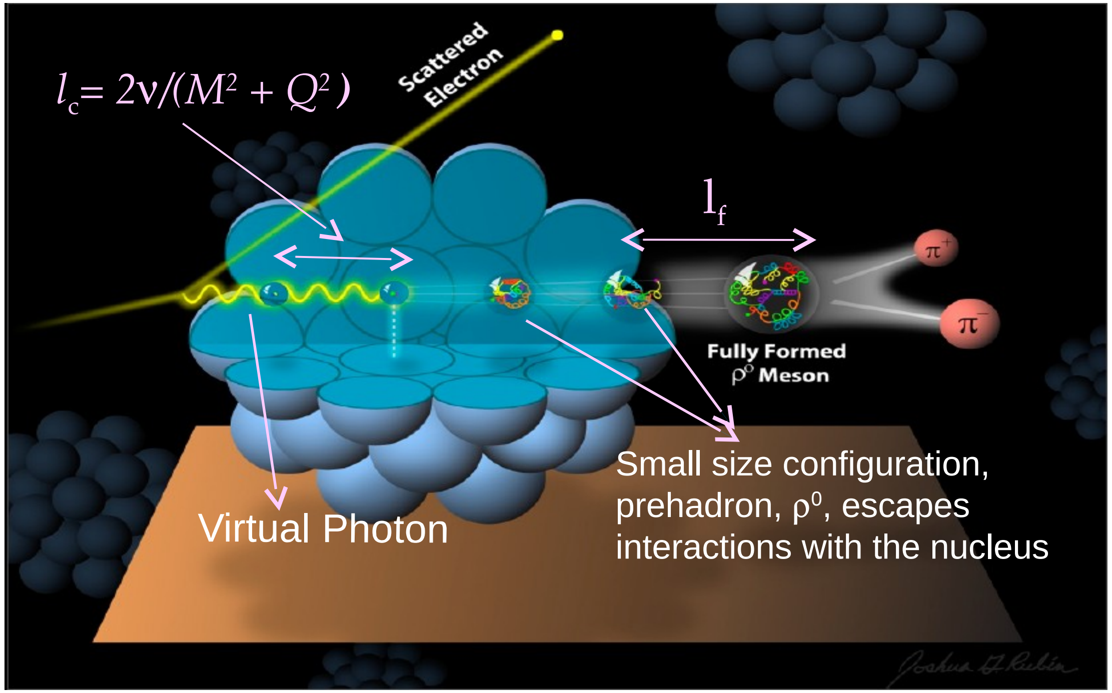
RG-D Readiness Status

CLAS Collaboration Meeting
June 19th, 2019

Lamiaa El Fassi
(for the RG-D Co-spokespersons)

RG-D Experiment

- E12-06-106, "Study of Color Transparency in Exclusive Vector Meson Electro-production off Nuclei", approved with 60 PAC days.



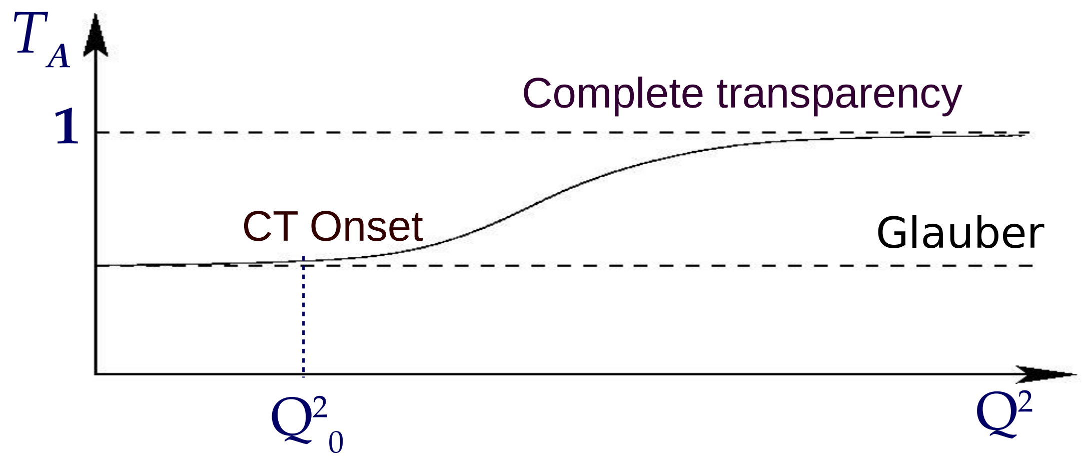
- Coherence length, l_c, is the lifetime of the qq-bar pair.
- Formation time, l_f, is the lifetime of thesmall size configuration before evolving to a full ρ^0 meson.

The CT signature is the increase of the medium "nuclear" transparency, T_A, as a function of the four-momentum transfer squared, Q^2.

