The Geant4 simulation of G2P|GEP Experiments

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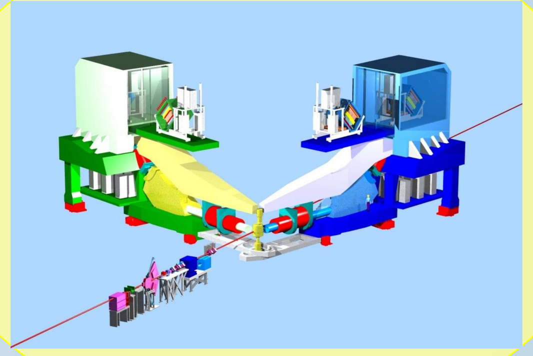
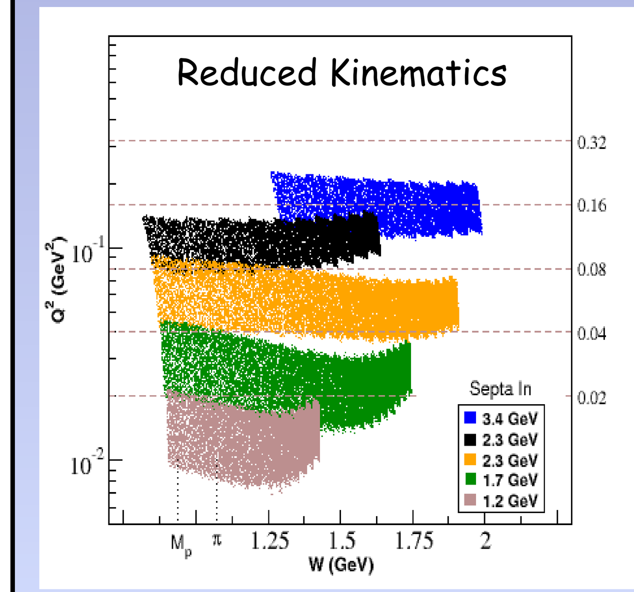
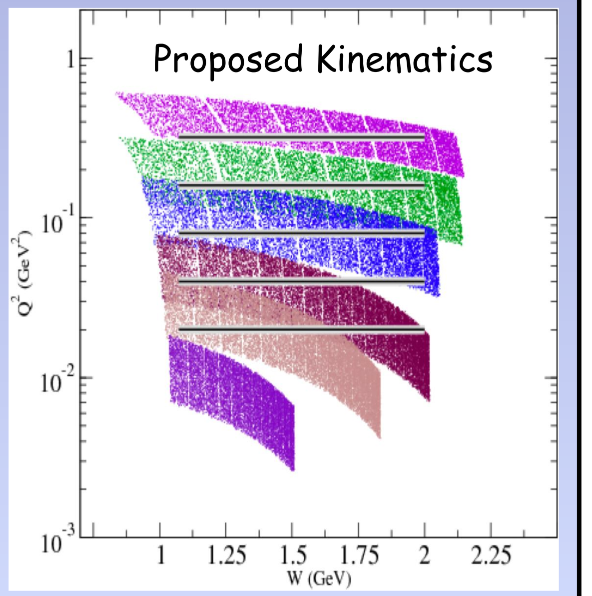


G2P Experiment (E08-027)

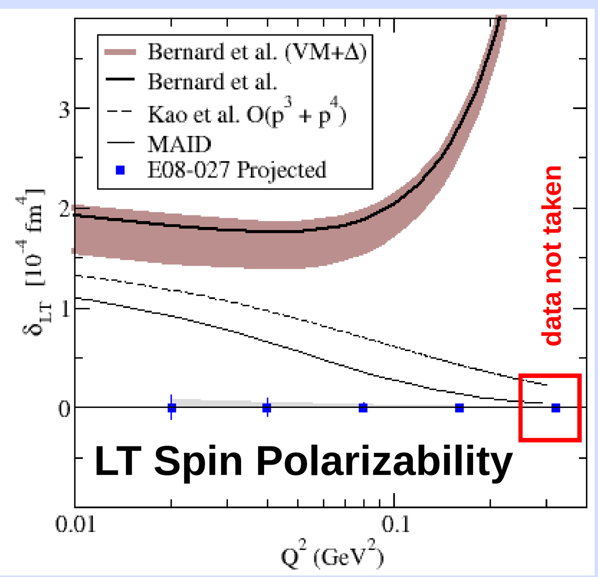
A Measurement of g2p and the Longitudinal-Transverse Spin Polarizability

