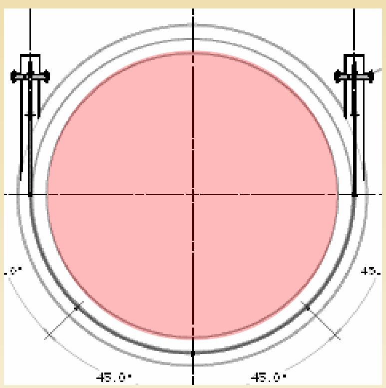


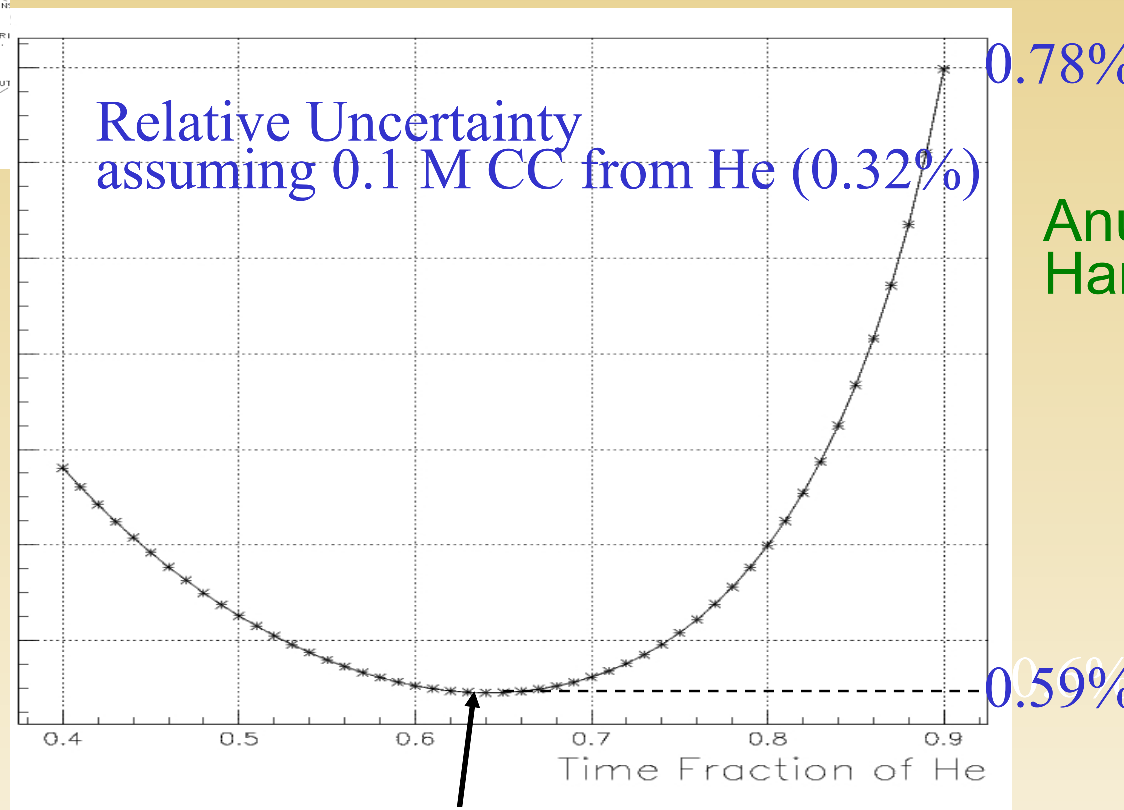
About 0.53 M DIS and 0.40 CC produced from Helium.
About 0.17 M CC with W>1 (0.10 M CC with W>2) detected.

On Empty target Run

With Vertex_r<76, |Vertex_z|<76 for all CC events, Al/He=1815/4011=45.3% R_{empty}/R_{he}=0.453/1.453