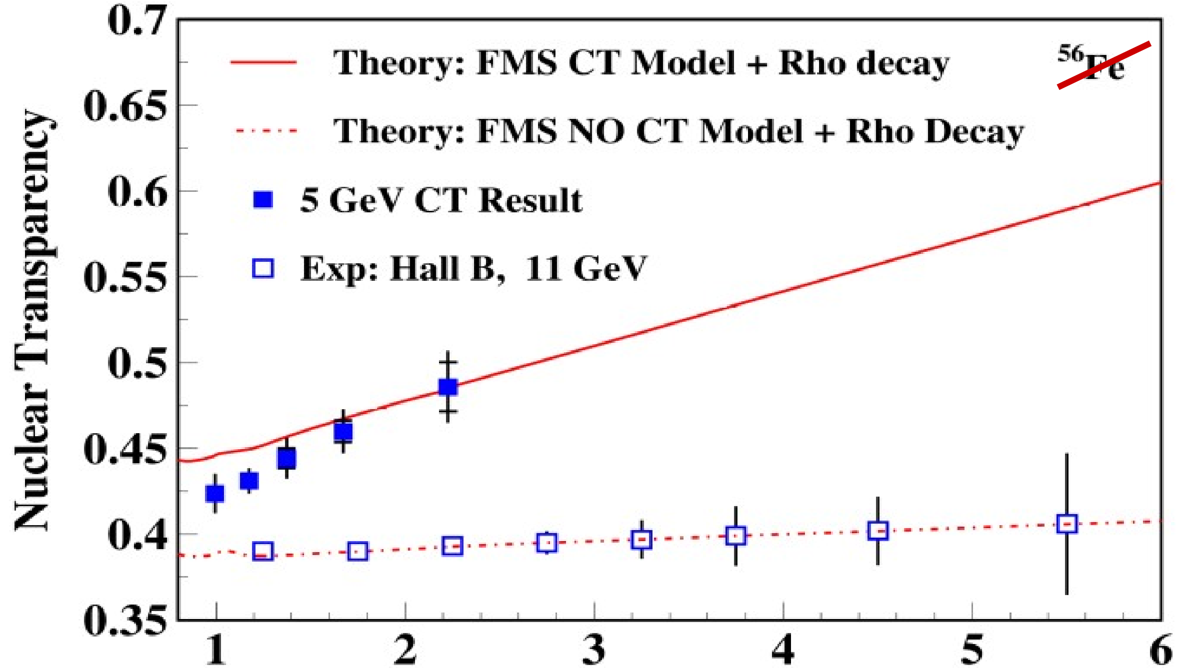
$$T_A = \frac{\sigma_A}{A\,\sigma_N}$$

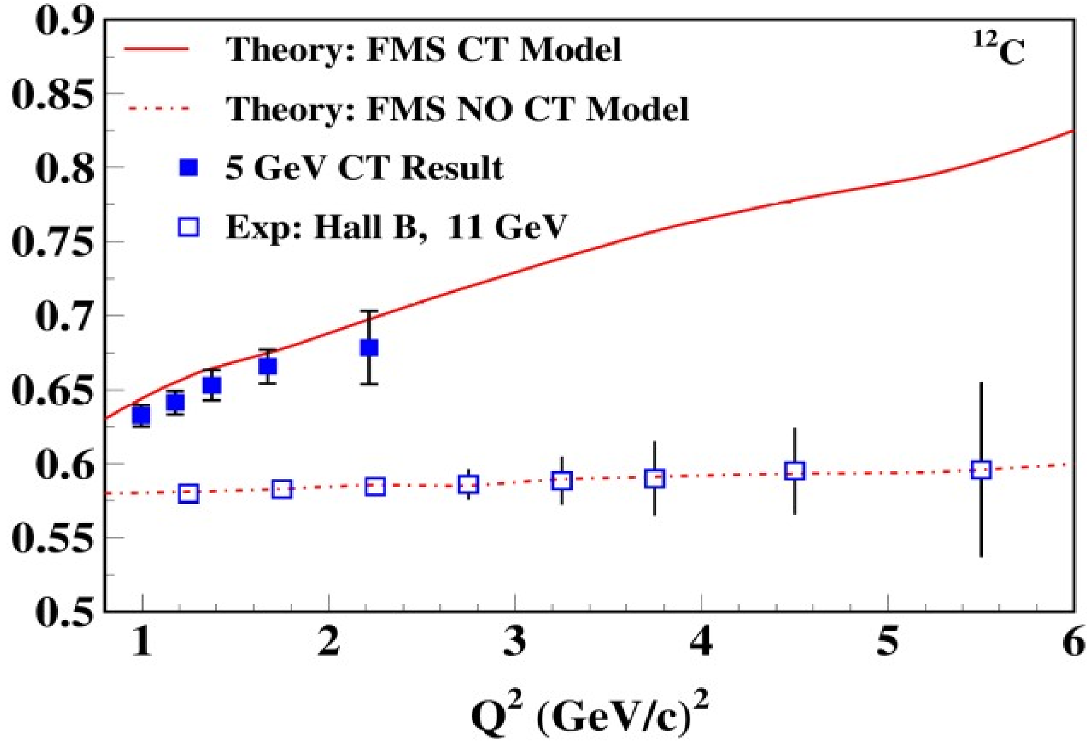
σ_A is the nuclear cross section

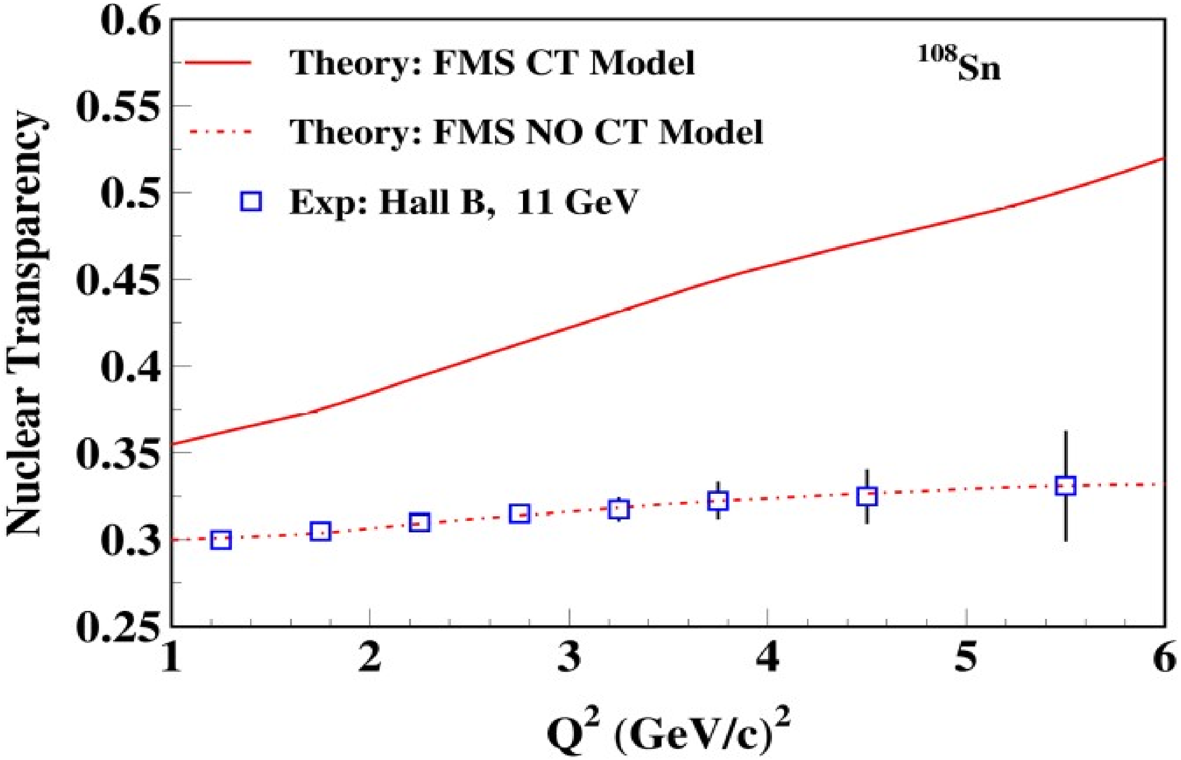
σ_N is the free (nucleon) cross section

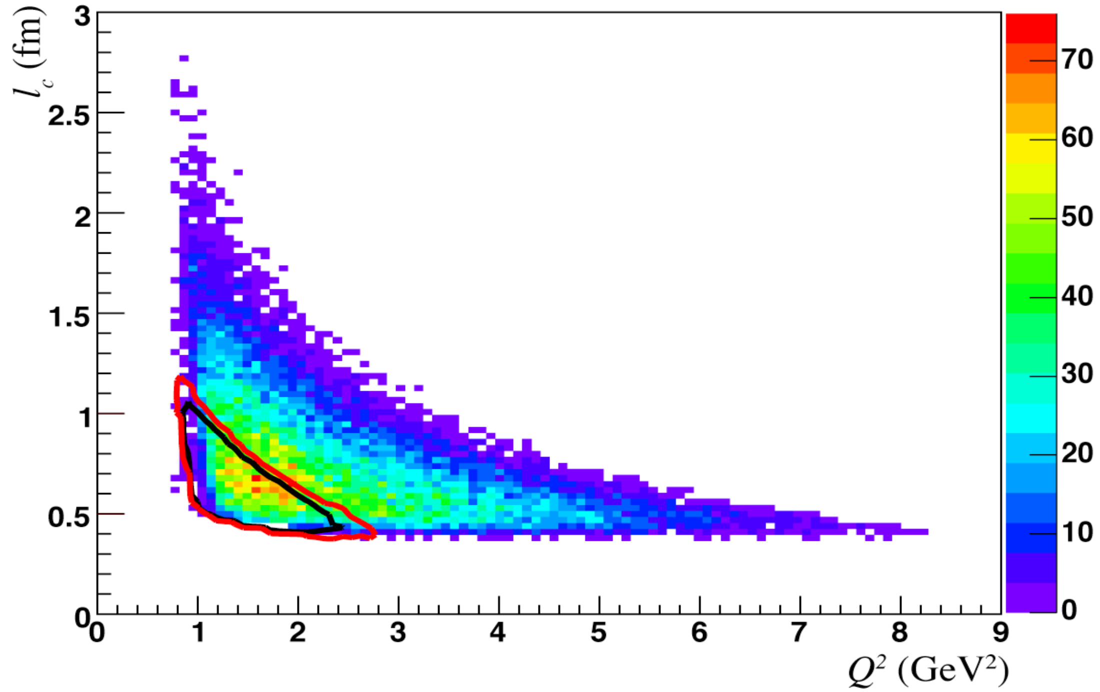


Approved 11 GeV CT Experiment Projections









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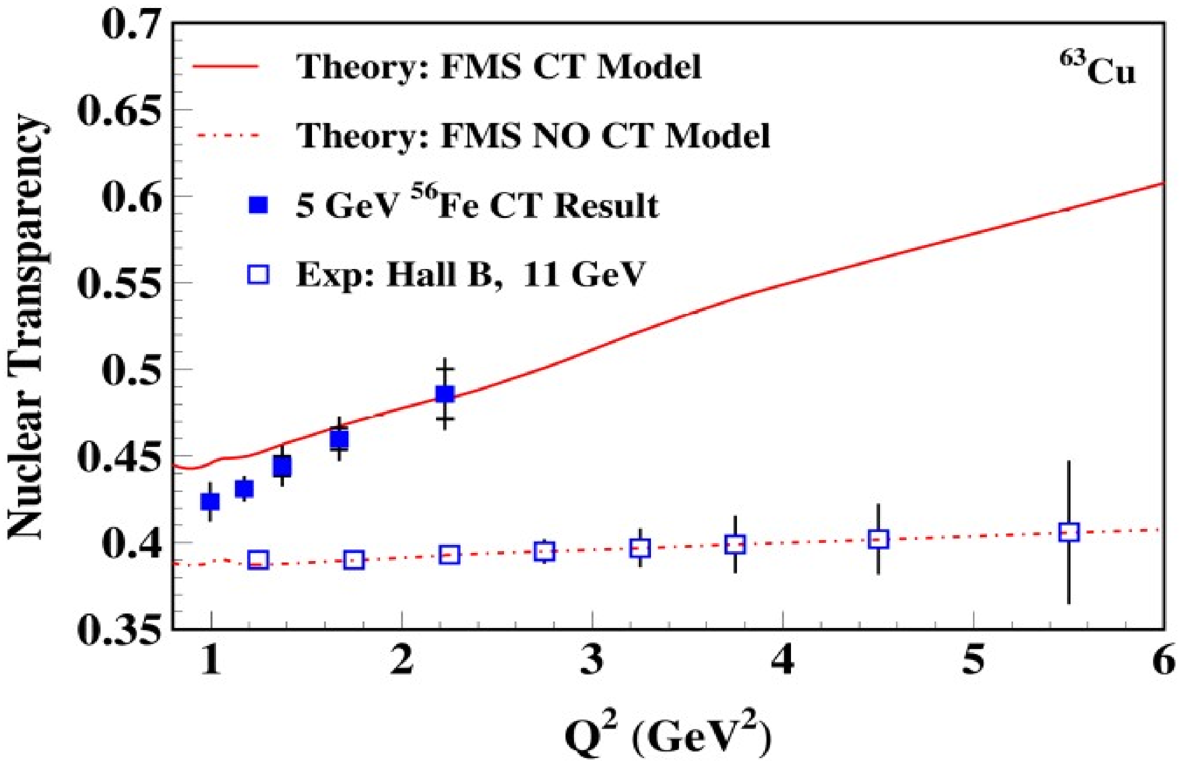


^{63}Cu projections assuming the initially approved ^{56}Fe beam time with the dual target setup.

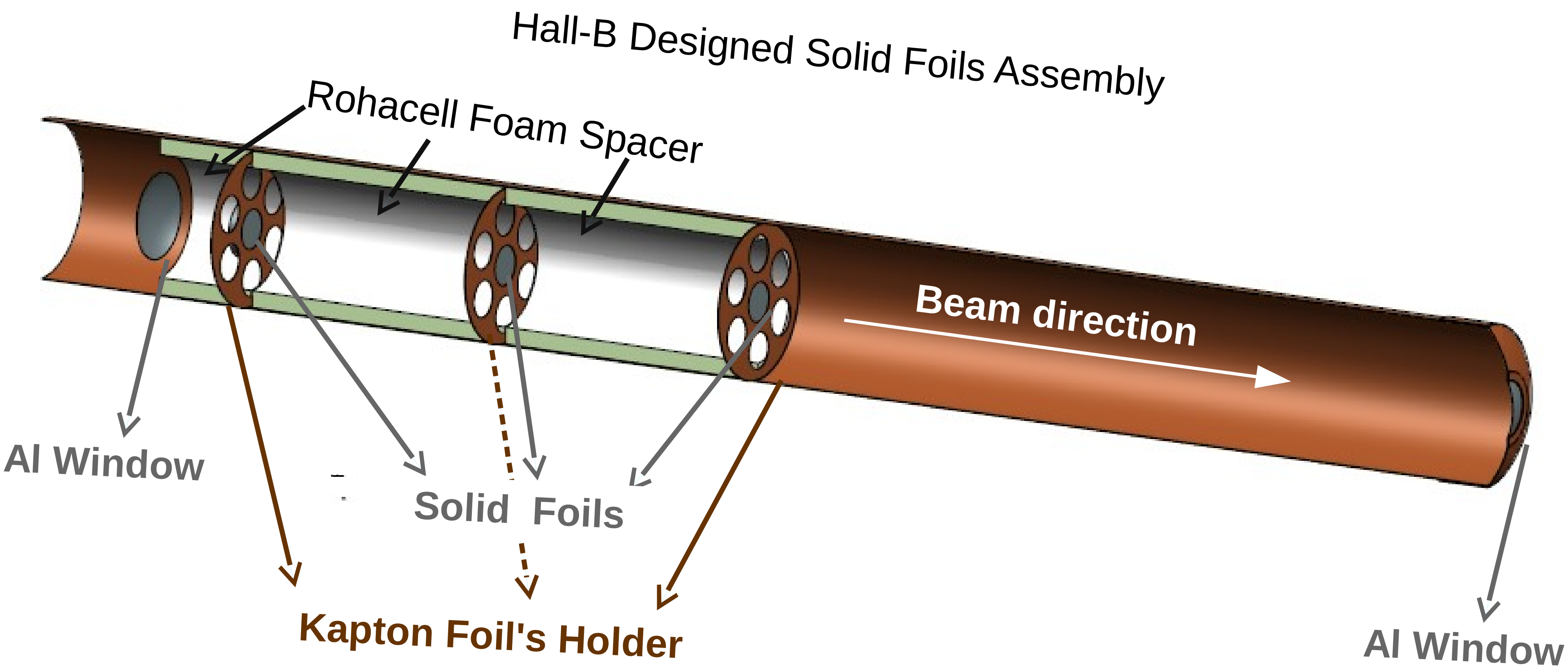
Targets	Beam Time (PAC days)
^{1}H	8
^{12}C (+ LD_2)	12
~~^{56}Fe~~ ^{63}Cu (+ LD_2)	16
^{118}Sn (+ LD_2)	24

- Expected statistical uncertainties for the approved beam time and one coherence length bin (0.4 – 0.5 fm):

Q^2(GeV^2) / Targets	1.25 ± 0.25	1.75 ± 0.25	2.25 ± 0.25	2.75 ± 0.25	3.25 ± 0.25	3.75 ± 0.25	4.5 ± 0.5	5.5 ± 0.5
^{12}C (%)	0.6	0.5	0.8	1.2	2	3	3.5	7
^{63}Cu (%)	0.6	0.5	0.8	1.2	2	3.2	3.6	7.4
^{118}Sn (%)	0.6	0.5	0.6	1	1.6	2.4	3.4	6.9

Running Conditions: Updated Target Configuration

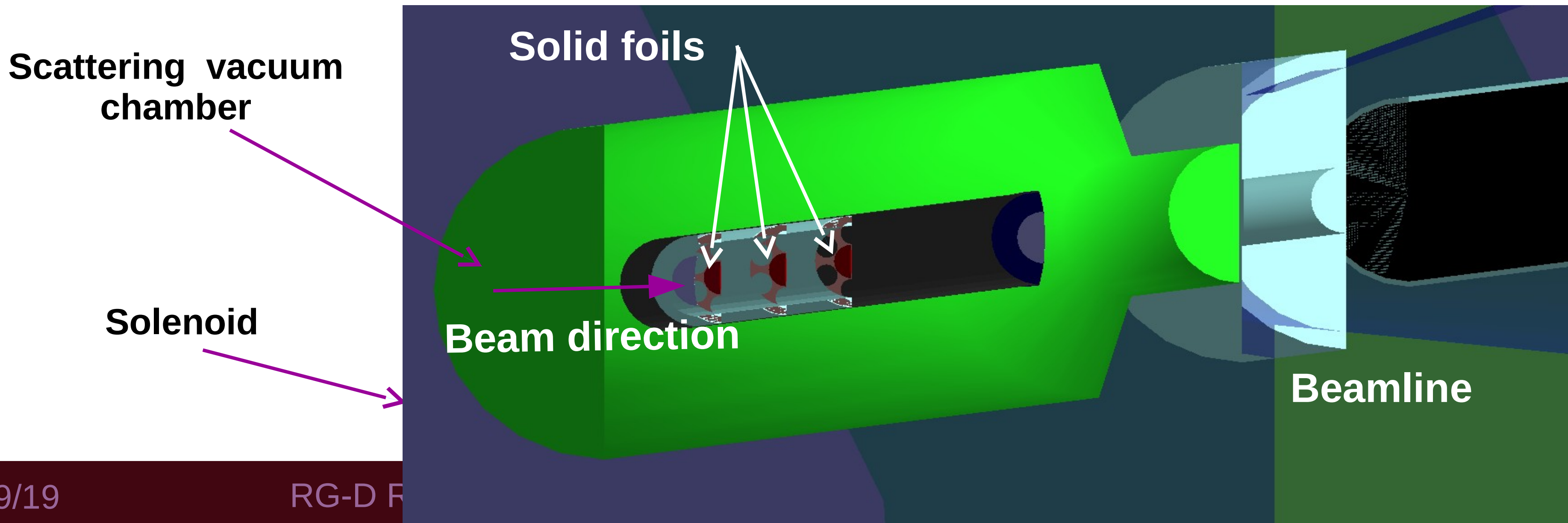
- Alternating the liquid deuterium (LD2) target with a set of three solid targets 5 cm apart:
  - ✔ Design already exists,
  - ✔ 5 cm guarantees a good vertex separation,
  - ✔ Solid foils are glued to a kapton disk, then to a foam cylinder, and mounted inside a 20 mm diameter Kapton cell (similar to the liquid target cell),
  - ✔ The cell will be purged with cold helium to dissipate heat from the beam interaction.



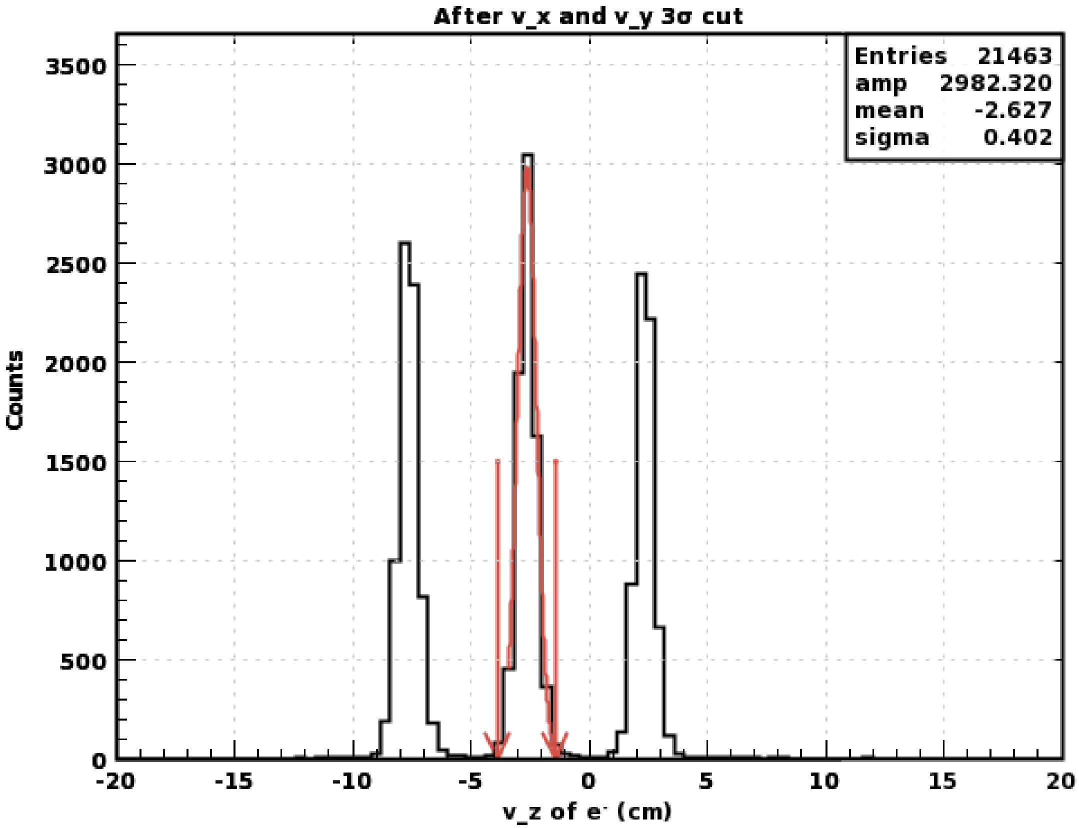
Running Conditions: Beam & Target Configuration

- Run with 11 GeV beam energy, different beam current to achieve the expected luminosity of 10^{35} cm^{-2}s^{-1}.