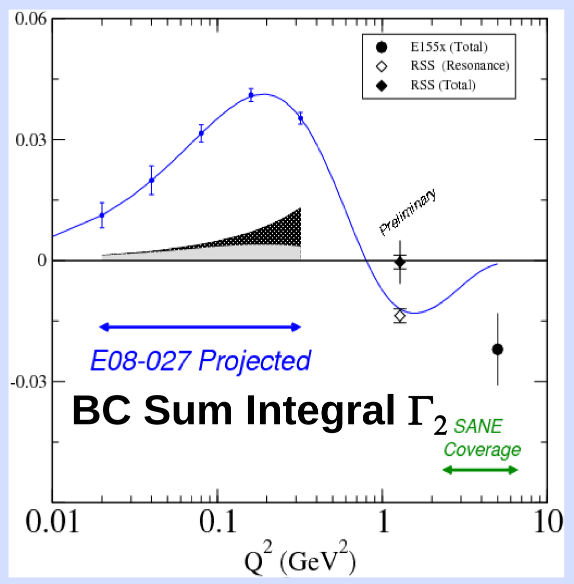
- **Goal**: to measure the spin-dependent structure function g2 for the proton at resonance region and in low Q^2 (0.02-0.2 GeV^2).
- **Beam Energies**: 1.159, 1.706, 2.254, 3.357 GeV.
- **Scattering Angle**: 5.65 degrees.
- **Target**: transverse polarized NH_3, with up to 5 Tesla transverse target field.
- **Kinematics Coverage**:





- **Projected Result**:

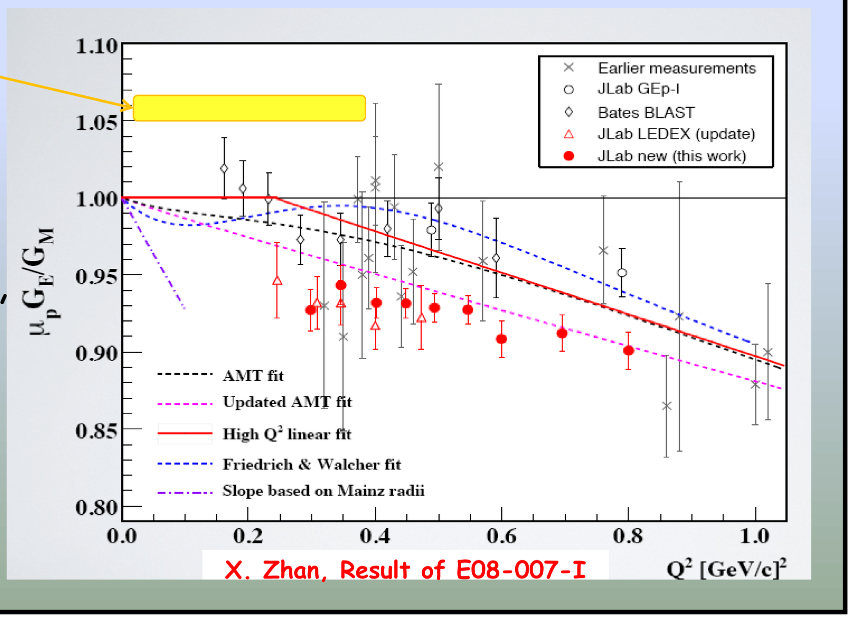




GEP Experiment (E08-007-II)

- **Goal**: to measure the proton elastic form factor ratio at low Q^2 (0.02-0.4)
- **Kinematics**:

Only took e-p elastic events with beam energies of 1.159, 1.706 and 2.254 GeV, at 5.65 degrees central ray scattering angle .



