MOLLER: Beam Trajectory; Towards Alignment Specs

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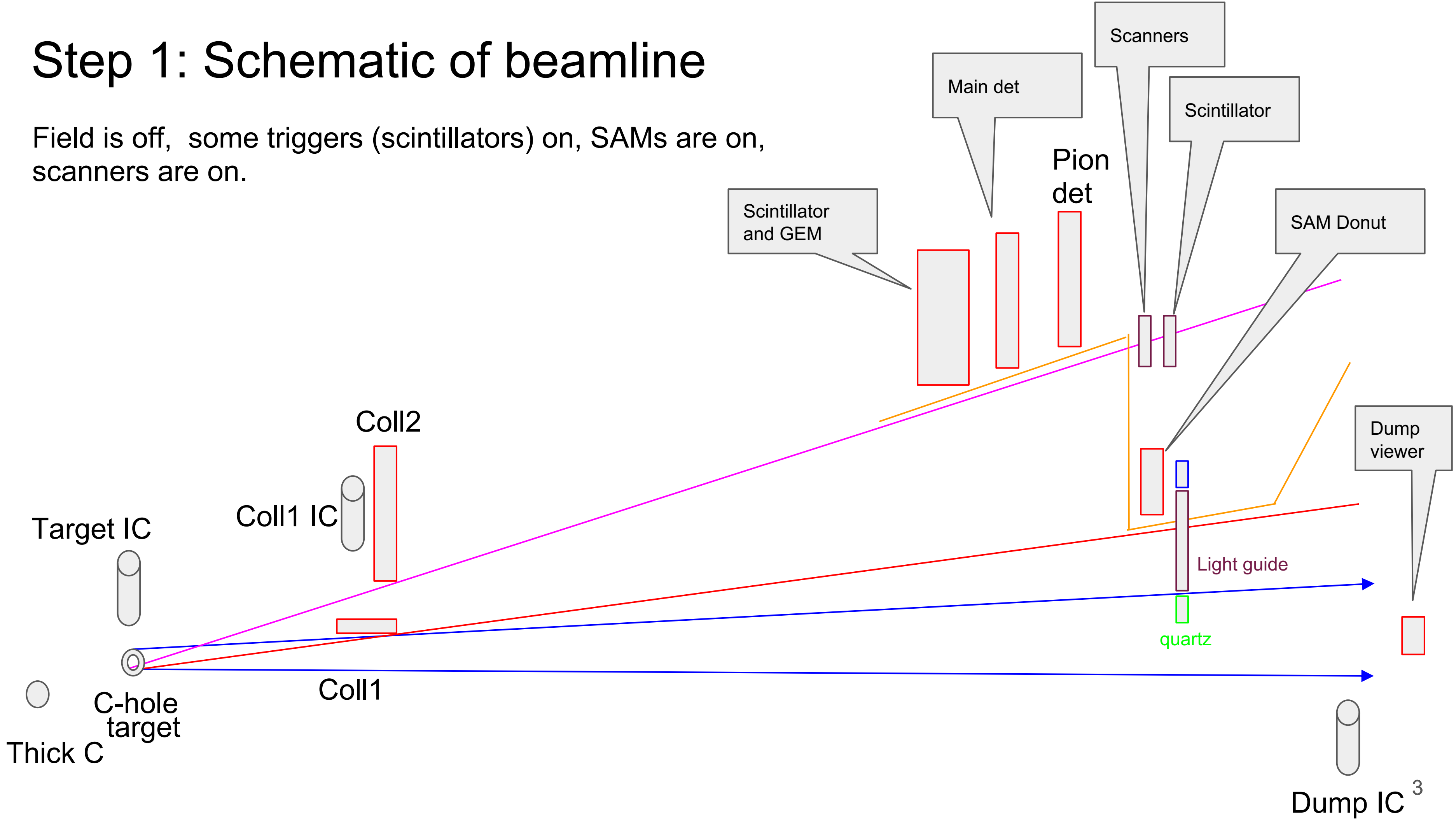
Overview