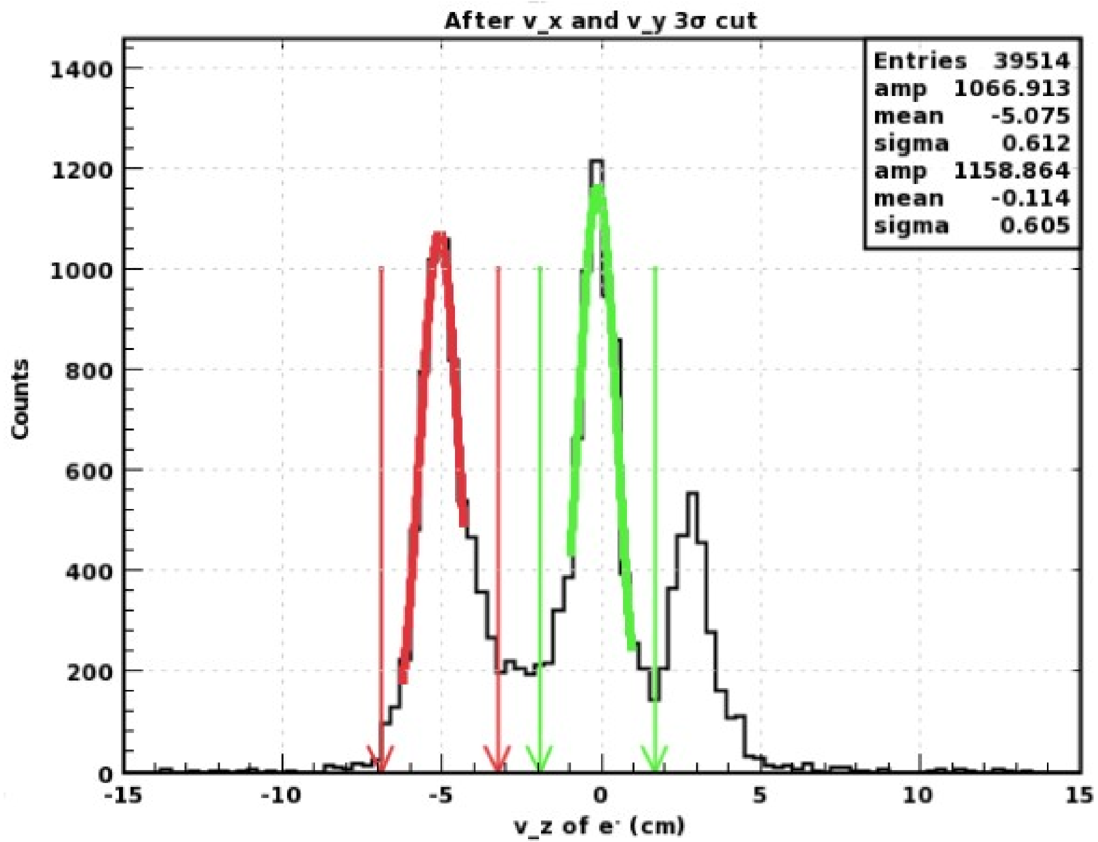
Targets	Thickness (3 foils) (cm)	Density (g.cm^{-3})	Areal Density (mg.cm^{-2})	Radiation Lengths (T/X_0)	Beam Current (nA)	Per-Nucleon Luminosity (cm^{-2} s^{-1})
D2	5	0.164	820	0.0065	35	10^{35}
^{12}C	0.172 (0.516)	1.747	300	0.007	30	10^{35}
^{63}Cu / ^{118}Sn / ^{118}Sn	0.036 / 0.03 / 0.03	8.96 / 7.31 / 7.31	322.56 / 219.3 / 219.3	0.025 / 0.025 / 0.025	35	10^{35}



Vertex Distribution



Simulated Electron z-vertex distribution for the Hall-B 5 cm apart solid foils assembly



Electron z-vertex distribution from a newly calibrated, aligned and reconstructed empty target RG-A run

Updated Run Plan & Projections

- Adjust a run plan to dedicate beam time for the separate cryo-target and solid targets run:

Targets/Plan	Beam Time (PAC days)
^{12}C / ^{12}C / ^{12}C	10
LD_2	10
^{63}Cu / ^{118}Sn / ^{118}Sn	36
LH_2	4

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Q^2(GeV^2) / Targets	1.5 ± 0.5	2.25 ± 0.25	2.75 ± 0.25	3.25 ± 0.25	3.75 ± 0.25	4.5 ± 0.5	5.5 ± 0.5
^{12}C (%)	0.9	1.2	1.6	2.2	2.8	3.1	6.7
^{63}Cu (%)	1.1	1.4	1.7	2.4	2.9	3.4	7.2
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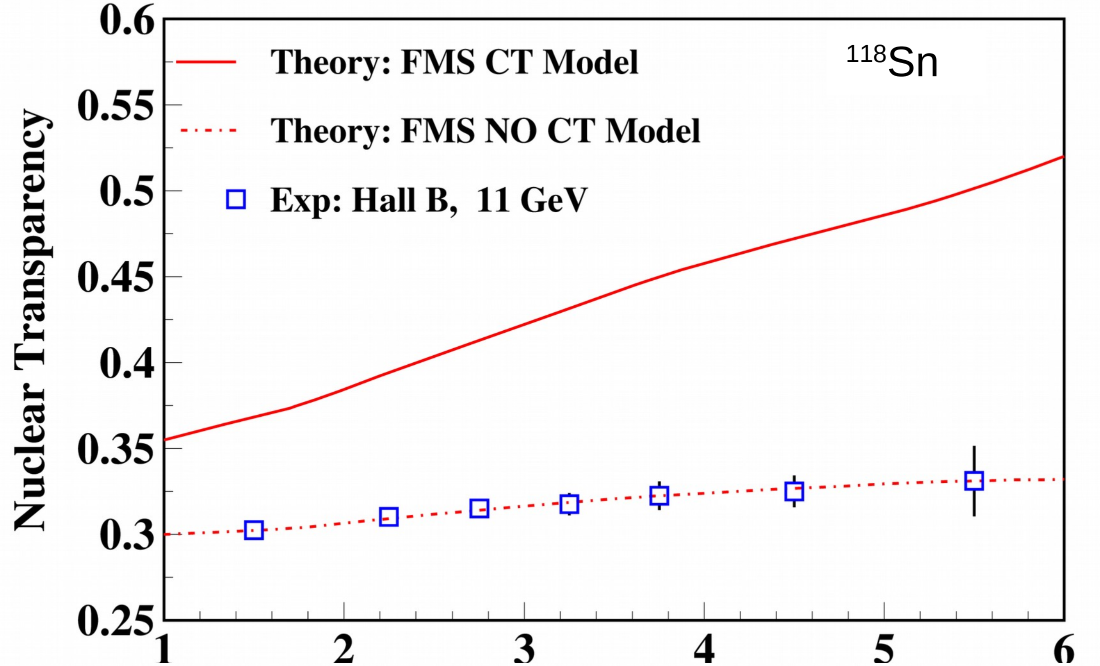

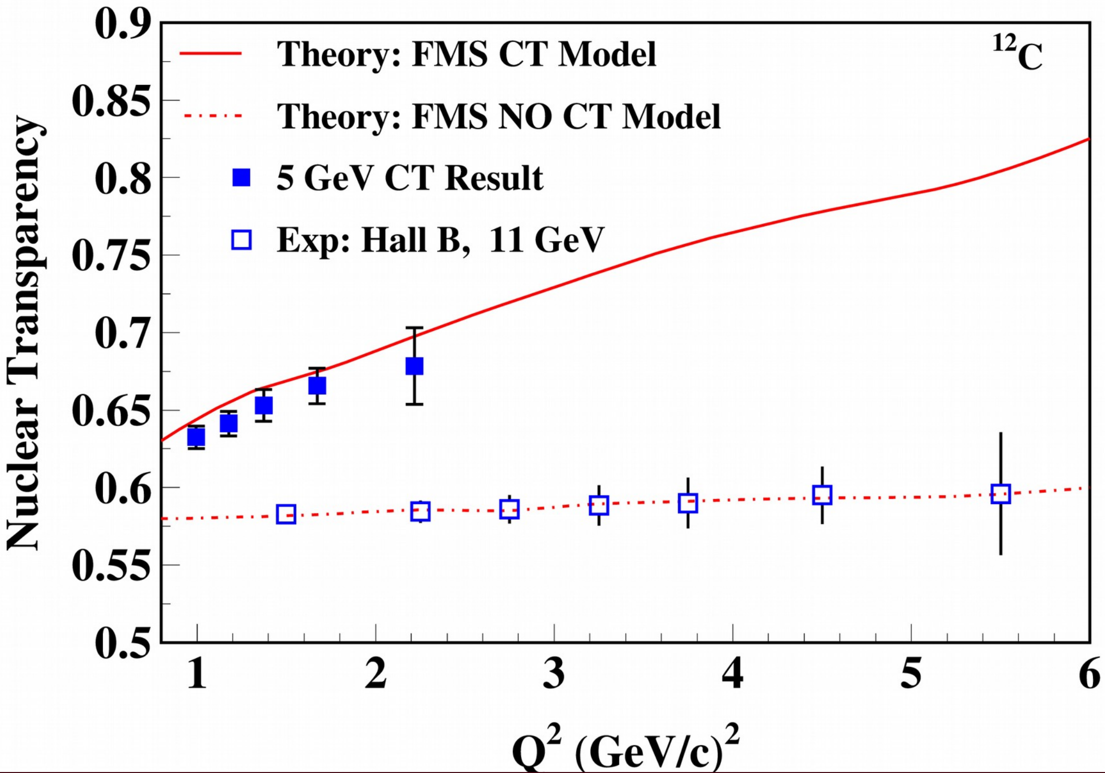

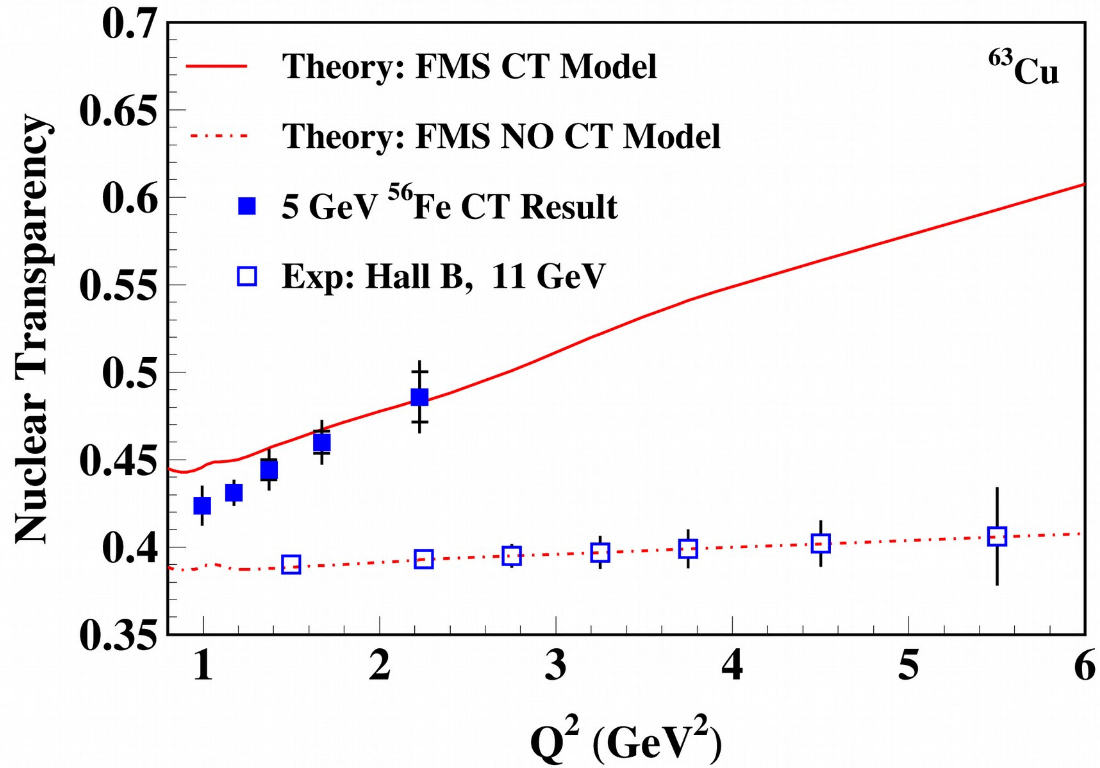

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- With this configuration, we need:
  - 4 calendar days for commissioning,
  - 4 calendar days for target configuration change:
    - 28h to switch for solid to liquid target,
    - 48h to switch from liquid to solid targets assembly,
    - 24h to switch from one set of solid foils to an other.