Introduction of The Simulation

◆ **Purpose**:

➢Help to design detector and necessary devices, such as the local beam dump, the sieve slits, the 3rd arm …etc.
➢Study detector response
➢Estimate the radiation level (bremsstrahlung and neutron …)
➢Study HRS optics and acceptance
➢ Other interested physics process

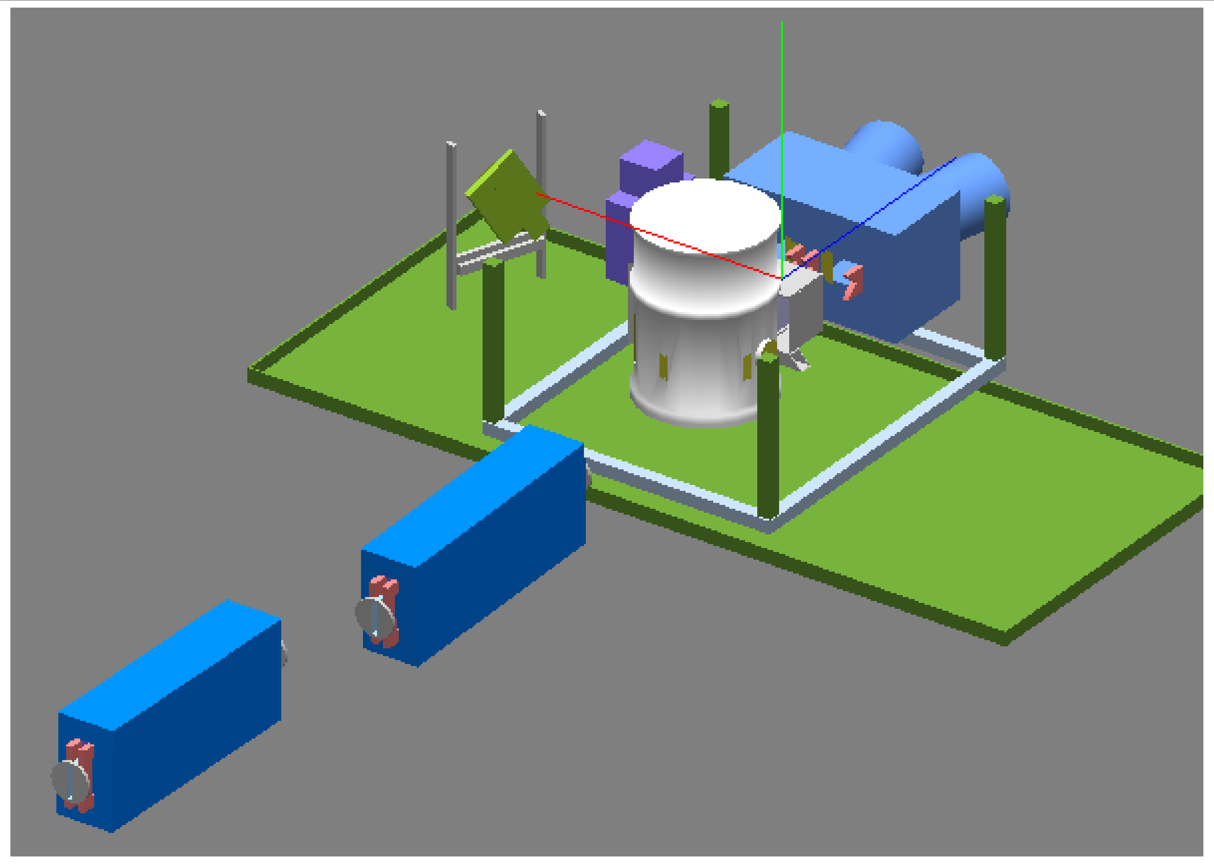
◆**Physics Process**:

➢Full physics process are included and optimized for Jlab's beam energy range
➢Low energy high precision neutron model is available to simulate neutron and neutron induced radiation level

◆ **Simulation Strategy**:

Geant4 + Parameterized HRS Transport Model (from SNAKE)

➢Electron's trajectories from the target center to the focal plane of the HRS were simulated with SANKE and parameterized as a forward transportation model and a backward (reconstruction) model for these two situations: 1) only HRS and 2) septum and HRS.
➢Use Geant4 packages to simulate the physics processes of a particle till it goes into a virtual boundary, which is the septum entrance aperture for 6 degrees setting or the HRS Q1 entrance aperture for the 12.5 degrees setting.
➢Then use the forward transportation model to propagate this particle from the virtual boundary to the focal plane.
➢Then reconstruct the particle from the focal plane back to the target plane using the backward model.