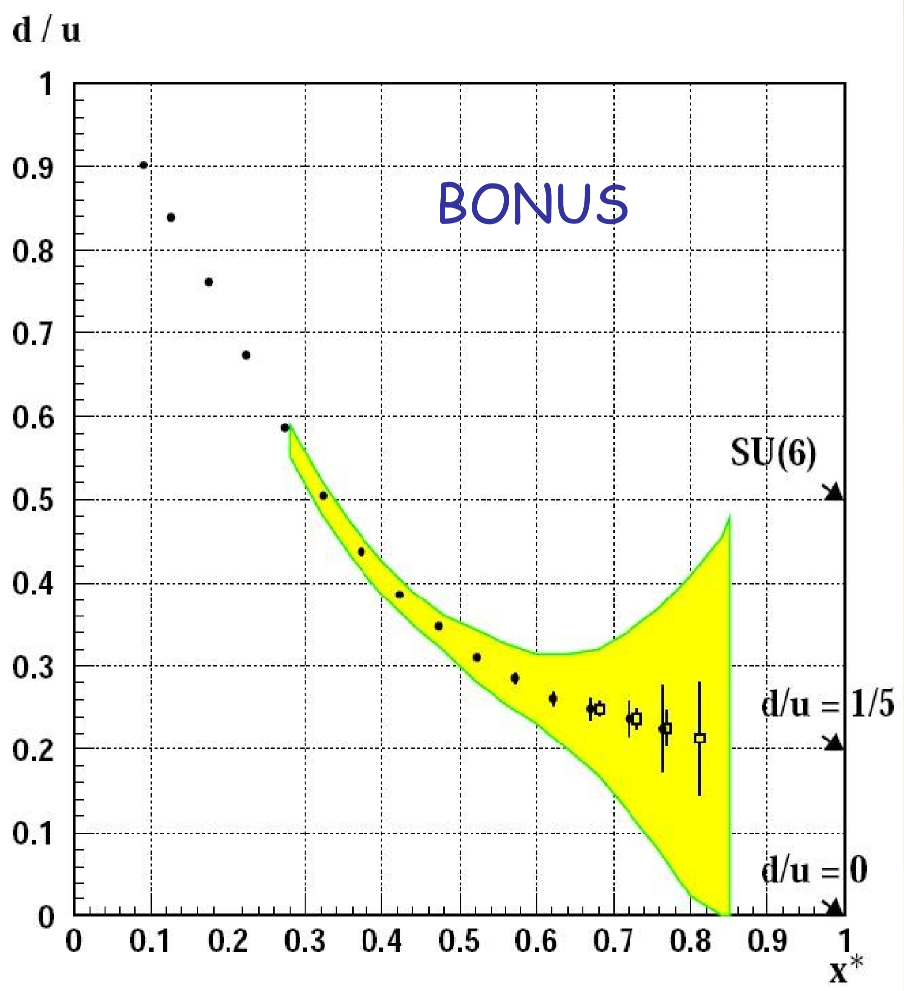


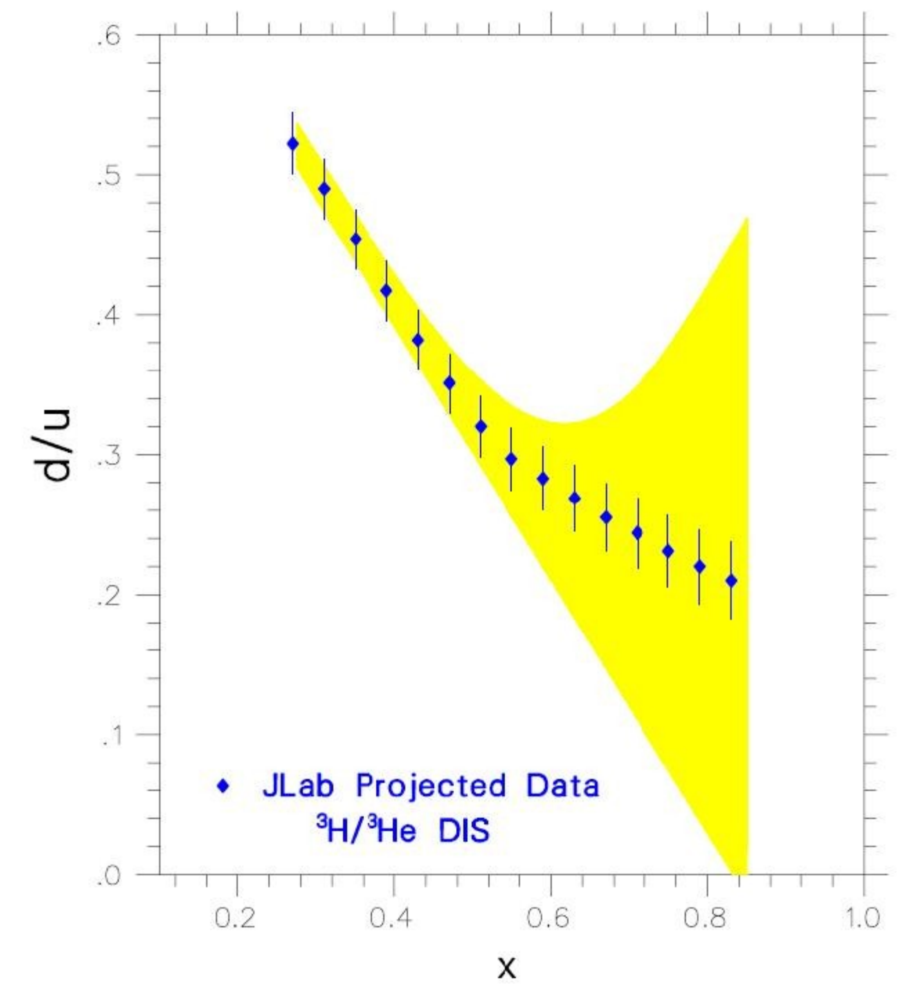


Anusha, HamptonU

$$\frac{T_{\text{empty}}}{T_{\text{he}}} = \sqrt{\frac{R_{\text{empty}}}{R_{\text{he}}}} \Rightarrow \frac{T_{\text{he}}}{T_{\text{total}}} = 0.642$$

Proposed d/u Experiments at JLab





(Anti)Neutrino Cross Section on Hydrogen

$$\frac{d^2\sigma^{\nu(\bar\nu)}}{dx\,dy} = \frac{G_F^2 M_p E_\nu}{\pi}\left[xy^2F_1^{\nu(\bar\nu)}(x,Q^2) + (1-y-\frac{M_p xy}{2E_\nu})F_2^{\nu(\bar\nu)}(x,Q^2) \pm y(1-\frac{y}{2})xF_3^{\nu(\bar\nu)}(x,Q^2)\right]$$

$$\begin{aligned}
F_1^\nu &= d(x)+s(x)+\bar u(x)+\bar c(x) \sim \frac{F_2^\nu}{2x}\\
F_1^{\bar\nu} &= u(x)+c(x)+\bar d(x)+\bar s(x) \sim \frac{F_2^{\bar\nu}}{2x}\\
F_3^\nu &= 2\left[d(x)+s(x)-\bar u(x)-\bar c(x)\right]\\
F_3^{\bar\nu} &= 2\left[u(x)+c(x)-\bar d(x)-\bar s(x)\right]
\end{aligned}$$

$$\begin{aligned}
\frac{d^2\sigma^\nu}{dx\,dy} &\sim \frac{G_F^2 M_p E_\nu}{\pi}\left[2x(1-y+y^2/2)(d+s+\bar u+\bar c) + 2x(y-y^2/2)(d+s-\bar u-\bar c)\right]\\
&= \frac{G_F^2 M_p E_\nu}{\pi}\cdot 2x\left[(d+s) + (1-y)^2(\bar u+\bar c)\right]\\
\frac{d^2\sigma^{\bar\nu}}{dx\,dy} &\sim \frac{G_F^2 M_p E_\nu}{\pi}\left[2x(1-y+y^2/2)(u+c+\bar d+\bar s) - 2x(y-y^2/2)(u+c-\bar d-\bar s)\right]\\
&= \frac{G_F^2 M_p E_\nu}{\pi}\cdot 2x\left[(1-y)^2(u+c) + (\bar d+\bar s)\right]
\end{aligned}$$