Running Conditions: Target Configuration Change

- To change from solid targets assembly to LD2 (info from B. Miller):
  - 2 hours to decable target so target can be moved upstream far enough to remove scattering chamber.
  - 4 hours to change target cell, fill cell with N2 and leak check.
  - 4 hours to align cell and install scattering chamber.
  - 2 hours to reconnect cabling and establish beam line.
  - 12 hours to pump down vacuum in target vacuum vessel and fill the target cell with helium.
  - 4 hours to cool and fill the liquid target.
  - Total: **28 h**.
- To change from LD2 to solid targets assembly (info from B. Miller):
  - 24 hours to empty target and heat cryostat so vacuum vessel can be opened to change target. In parallel, bleed up beam line vacuum, remove beam pipe to move target upstream.
  - 2 hours to decable target so target can be moved upstream far enough to remove scattering chamber.
  - 4 hours to change target cell, fill cell with N2 and leak check.
  - 4 hours to align cell and install scattering chamber.
  - 2 hours to reconnect cabling and establish beam line.
  - 12 hours to pump down vacuum in target vacuum vessel and fill the target cell with helium.
  - Total: **48 h**.

Running Conditions: Target Configuration Change

- To change a set of solid targets to an other (info from B. Miller):
  - 2 hours to decable target so target can be moved upstream far enough to remove scattering chamber.
  - 4 hours to change target cell, fill cell with N2 and leak check.
  - 4 hours to align cell and install scattering chamber.
  - 2 hours to reconnect cabling and establish beam line.
  - 12 hours to pump down vacuum in target vacuum vessel and fill the target cell with helium.
  - Total: **24 h**.

- The Hall-B solid target assembly has been developed and the final design was done by the end of March. Parts were fabricated in April/May and the cells will be pressure tested in July (B. Miller).

Running Conditions: Magnet & Detector Setup

- Run with the default magnet's setting: inbending/upstream torus/solenoid field,
  - No big impact of different torus field polarity and magnitudes especially on the acceptance of the lowest Q^2 bin, 1 - 1.5 GeV^2, as initially proposed. This bin is merged with the subsequent one.

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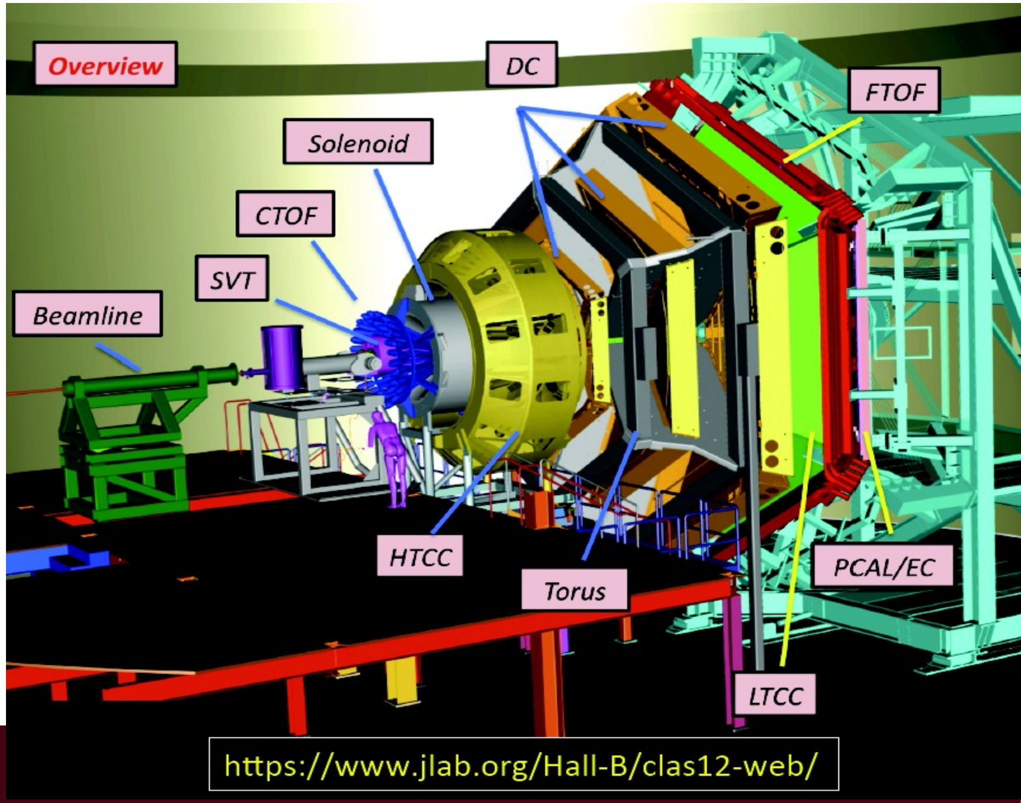
  - No big impact of different torus field polarity and magnitudes especially on the acceptance of the lowest Q^2 bin, 1 - 1.5 GeV^2, as initially proposed. This bin is merged with the subsequent one.
- Will use the CLAS12 in its standard configuration but with
  - **FT-OFF** because
    - the interest to a high-Q^2 region,
    - no interest to detect photons at small angles (2.5°- 4.5°),
    - Extended beamline vacuum reduces DC R1 background, hence improves the FD efficiency.
  - **FMT-Out** unless its light version that is currently made for the BONUS experiment is fully functional.

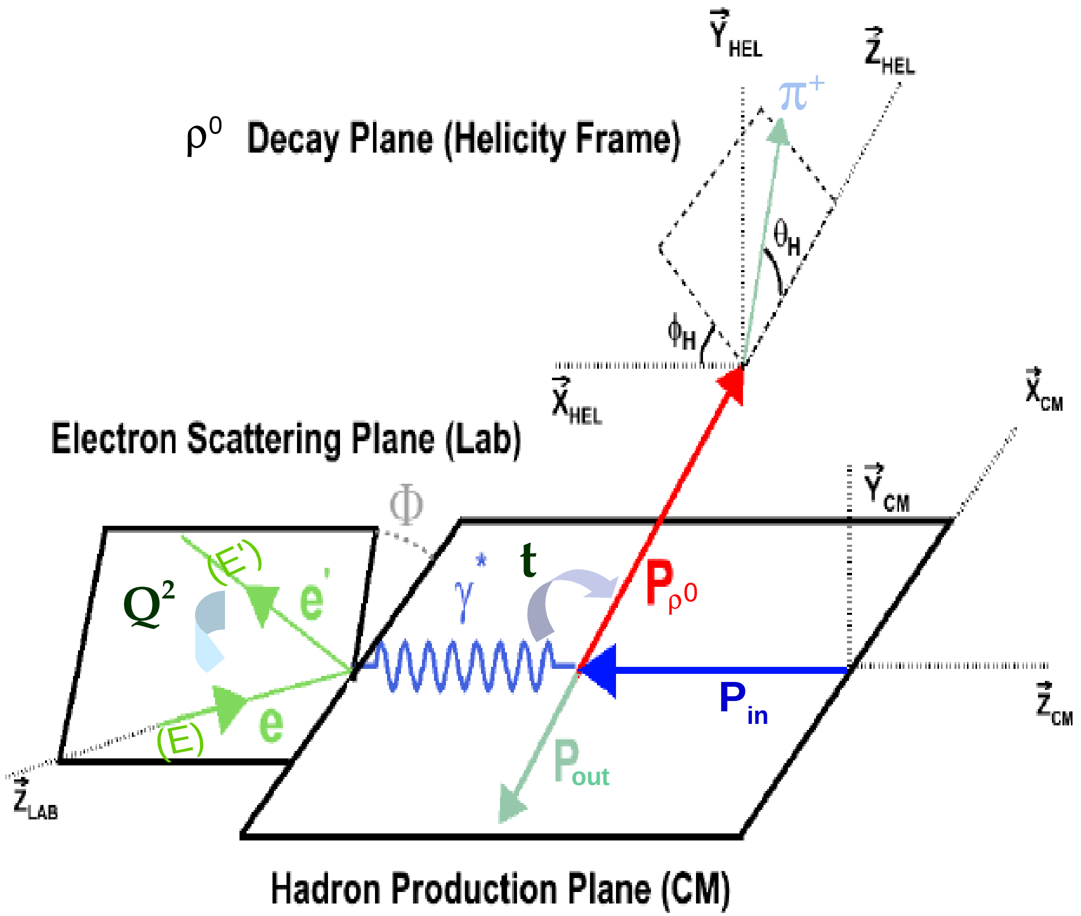


First Look to Negative Polarity Data

- The reconstructed ρ^0 invariant mass distribution in our kinematics range.

ρ^0 Electro-production Kinematics

- $\nu = E - E'$: virtual photon (γ^*) energy in the Lab frame,
- $Q^2 = -(P^\mu_e - P^\mu_{e'})^2 = 4\,E\,E'\sin^2(\theta/2)$: photon virtuality,
- $t = (P^\mu_{\gamma^*} - P^\mu_\rho)^2$: momentum transfer square,
- $W^2 = (P^\mu_{in} + P^\mu_{\gamma^*})^2 = -Q^2 + M_p^2 + 2M_p\nu$: invariant mass squared in (γ^*, p) center of mass (CM).



- **W ≥ 2 GeV**
  ⇒ avoid resonance region
- **$-t < 0.4$ GeV^2**
  ⇒ select diffractive process
- **$-t > 0.1$ GeV^2**
  ⇒ exclude coherent production
- **$Z_h = E_h/\nu \geq 0.9$**
  ⇒ select elastic channel

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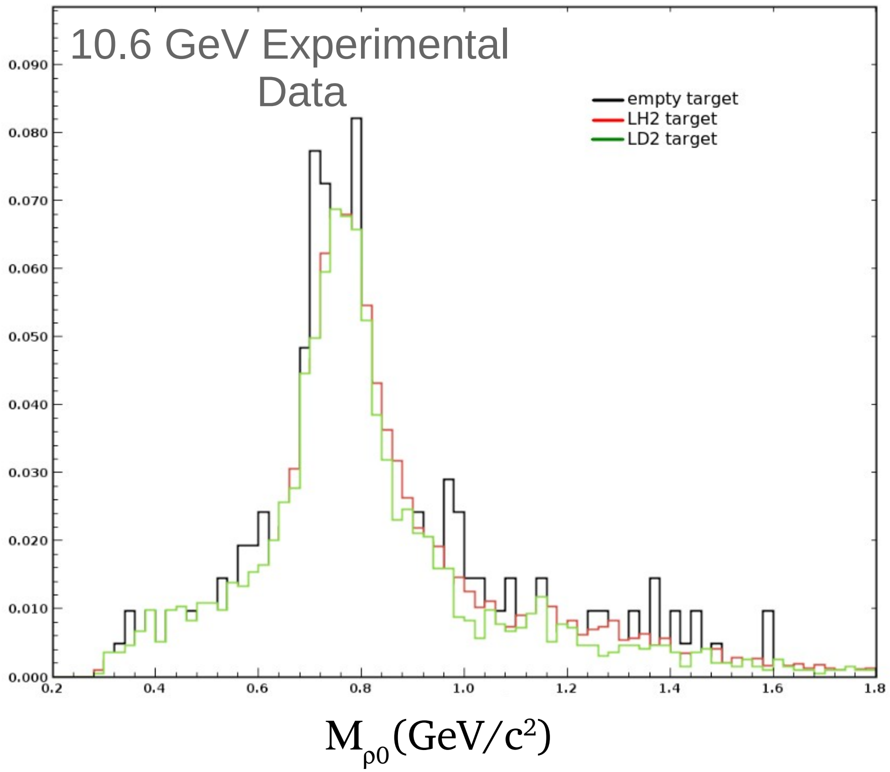