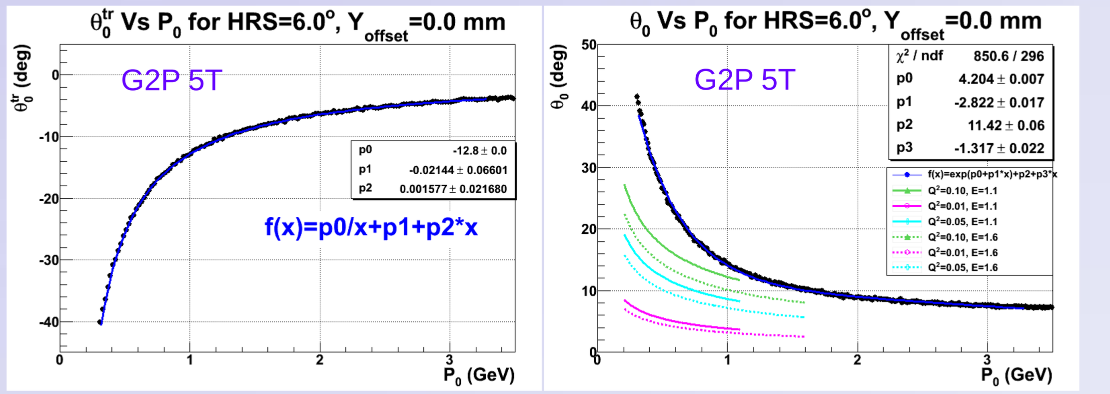


◆ **Built-in Devices and Functions**

➢Chicane magnetic fields, target field and septum field (3 sets of utilized septum fields are all available).
➢Chicane, two-story-target-platform (only one story is shown here), full target chamber and the Helmholtz coils, g2p target insert, local dump and its shielding, sieve slits, septum magnet and HRS Q1 apertures.
➢The 3rd arm: only sensitive detector and its stand.
➢HRS transport and reconstruction models (can be used for any HRS trajectory simulation).
➢Elastic, QFS and EPC cross section models are included to estimate elastic and inelastic event rates
➢Multiple particle guns (up to 8).
➢Built-in recursive and many useful event generators
➢Particle trajectories and detector response are written into root ntuple.

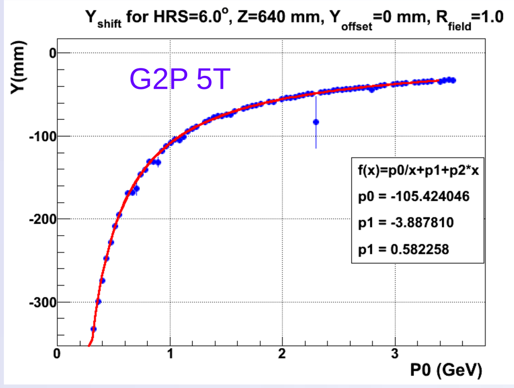
The Target Field

The transverse target field, along x axis, bends beam electrons vertical down. To compensate this effect, a vertical adjustable chicane was placed upstream to make the beam coming with an tilted angle pointing vertical up. For some kinematics, the chicane's vertical position is out of its adjustable limit therefore can not provide enough tited angle. A local beam dump was placed at 79 cm downstream to block the beam. To minimized the radiation damage, the beam was chosen to hit the Hall A main dump (if possible) instead of the local dump.