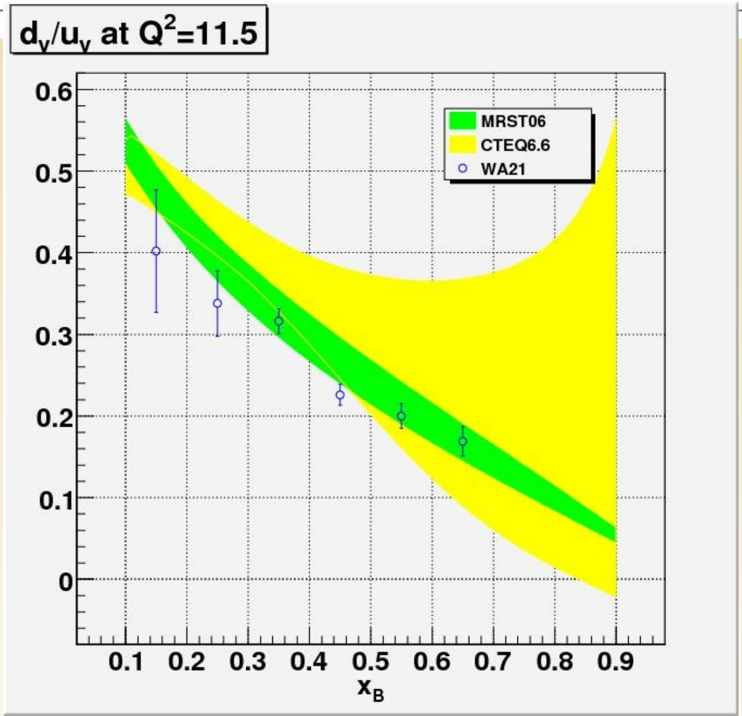
$$\frac{d_v}{u_v} \equiv \frac{d-\bar d}{u-\bar u} \sim \frac{[F_2^\nu/x + F_3^\nu]-[F_2^{\bar\nu}/x - F_3^{\bar\nu}]}{[F_2^{\bar\nu}/x + F_3^{\bar\nu}]-[F_2^\nu/x - F_3^\nu]} = \frac{(d+s)-(\bar d+\bar s)}{(u+c)-(\bar u+\bar c)}$$

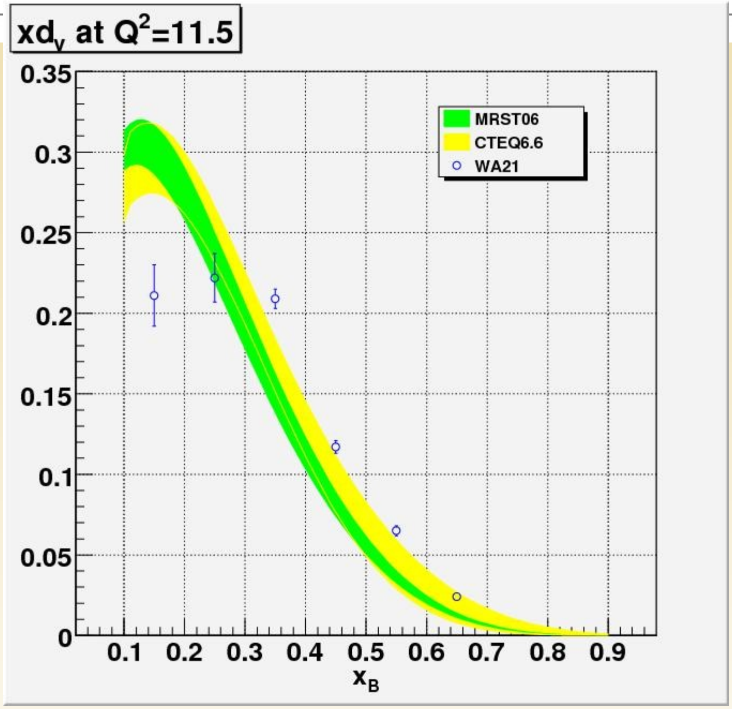
WA21 Data

Table 5. Structure functions $x\,d_v$, $x\,u_v$ and the ratio d_v/u_v

Jones, Z. Phys. C44(1989)379

x interval	$x\,d_v$	$x\,u_v$	d_v/u_v
0.0–0.1	$0.189 \pm 0.033 \pm 0.023$	$0.617 \pm 0.116 \pm 0.073$	$0.306 \pm 0.107 \pm 0.052$
0.1–0.2	$0.211 \pm 0.019 \pm 0.019$	$0.524 \pm 0.062 \pm 0.058$	$0.402 \pm 0.075 \pm 0.057$
0.2–0.3	$0.222 \pm 0.015 \pm 0.018$	$0.656 \pm 0.047 \pm 0.067$	$0.338 \pm 0.040 \pm 0.044$
0.3–0.4	$0.209 \pm 0.006 \pm 0.010$	$0.660 \pm 0.025 \pm 0.037$	$0.316 \pm 0.015 \pm 0.023$
0.4–0.5	$0.117 \pm 0.004 \pm 0.012$	$0.517 \pm 0.023 \pm 0.054$	$0.226 \pm 0.013 \pm 0.033$
0.5–0.6	$0.065 \pm 0.003 \pm 0.006$	$0.324 \pm 0.018 \pm 0.009$	$0.200 \pm 0.015 \pm 0.019$
0.6–0.7	$0.024 \pm 0.002 \pm 0.002$	$0.141 \pm 0.011 \pm 0.015$	$0.169 \pm 0.018 \pm 0.023$