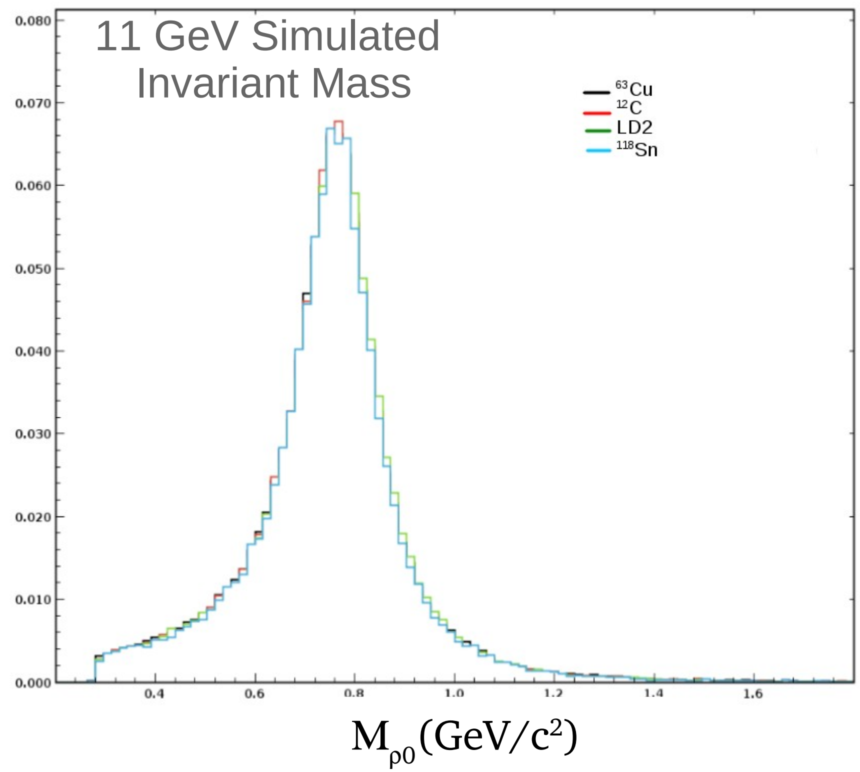

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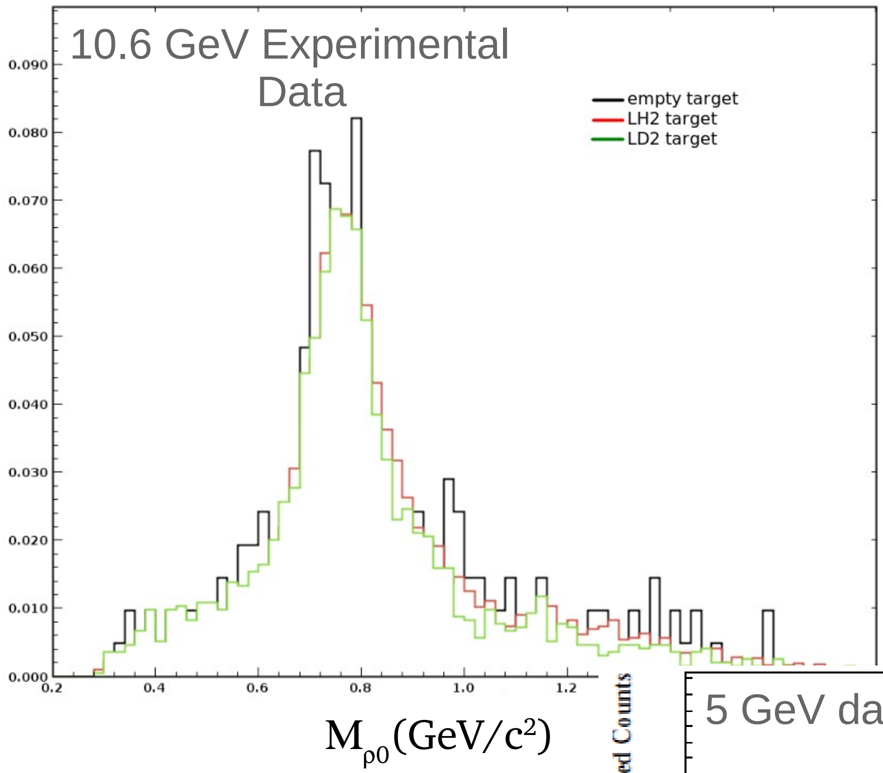
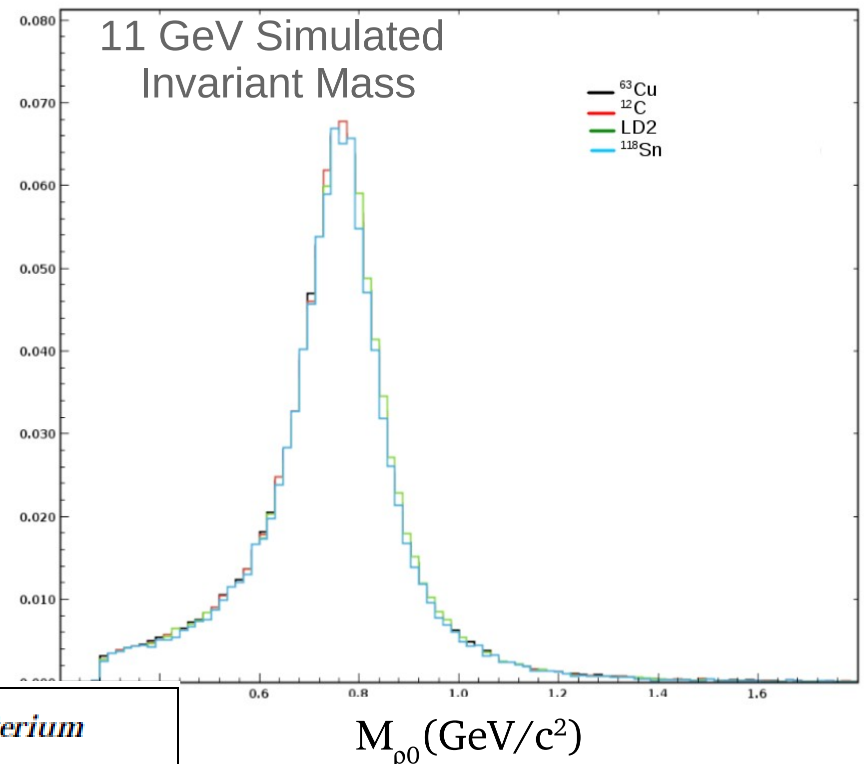
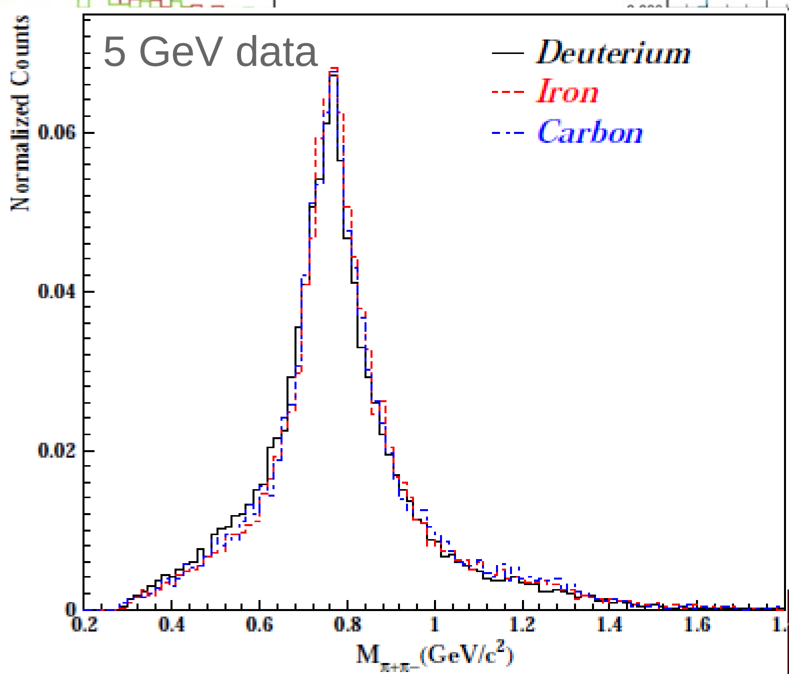
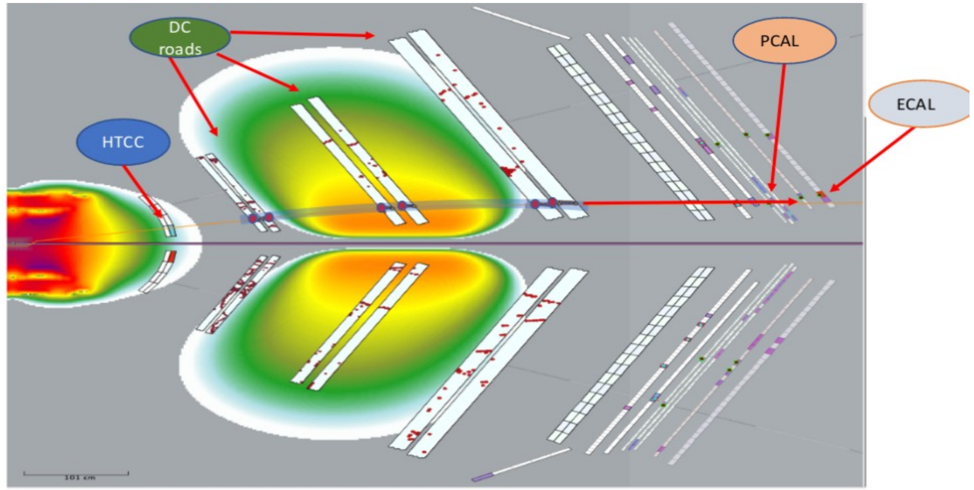




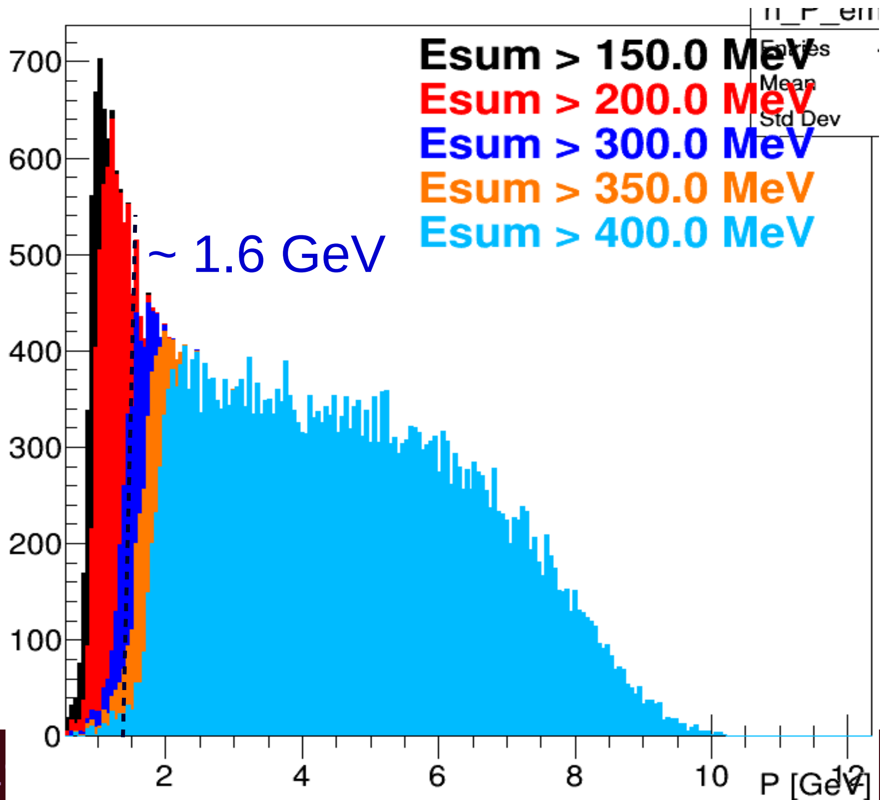


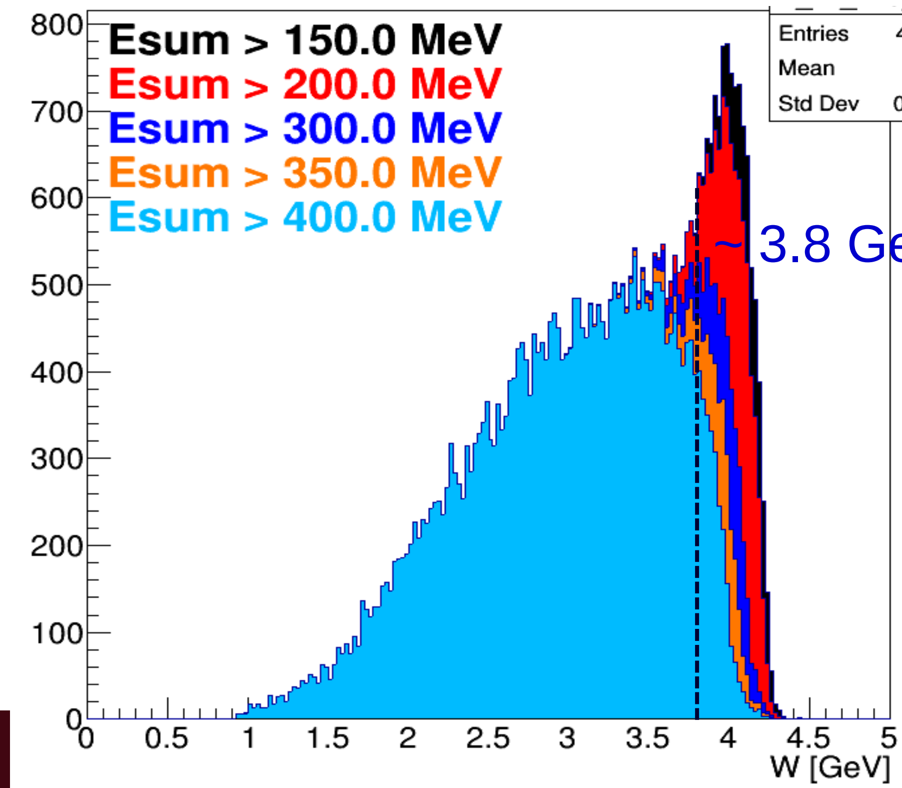
Running Conditions: Trigger

- Use the RG-A/B electron trigger:
  - ✔ Minimum number of HTCC photoelectrons >2
  - ✔ Minimum PCAL cluster energy > 60 MeV
  - ✔ Sum of the energy deposition in PCAL & ECAL greater than 250 - 300 MeV.
  - ✔ DC segments 5 out of 6
  - ✔ Negative DC roads matching the PCALU cluster



- The main trigger parameter is $E_{sum} = E_{PCAL} + E_{ECAL}$ because it controls the trigger rates (expecting ~ 8 kHz which is below the DAQ limit).
- This threshold affects the scattered electron momentum and kinematics, mainly W!