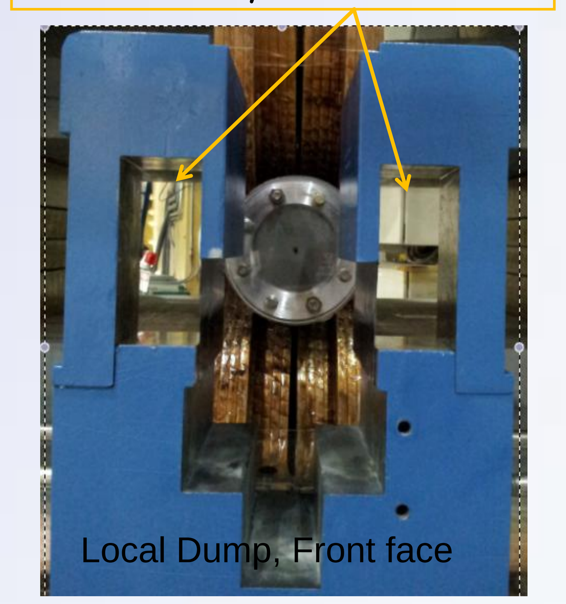
The vertical bending angle (left) and the polar angle (right) as a function of electron momentum for 5.0T target filed, assuming the beam coming along z axis without tilting. Angles are measured at 64 cm downstream, the front face of the local dump. If the target field drop to 2.5T, the bending effect will also drop by 50%. The color curves in the right figure are with constant Q^2 and beam energy values.

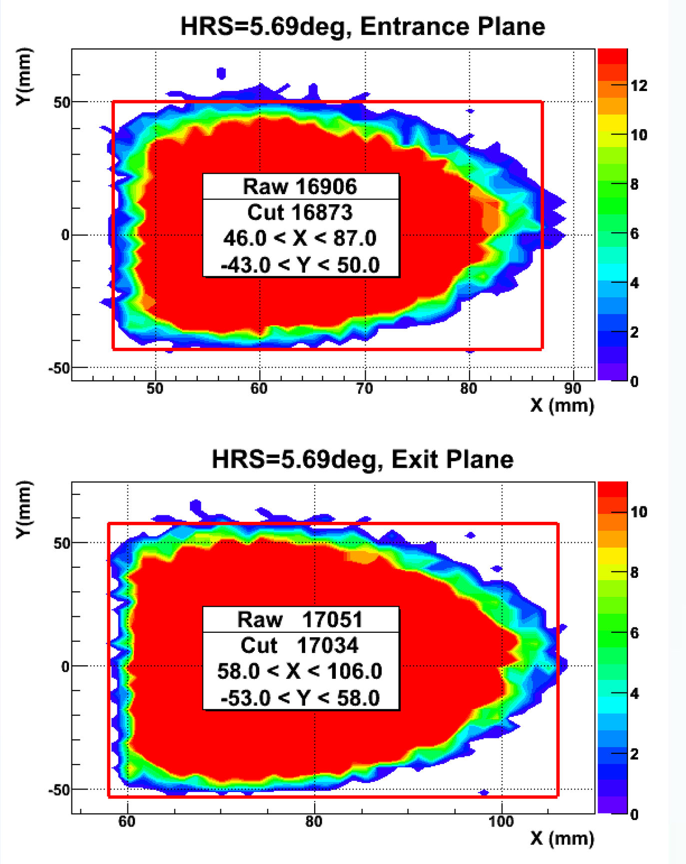
The Local Beam Dump



The vertical position as a function as electron momentum measured at z=64 cm, assuming electron coming out along z axis from the target center. This is used to determine the opening for the beam pipe at the local dump.

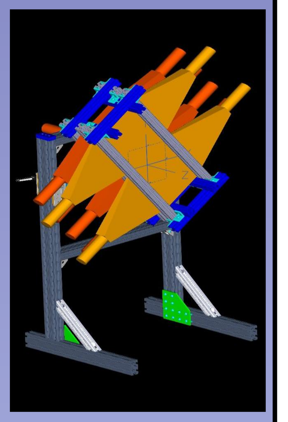
The local dump has 2 opennings for the scattered electrons to go through, which is also determined by this simulation.