- Step 1: Ideal trajectory without field: collimator 2 center (acceptably going through target nipples and acceptably close to center of beam dump)
- Step 2: Collimator 1 center search
- Step 3: Turn on Field, check beam trajectory, check magnetic axis
- Step 4: Check rate modulation in GEMs: validation of physics requirement
- Step 5: Depending on Step 4 result, revisit step 1 at slightly different angle of approach; then redo Step 2 to reconfirm collimator 1 positioning is acceptable

Step 1: Schematic of beamline

Field is off, some triggers (scintillators) on, SAMs are on, scanners are on.



Step 1: Ideal trajectory without field

A. (Tune mode), ~ few uA, field off, C- hole target, raster (large) ON
B. Scintillator trigger - (CW) check C-hole Spot data (raster currents) and change target lock (BPM) positions to put the beam center at the target. (This centering is based on survey data encoded on target position).
    a. Multiple C-hole (US & DS) targets to monitor target angles
    b. Look at beam on dump viewer
C. Thick C-target, smaller raster, field off. Target locks based on step B. Measure scanner radial profiles and SAMs rates.
    a. Scanner edge fits will tell us collimator 2 centering - Simulations required
    b. Rate difference in SAMs could warn us about a significantly anomalous beam angle
    c. Dump viewer position might also be supporting information on beam angle
D. Tweak position and angle (using BPM locks) based on **scanners edges**, SAMs and dump viewer; (within ~ +/- 1 mm of step B.)
E. Insert sieve blocker and record its position using scanners