Courtesy of
R. Paremuzyan
&
V. Kubarovsky

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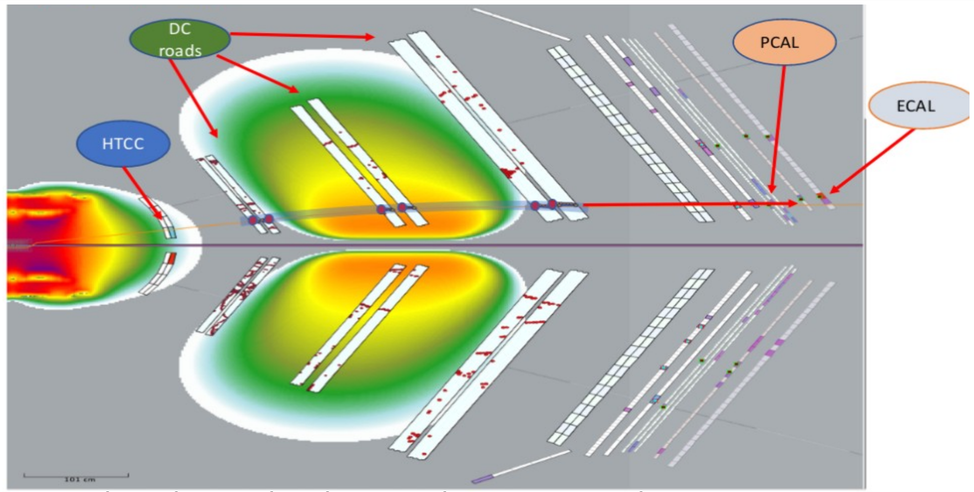

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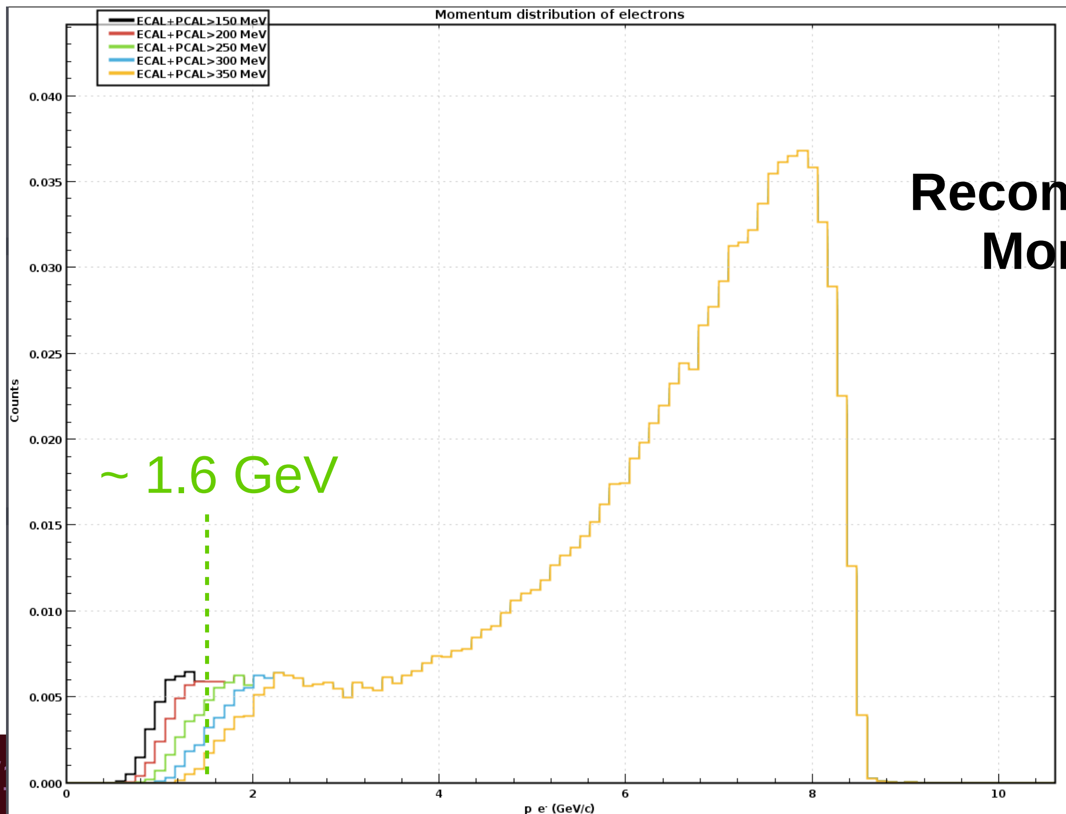
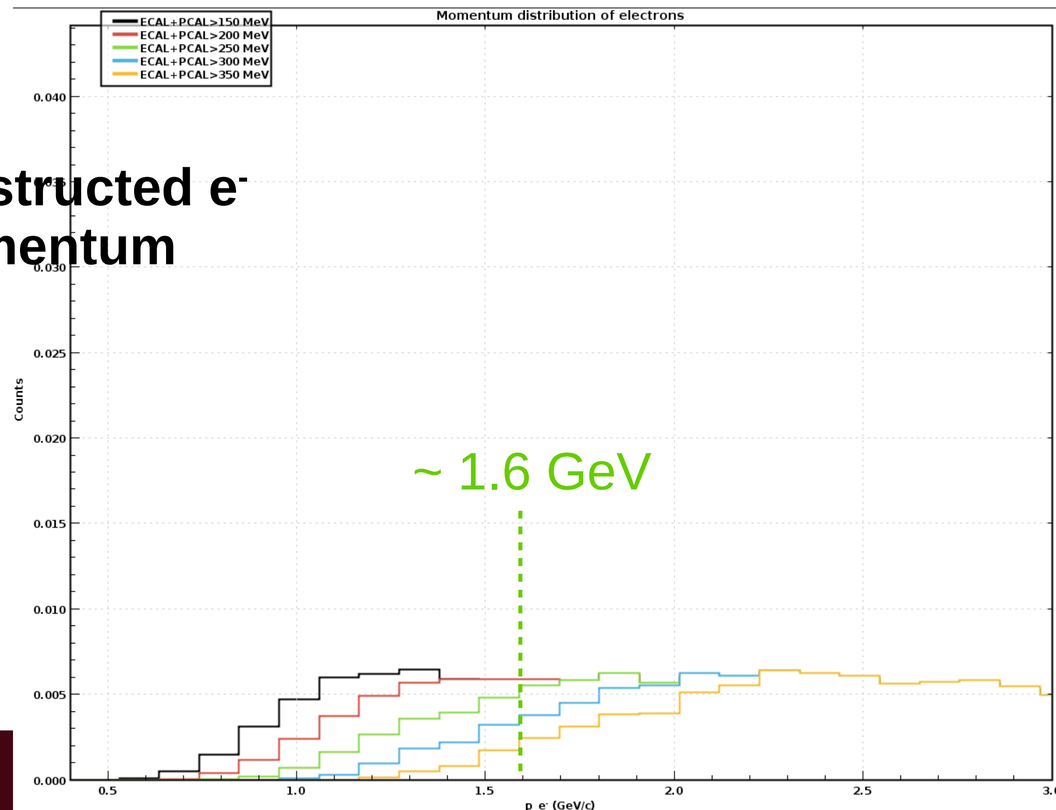


Reconstructed e^- Momentum



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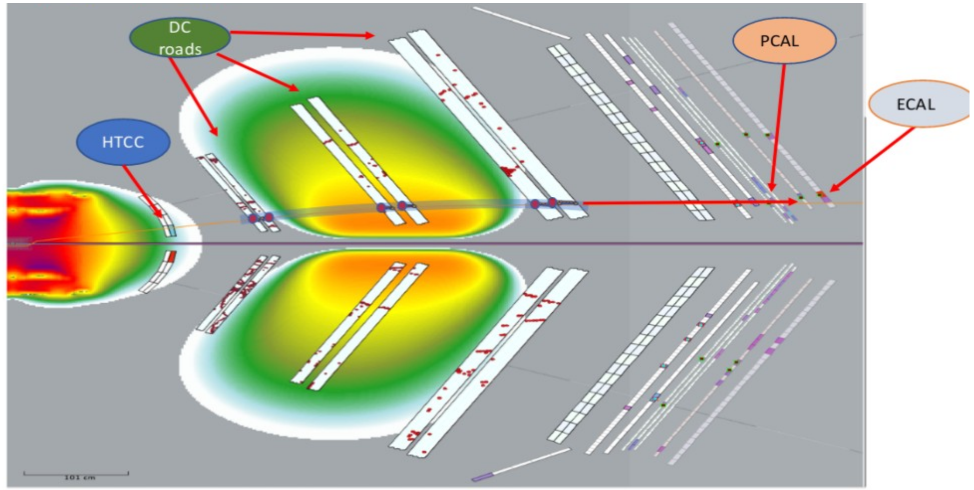

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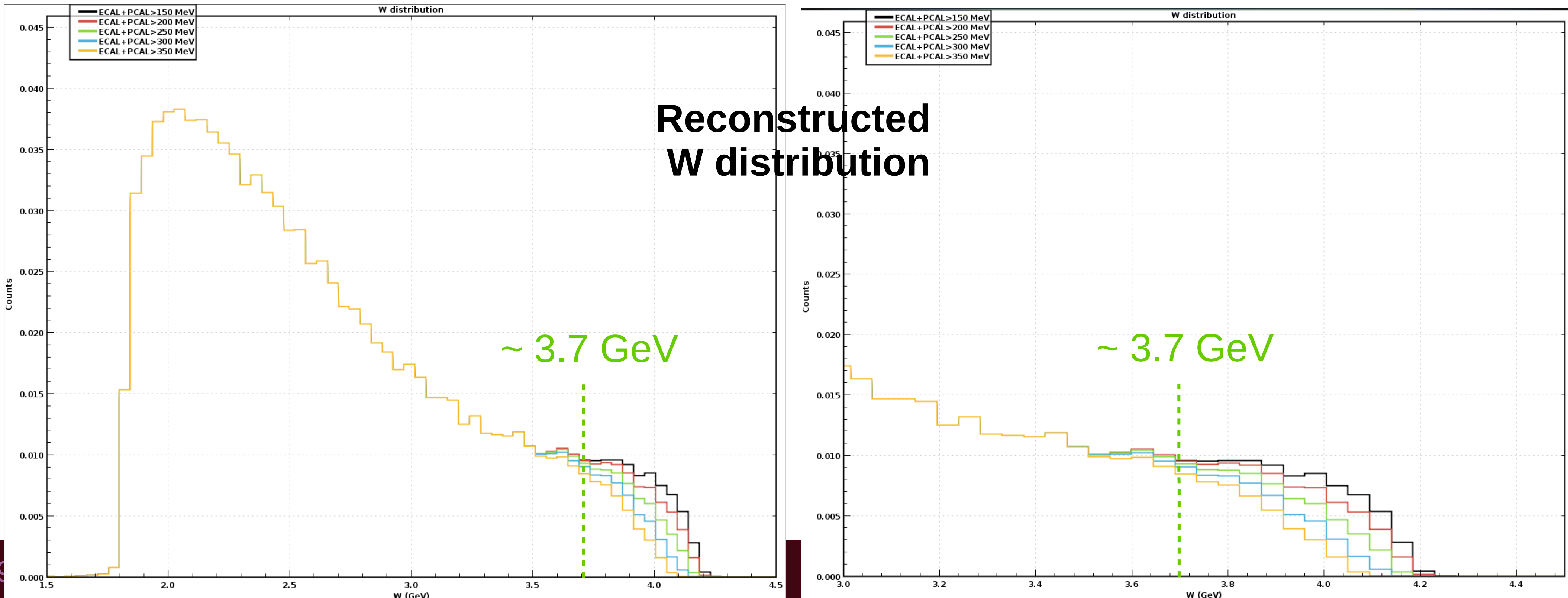

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- A lower beam energy, say 10.2 GeV, will reduce the highest Q^2 bin statistics by roughly 30% based on simulation.

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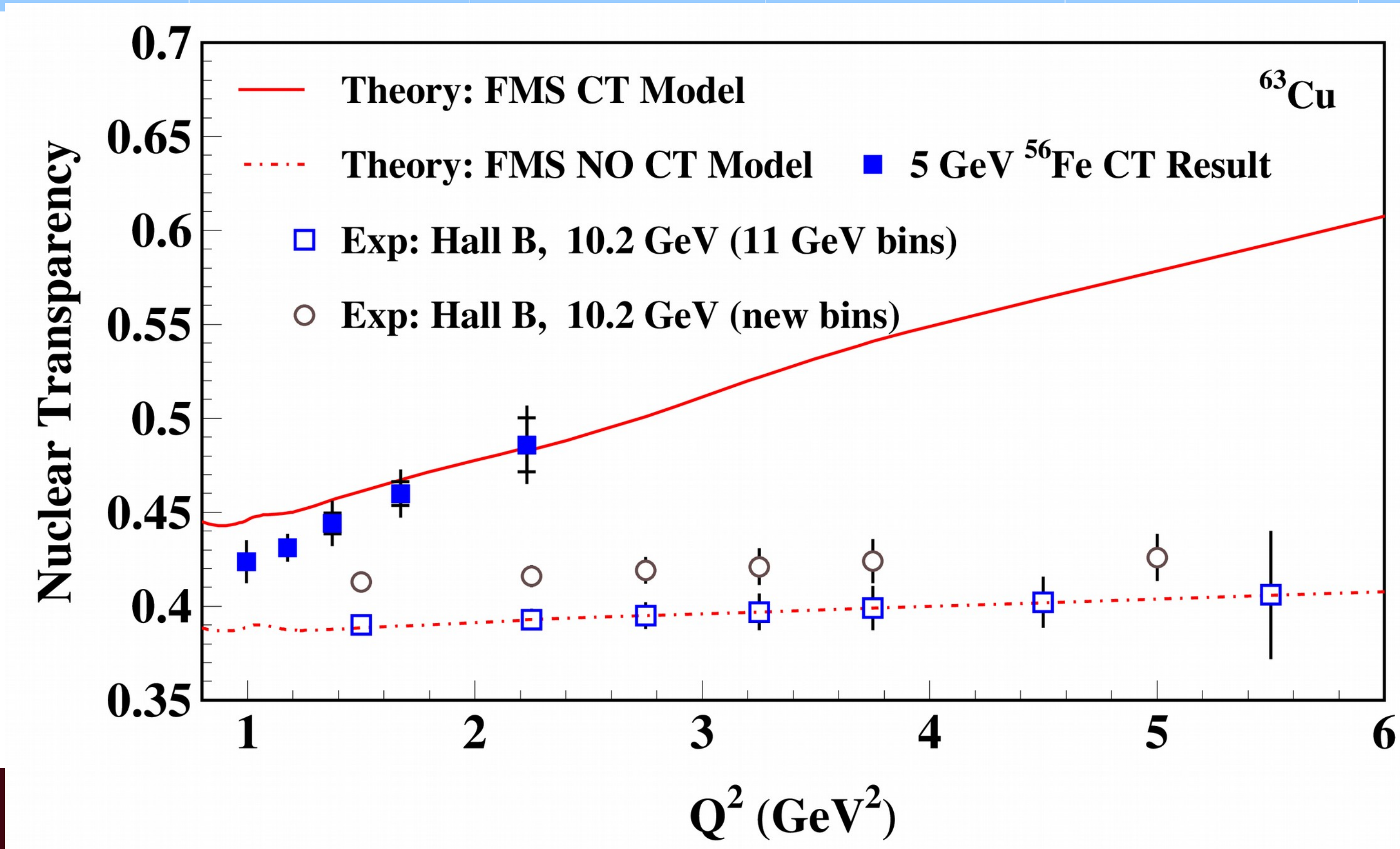
^{63}Cu (%) (11 GeV bins)	1.1	1.5	1.8	2.5	3.0	3.5	8.7
^{63}Cu (%) (10.2 GeV new bins)	1.1	1.5	1.8	2.5	3.0	Q^2: 5 ± 1 3.4	