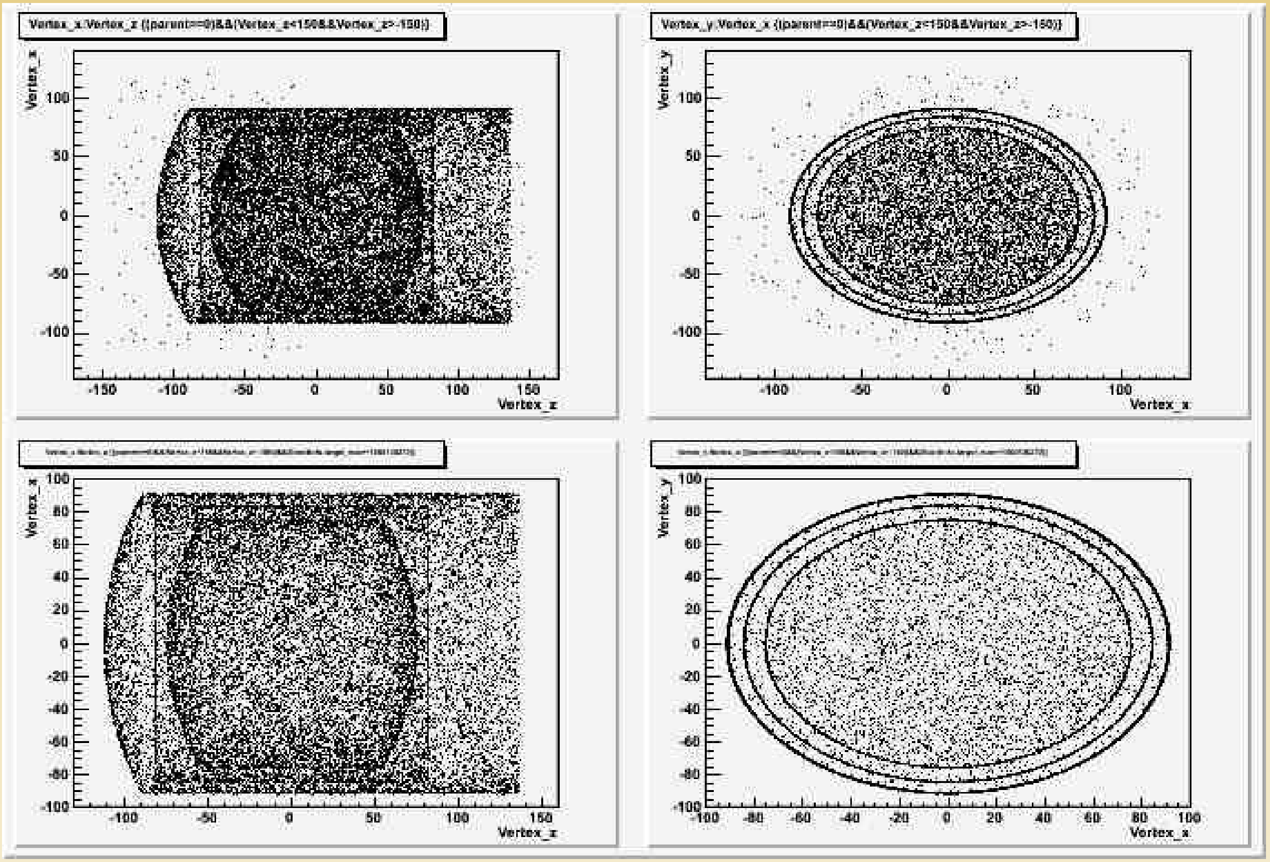




Hydrogen Simulation

Total simulation:
H, AL, air

AL simulation

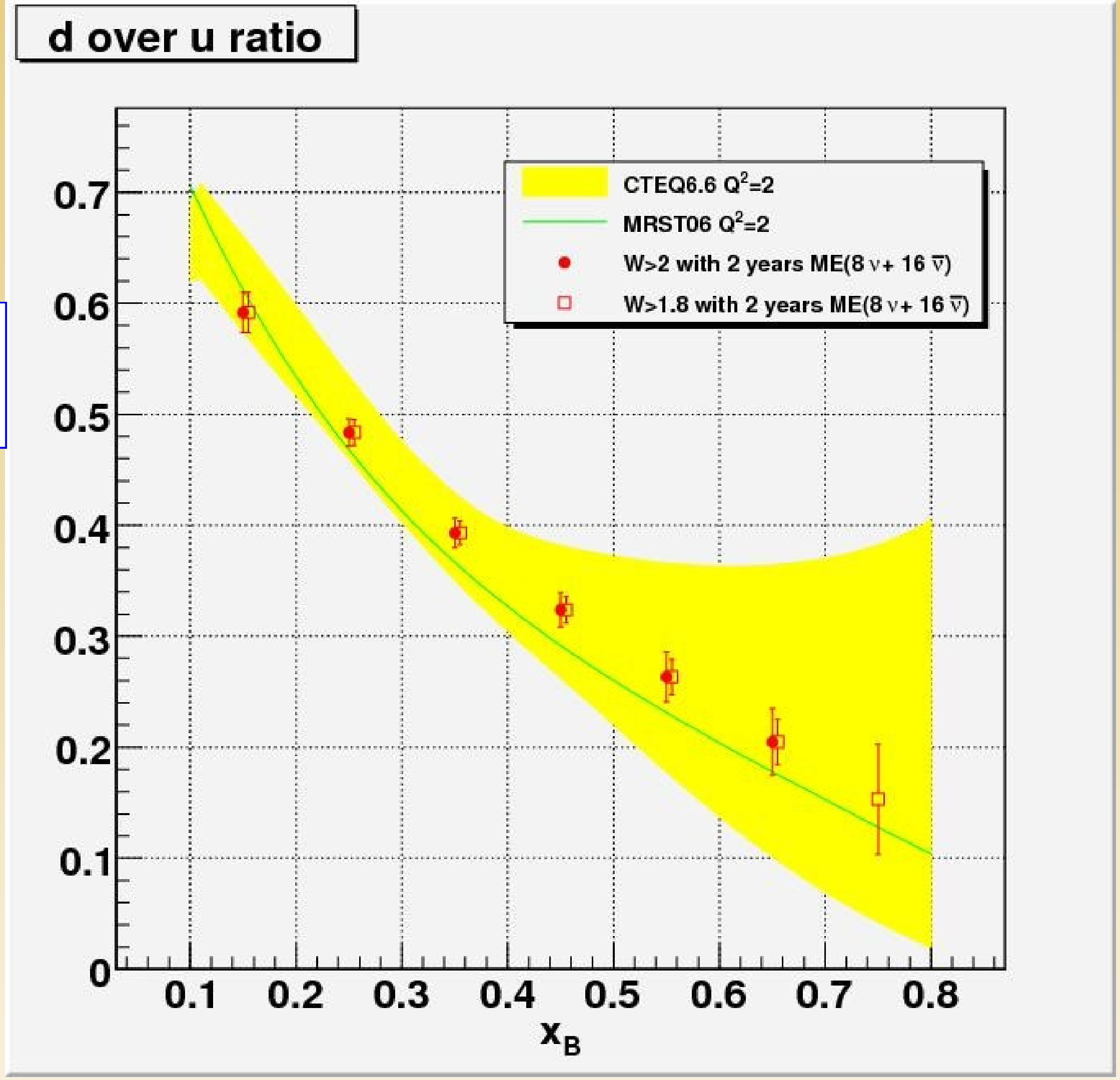


ρ_H=0.0708 g/cm^3, ρ_{He}=0.114 g/cm^3

Al/H~6 for combo neutrino beam while Al/He~3

Hydrogen Statistics