Step 2: Collimator 1 center search

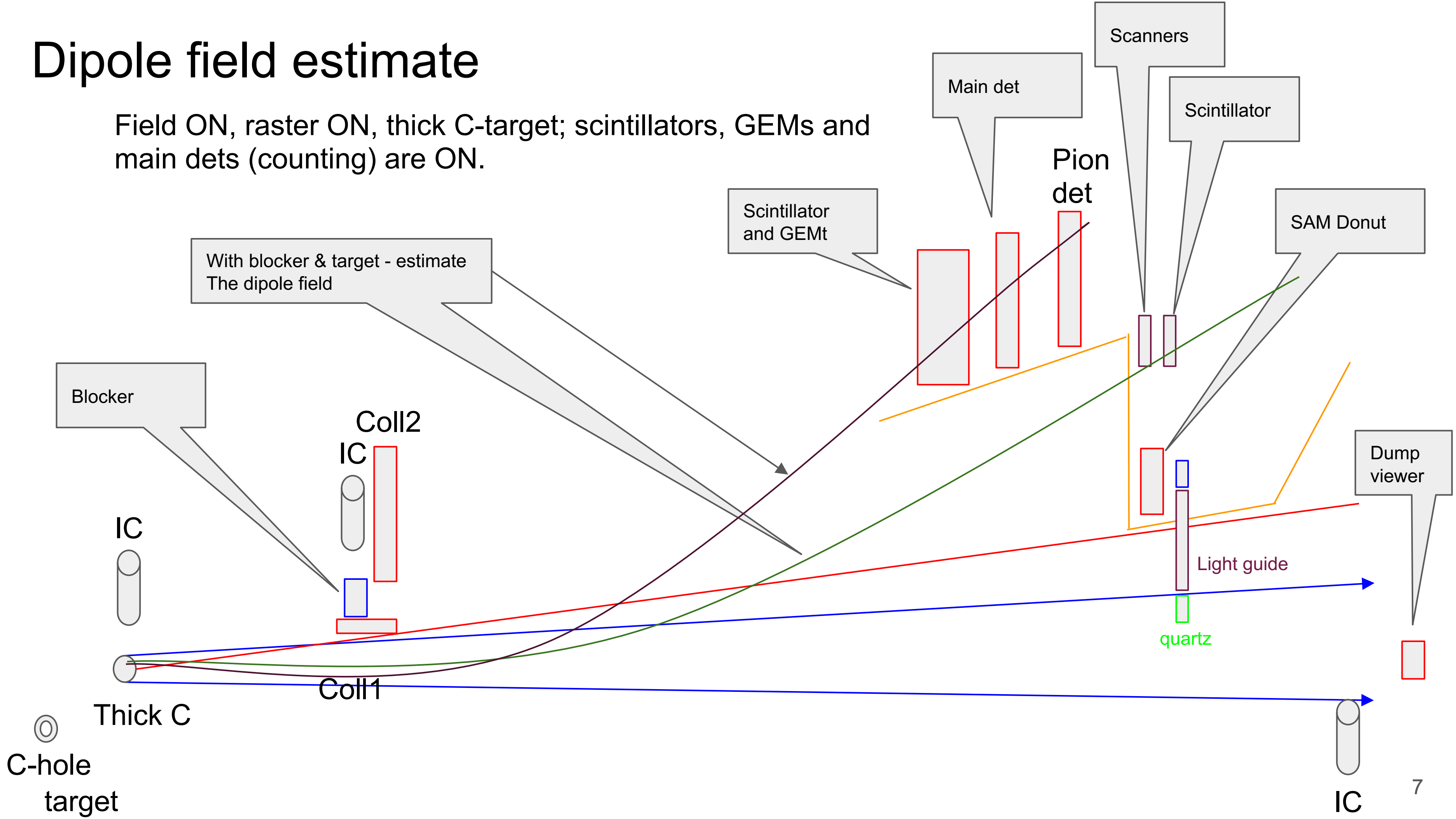
A. Low current (~100nA), field off, thick carbon, raster (large) ON, use target locks from Step 1.
B. Move beam horizontally and vertically to find the collimator center - maybe use BPM locks to make an angle to hit collimator 1. Metric - 1. collimator 1&2 ion chamber response; 2. Collimator power deposition; 3. new diagnostic: SEMs (need conceptual design) – Put beam at best guess of collimator 1 center.
C. Compare beam locks from Step 1.D and 2.B. How good is the agreement? Target lock from Step1.D is the priority trajectory. After review of any differences, find a compromise that keeps power relatively uniform, safe transport to beam dump while being relatively centered at collimator 2
D. Dump ion chamber calibration
E. Put in thick C-target and note down SAM rates with final trajectory.

Step 3: Check Impact of Spectrometer Fringe Fields

A. Low current (~100nA), field on slowly (25%, 50%, 75%, 100%) -upstream and downstream magnet one at a time, thick C target, raster (small) on, use target locks from Step 2.C. See dump ion chambers and SAM rate, Look at the dump viewer while increasing currents on magnets. Calculates SAM rate difference from the previous step's (2.E) SAM rates.
B. If beam at dump viewer unacceptably off, then find compromise to trajectories from 1D, 2B and 2C
C. Record scanners profiles and SAM rates for final trajectory of step 3B.

Dipole field estimate

Field ON, raster ON, thick C-target; scintillators, GEMs and main dets (counting) are ON.



Step 4: Minimize position and angular modulation

A. Low current (~100nA), field ON, Thick C target, raster (small) ON, use target locks from Step 2.C.Turn ON scintillators, GEMs and main dets (on counting mode). Main detectors being on is optional; can decide on the fly.