Reduced Beam Time Physics Reach

- If scheduled to run with ½ approved beam time we can still have publishable results by either
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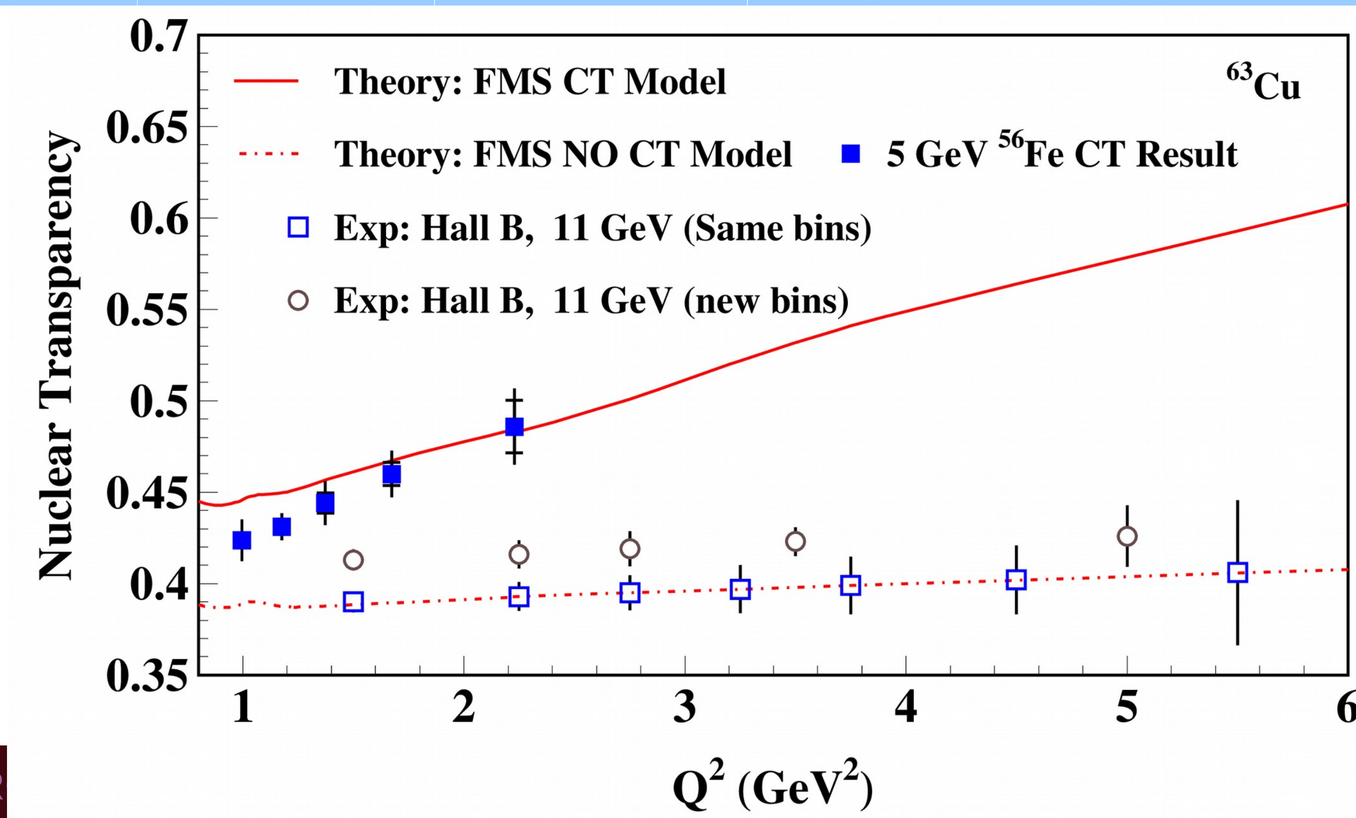
^{63}Cu (%) (Same bins)	1.5	2.0	2.5	3.4	4.1	4.8	10.1
^{63}Cu (%) (new bins)	1.5	2.0	2.5	Q^2: 3.5 ± 1 2.1		Q^2: 5 ± 1 4.4	



Running Conditions: Background & Radiation

- ✔ According to experts, no X-ray radiation damage due to the 50 um tungsten wrapped around the scattering chamber which shields detectors from low γ rays.

- ✔ In coordination with the collaboration experts, several avenues can be explored to understand the neutron damage to the SVT:
   i. Detailed simulation driven studies dose estimates,
   ii. Simulation validation from recent data to improve rate estimates, and
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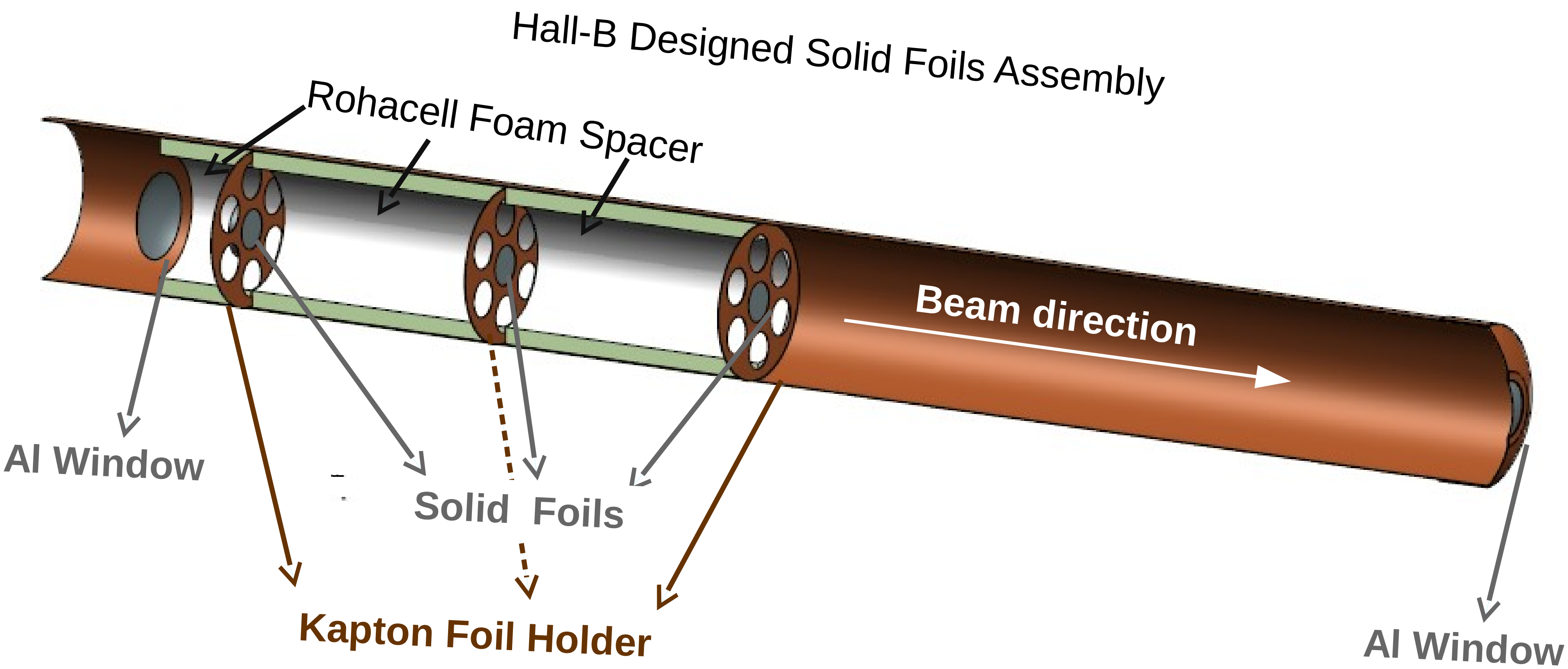
- ✔ Lorenzo will perform simulation and activation studies for the simple target configuration which would help at understanding which configuration could go first and which last.

Backup Slides

Hall-B Target Assembly Advantage

- Take liquid and solid targets data in similar vertex position which will minimize the acceptance correction,
- Reduce the amount of collected deuterium data as one set can be used with all nuclear targets to extract the physics results,
- Can accommodate several thinner solid targets, allowing to take full luminosity even on heavy targets.



Running Conditions: Detector Setup

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  - **FT-OFF** because
    - the interest to a high-Q^2 region,
    - no interest to detect photons at small angles (2.5°- 4.5°),
    - to reach the highest luminosity possible of 2 10^{35} $cm^{-2}s^{-1}$.
  - **FMT-Out** since the forward detector resolution is good enough for the 5 cm target separation.
    - But, if the light version that Saclay is currently making for the BONUS experiment is fully functional before the run, then we can use the FMT.
    - The light FMT version:

Metal screw replaced by nylon, plastic fixation, 3D print HV cover

Aluminum (RL 8.9 cm) fixation between disk replaced by Peek (RL 31.9 cm)