$$\frac{d^2\sigma^\nu}{d^2\sigma^{\bar{\nu}}}(x,y) \sim \frac{d(x)}{u(x)} \cdot \frac{1}{(1-y)^2}$$



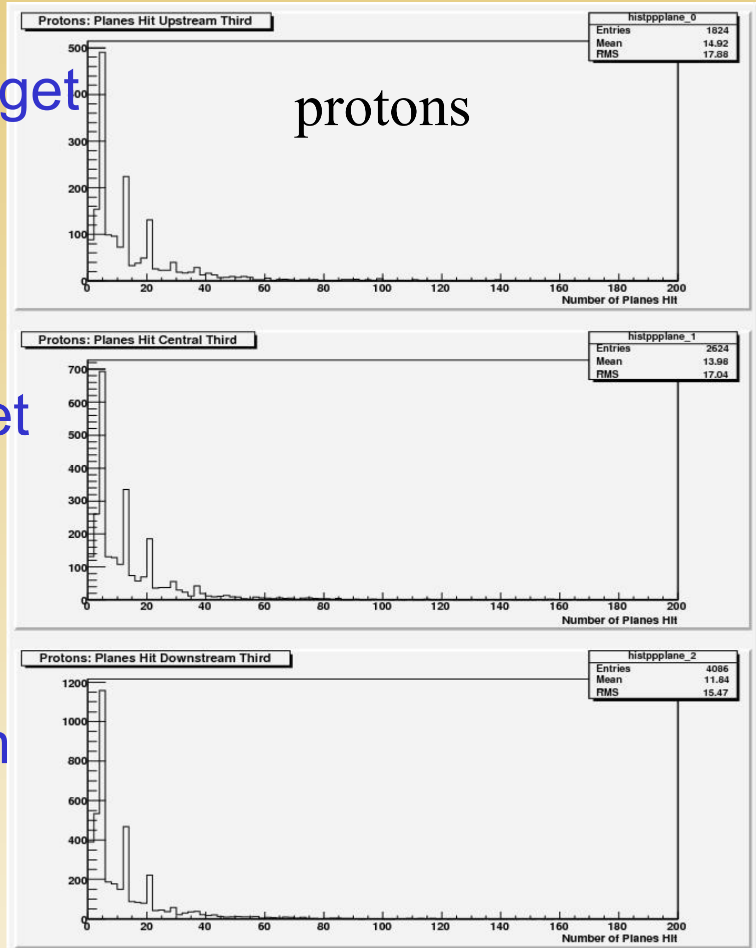
The contribution from the target vessels was not considered.

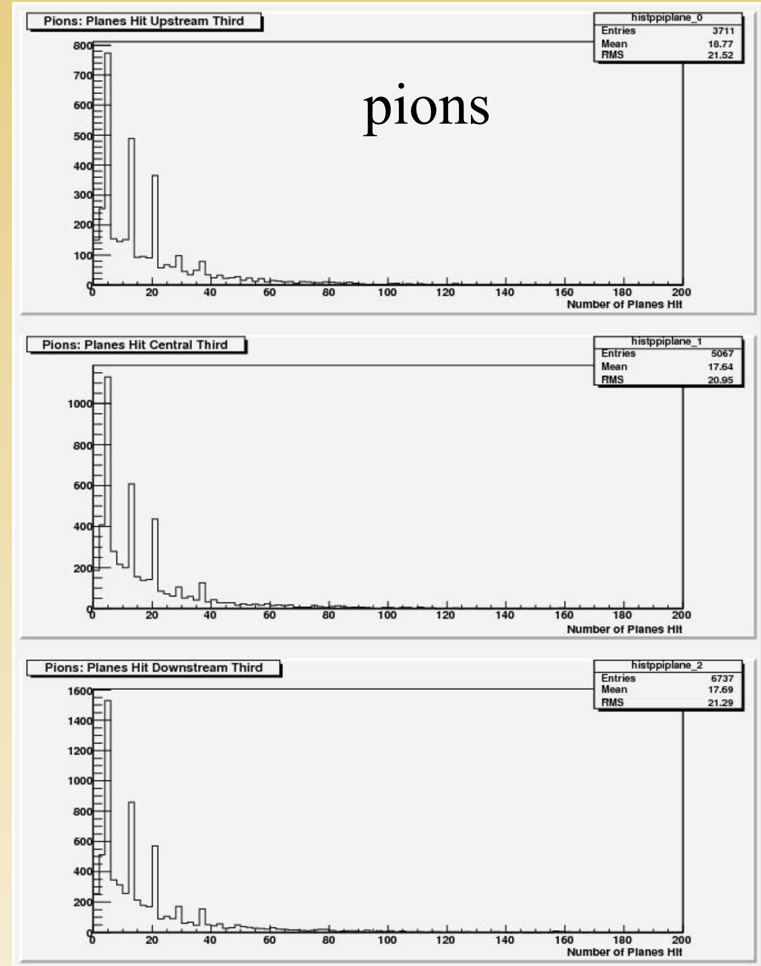
The Last Hit Plane Distribution for p and π