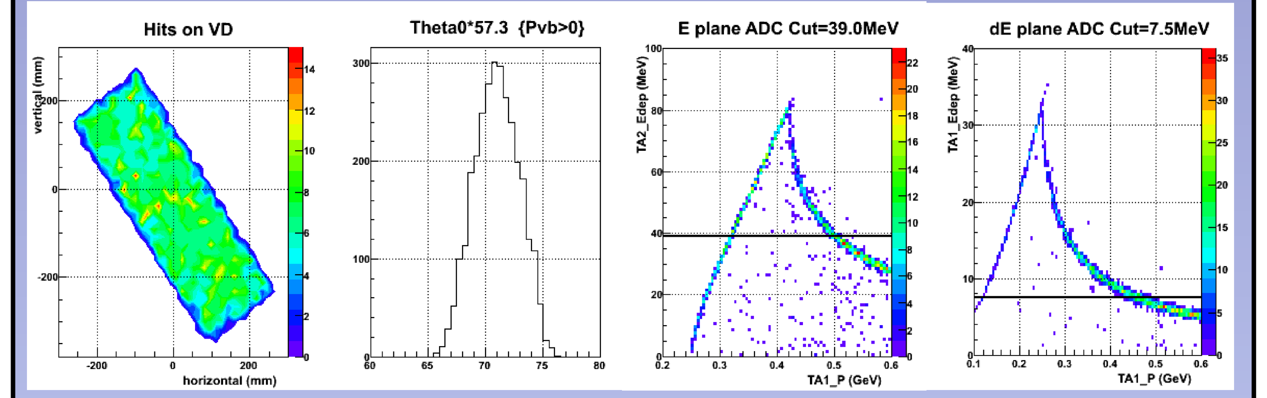




Recoil Proton Detector (3rd arm)

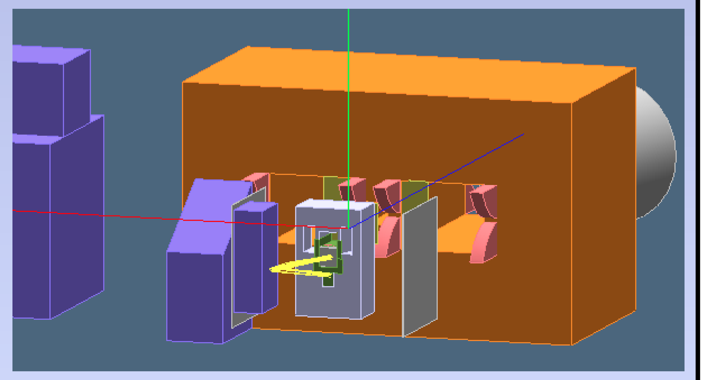
- Purpose: detect the elastic recoil proton from 0.3 to 0.6 GeV in momentum to monitor PbPt. It was expected to achieve result with 10% uncertanty in 24 hours, assuming 10 kHz DAQ rate and 40% Pt.
- A simple detector built with exist material to reduce cost. It contains 2 layers of scintillators: dE plane (6" x 24" x 0.3") and E plane (17" x 20" x 2").
- Determine the position and orientation of the detector, and the energy threshold with this simulation.