Preliminary schedule

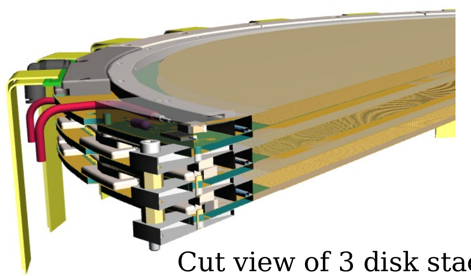
06/2019: drawing and material study

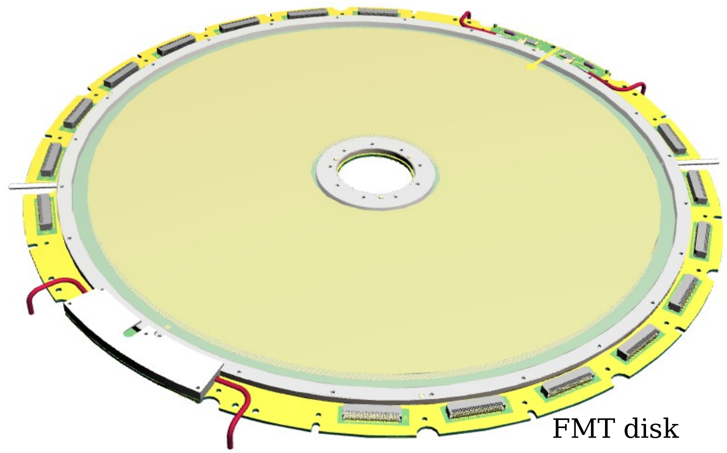
09/2019: Change and test disk 1

12/2019: upgrade disk 2-3

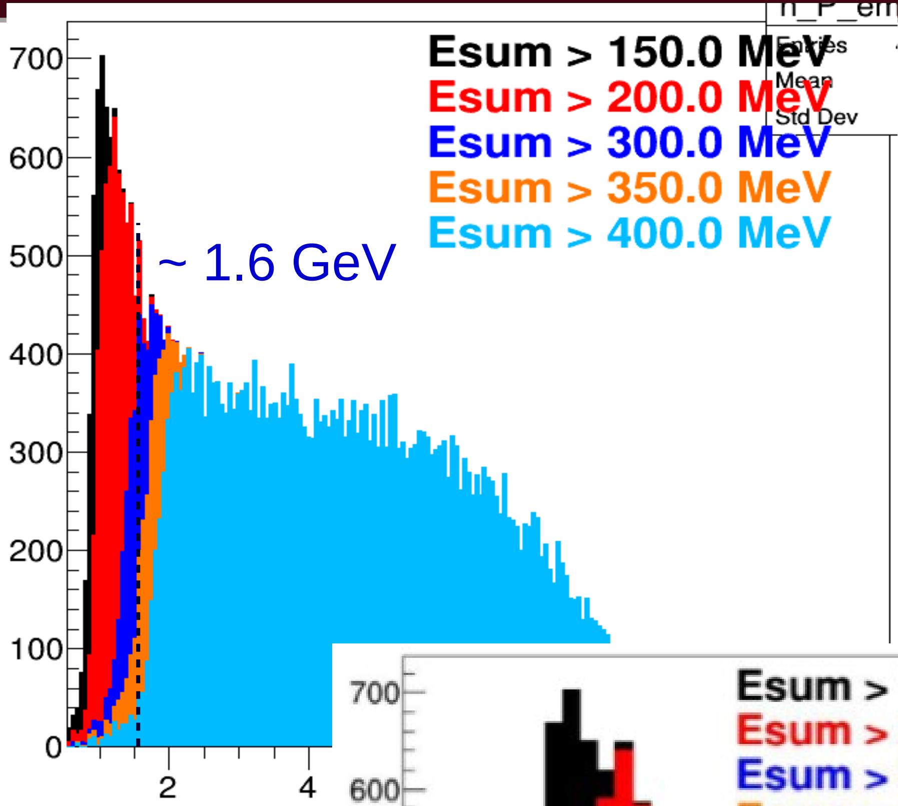
06/2020: upgrade disk 4 to 7

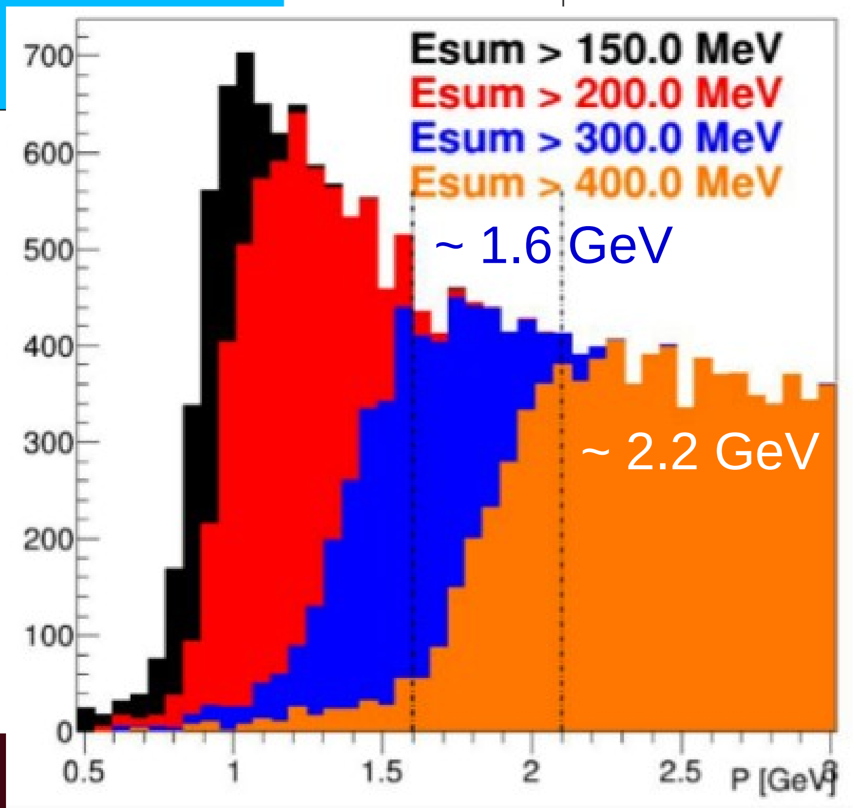
Volker, CLAS Collaboration Meeting, March 2019.

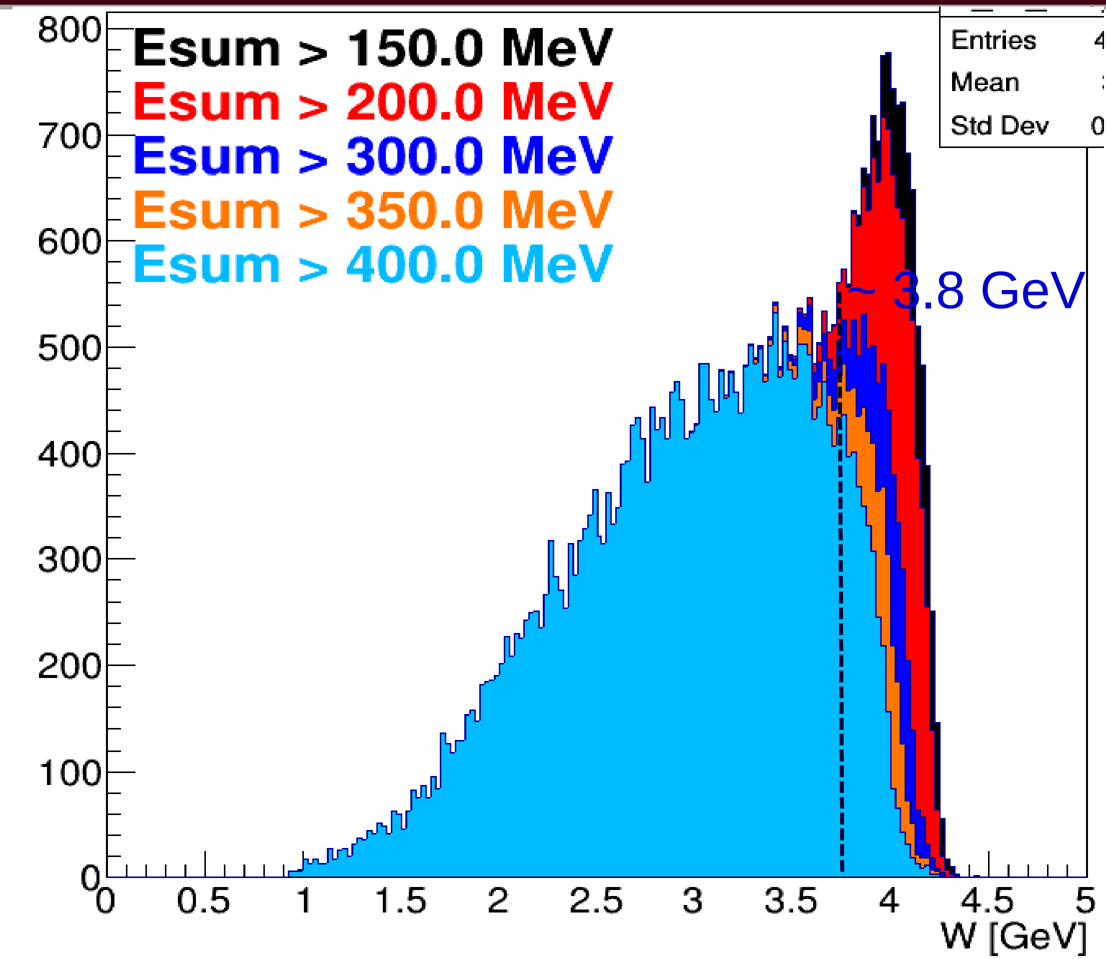

Cut view of 3 disk stack


FMT disk

Running Conditions: Trigger

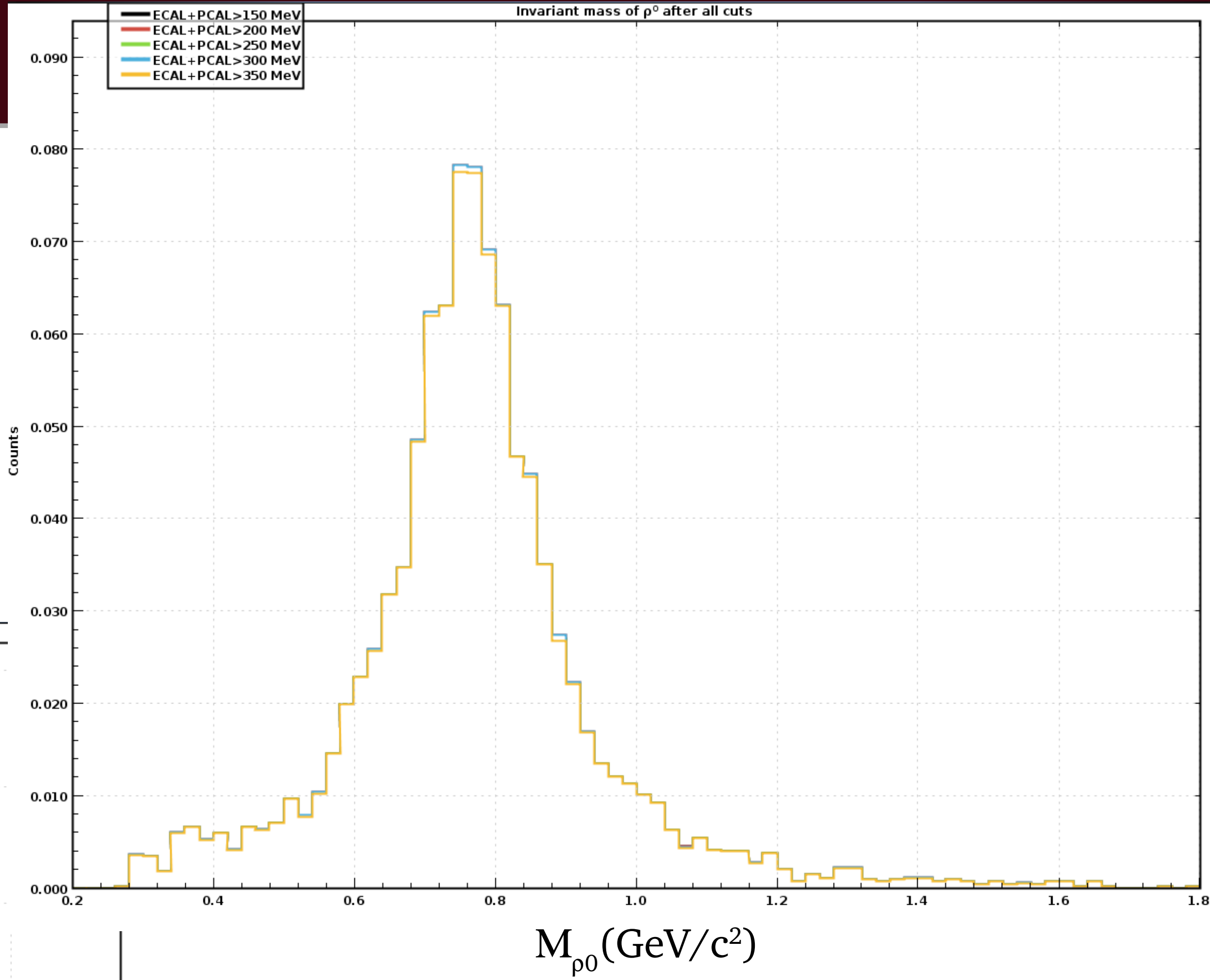


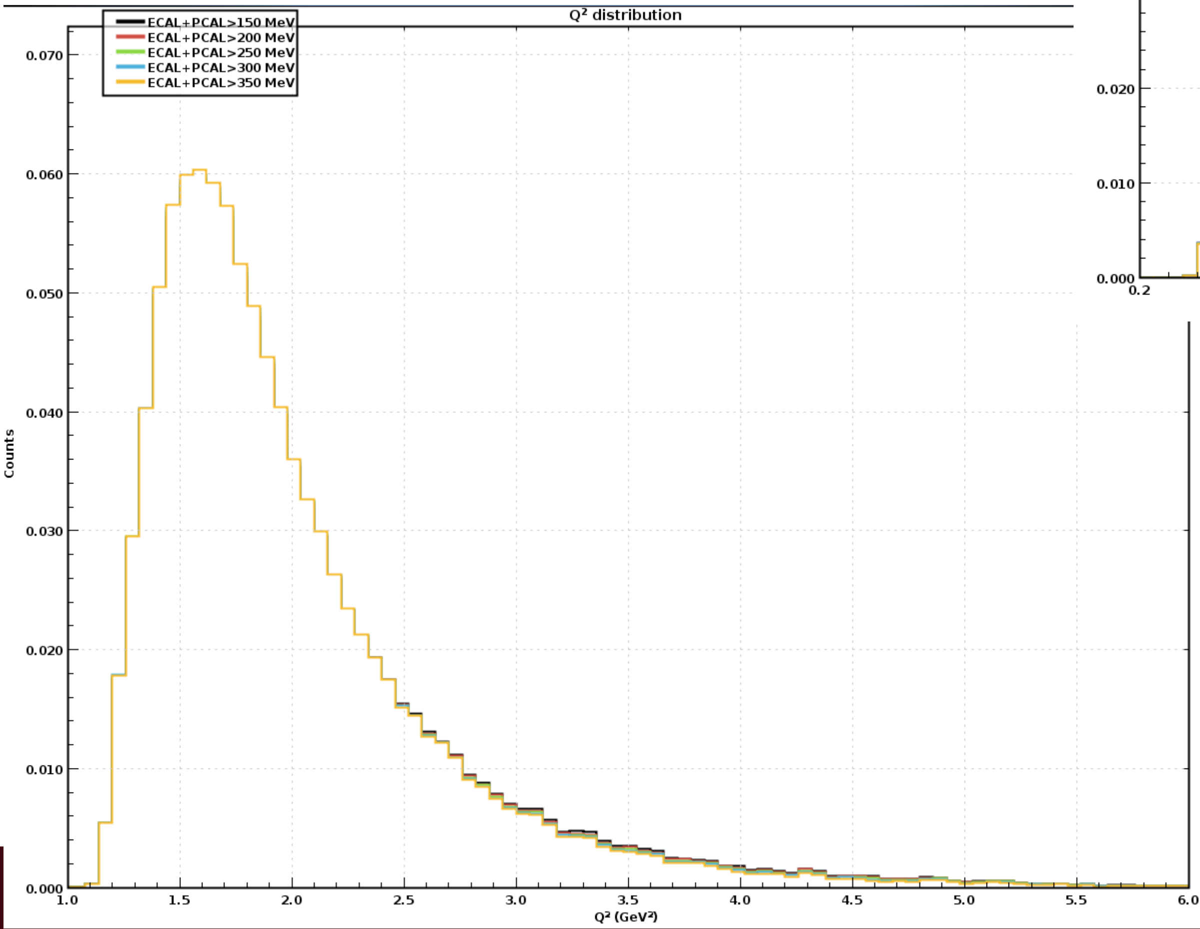




Running Conditions: Trigger

- ✔ No visible effect on Q^2 nor the invariant mass up to $E_{sum} = E_{PCAL} + E_{ECAL} > 350$ MeV.





Two pions invariant mass