Upstream target

Central target

Downstream

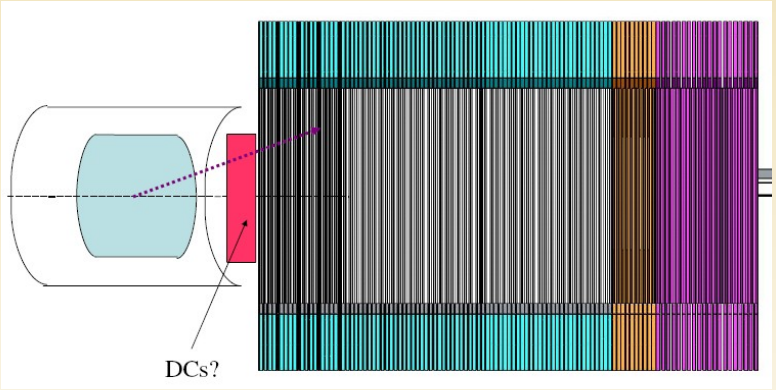




For |z|<73.8(upstream+central+downstream):
20.6% of all proton hits, 15.6% of all pion hits will be lost due to the first nuclear target: absorbed or get out from its sides.

Additional Tracking Module?

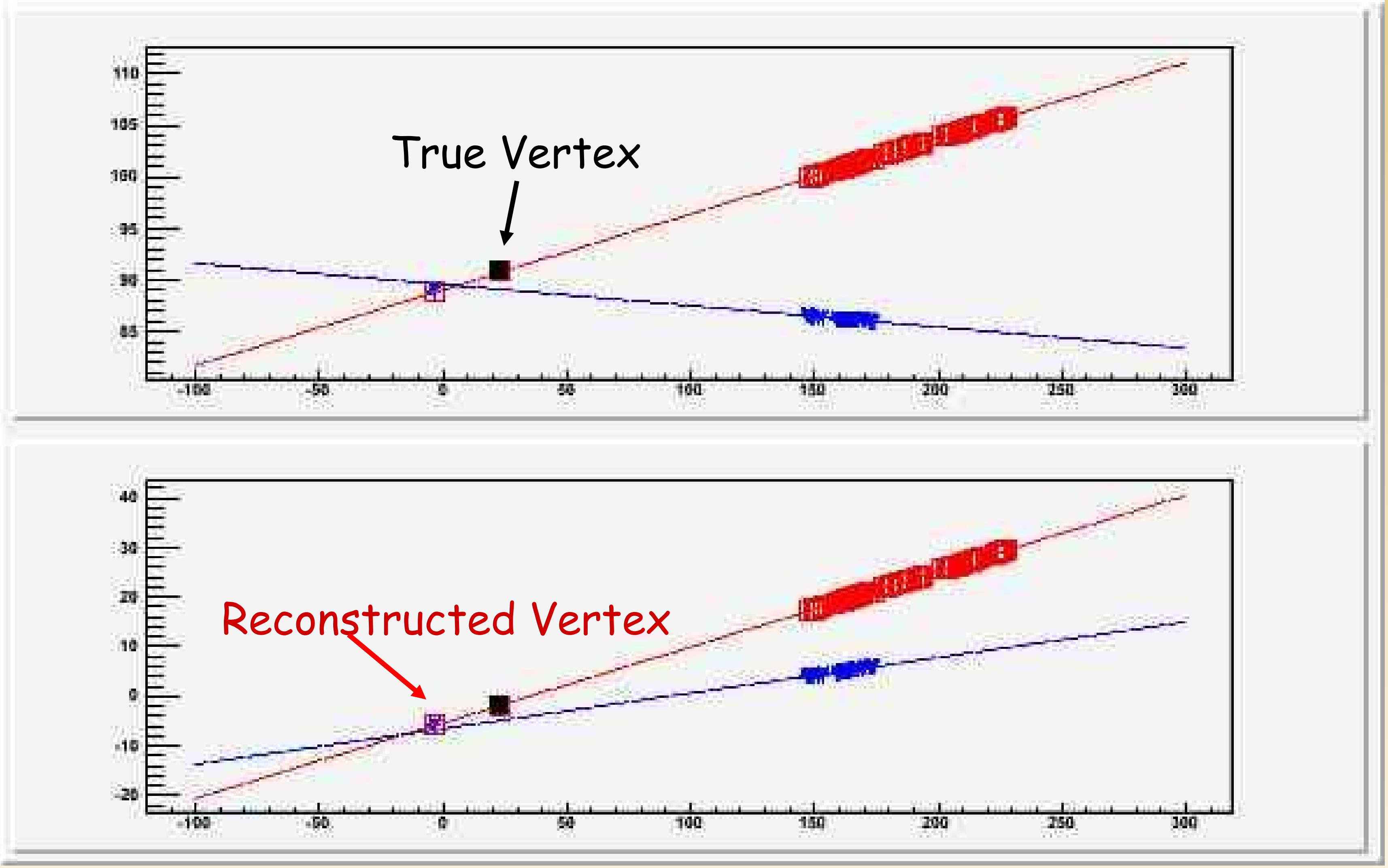
- Currently there are only two tracking modules (4 planes) between the cryogenic and the first nuclear target. Shall we add one tracking module (2 planes) from downstream?
- Shall we insert drift wire chambers between the cryogenic target and the minerva detector? For example, the SOS Drift chambers from JLab Hall C as proposed by Eric Christy in doc-2182. Two side by side chambers with 6 wires each (2X,2Y,2U orientations). The active area of the two chambers is ~60 cm$*(2*40)$ cm



Adding Wire Chamber to Simulation

- The Rutgers Version of the GEANT4 simulation.
- Inserted between the cryogenic target and the minerva tracking modules. Basically shifted the cryogenic target 10 cm upstream.
- Bigger Dimension than the JLab SOS not to affect acceptance for the moment.
- One virtual sensitive plane in the middle of the wire chamber, which gives us true hit position x/y at that z.