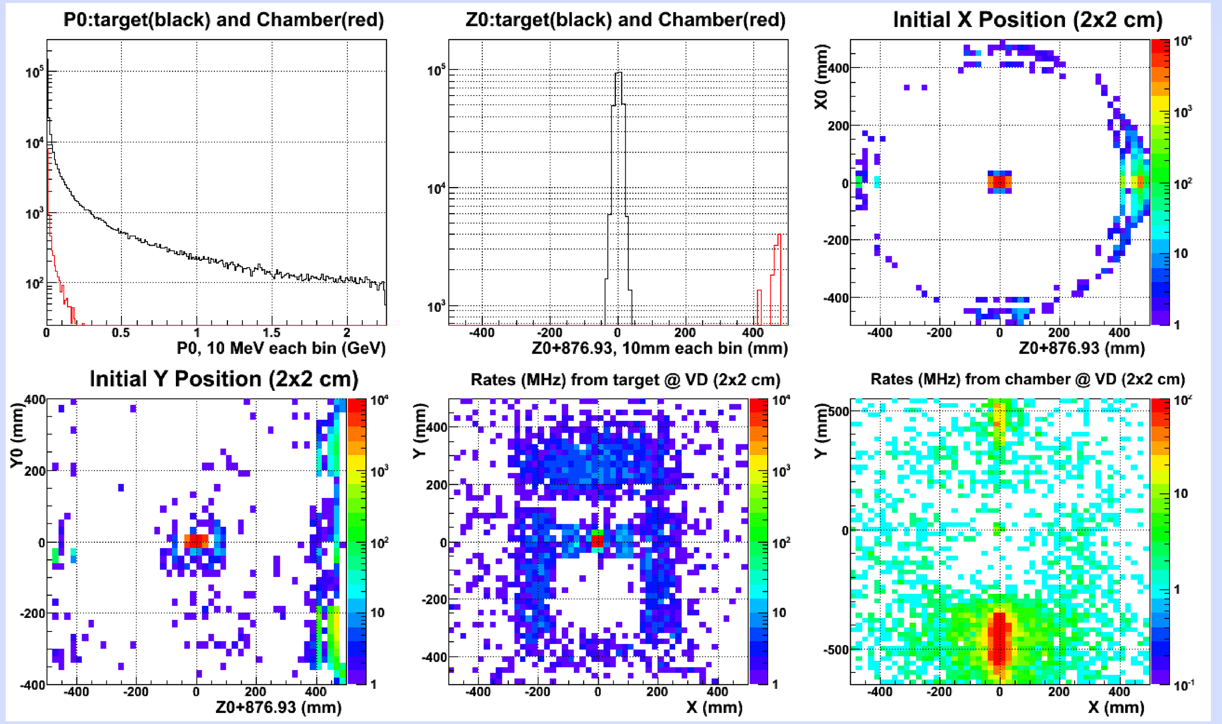


The simulation of the 3rd arm for E=2.254GeV and 5.0T target field. Detector was placed at 70 degrees and 210 cm away from the target. Simulated results show that the detector have to be rotated by 16 degrees and the the center of it have to be shift down by 4 cm. The energy thresholds for dE and E plane are 7.5 and 39 MeV, respectivley.

•Design the shielding: a 30 cm effective thickness of borated polyethylene shielding (3 pieces in total) was placed as shown in the right figure to block neutron radiation from the local dump at least 90%.

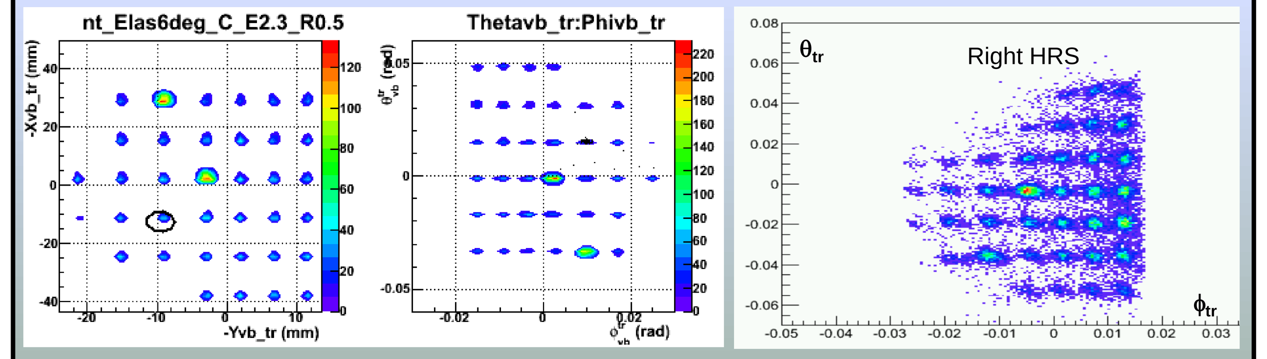


Bremsstrahlung Radiation



The bremsstrahlung radiation measured at z=90 cm, the back face of the local dump, for E=2.254 GeV and 5.0T target field. The result shows that most of the photon is from the target and a small portion of them are from the target chamber.

HRS Optics



The simulated sieve slit pattern of left HRS (left 2 pannel) and that for the right HRS from the real data (right panel).