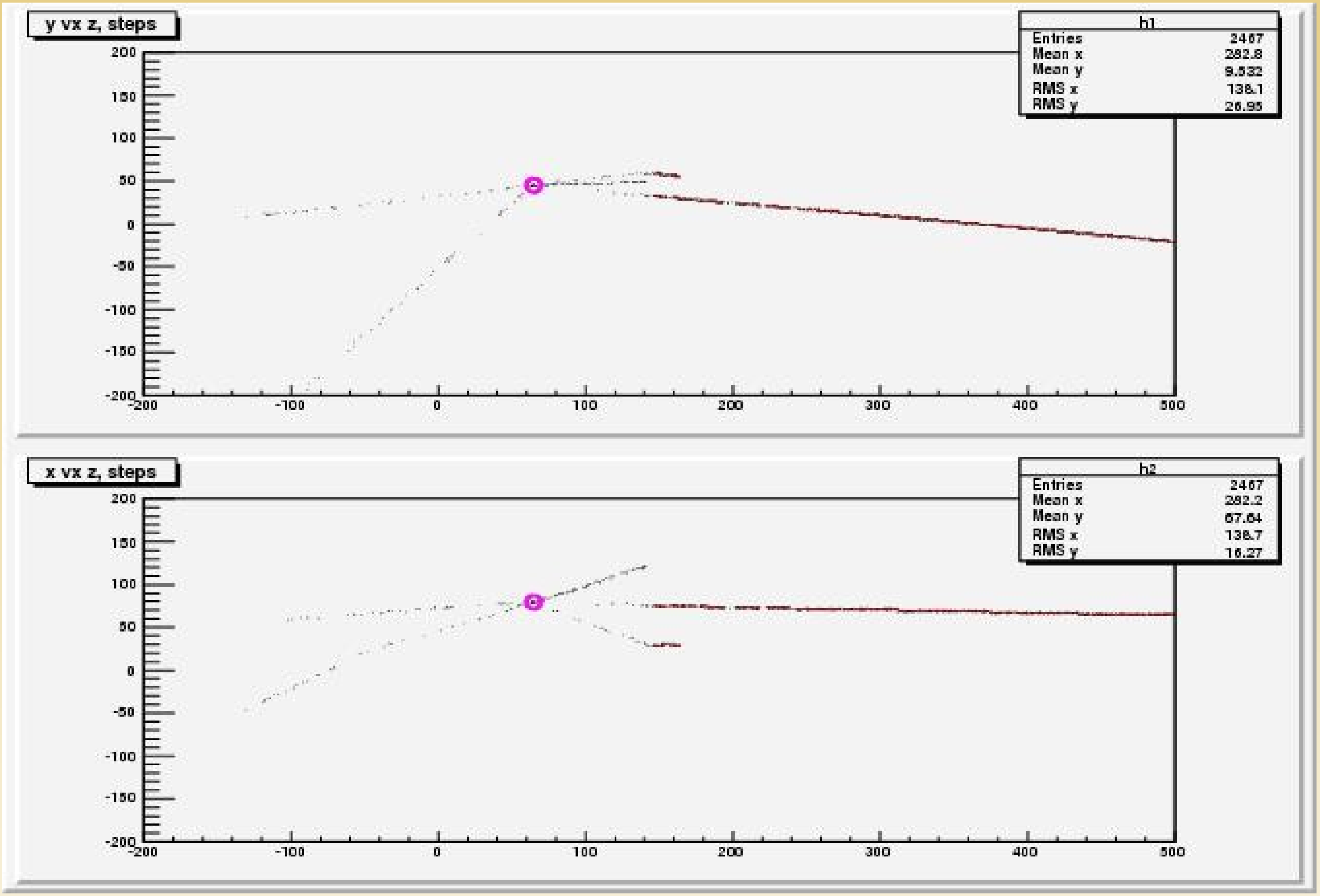
A Example Vertex Reconstruction



Current Vertex Reconstruction

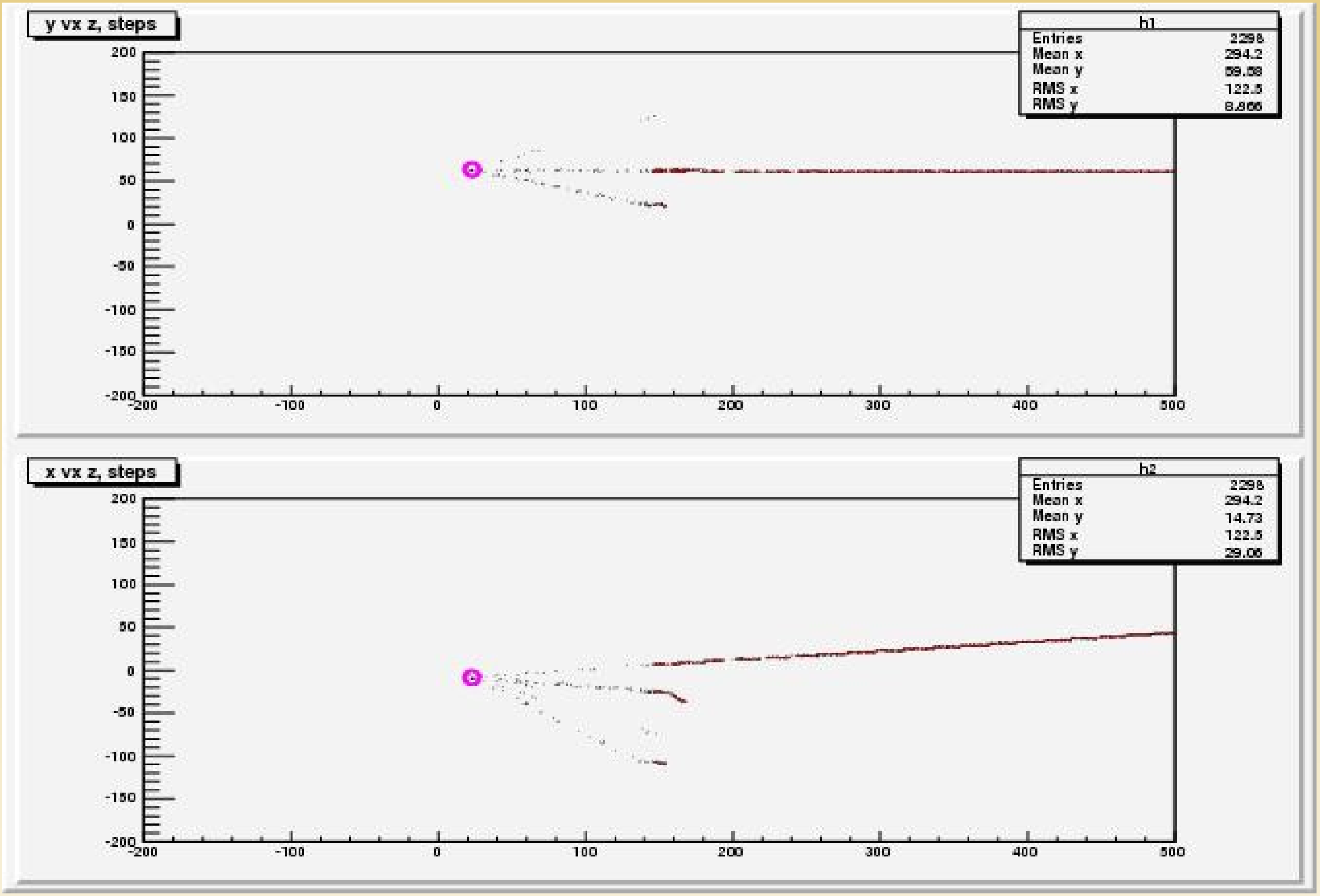
- Linear fit of all true hit positions with matrix operation. There were multiple hits per plane. The detector resolution and plane orientation (x/u/v) were not considered yet.
- The reconstructed vertices were averaged over all the track pairs.
- To improve vertex reconstruction, one of the two tracks used for vertex reconstruction was required to be a muon track.
- To improve vertex reconstruction, vertex was assumed to be the muon end of the minimum distance between two tracks.
- The track may bend due to secondary reaction including multi-scattering and nuclear processes.

Secondary Reaction before the Detector



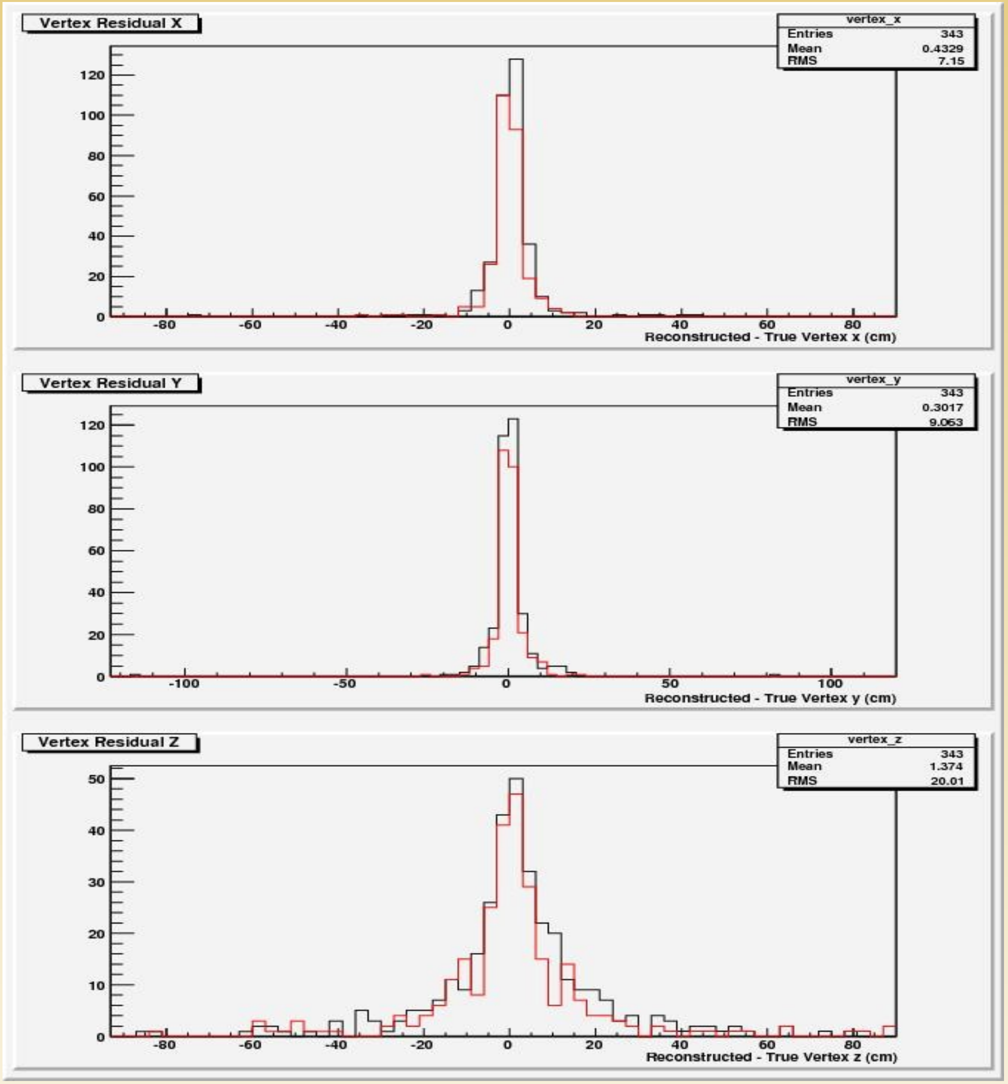
Reconstructed Vertex_z from muon and pion=1160.4

Secondary Reaction in the Detector



Reconstructed Vertex_z from muon and pions=-70

Vertex Residue with and w/o Big WCs



Vertex residue= Reconstructed – True Vertex (cm)