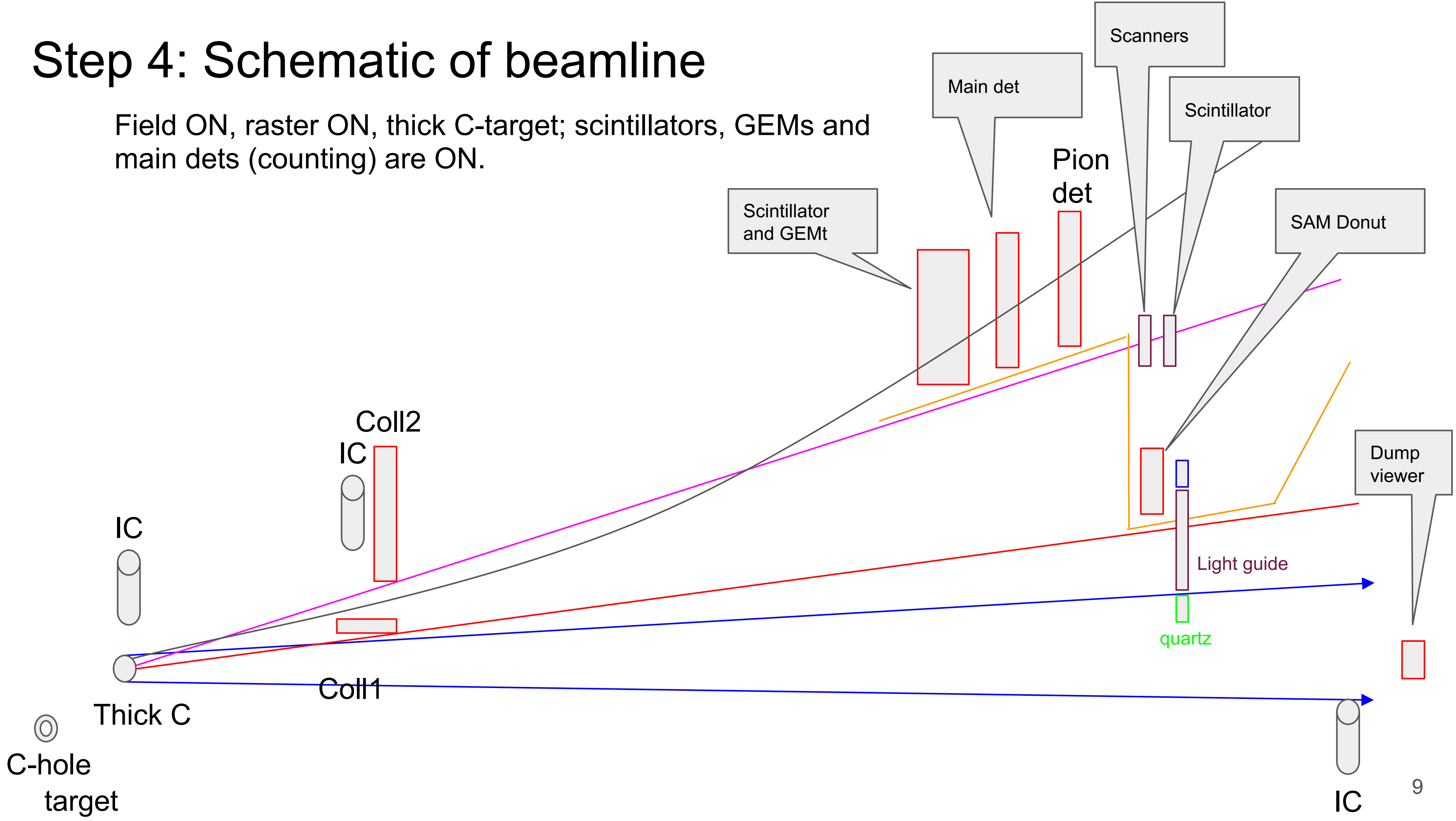
B. Check position and angular modulation of elastic carbon scattering and Moller scattering using GEMs. Start with scintillators rate for first order check. Analysis must measure relative rates for narrow equivalent phi bins in the seven sectors to achieve 1% modulation accuracy. Open and closed sector modulations for Moller scattering will have different behavior (in different phi regions)

C. Main physics requirement: phi modulations should be small enough (< 5% for elastic scattering and < 2% for Moller scattering)

D. Put in ”full” blocker and compare field off vs field on rates in scanner profile and GEMS/main detector: main check of hybrid beamline fringe dipole field

Step 4: Schematic of beamline

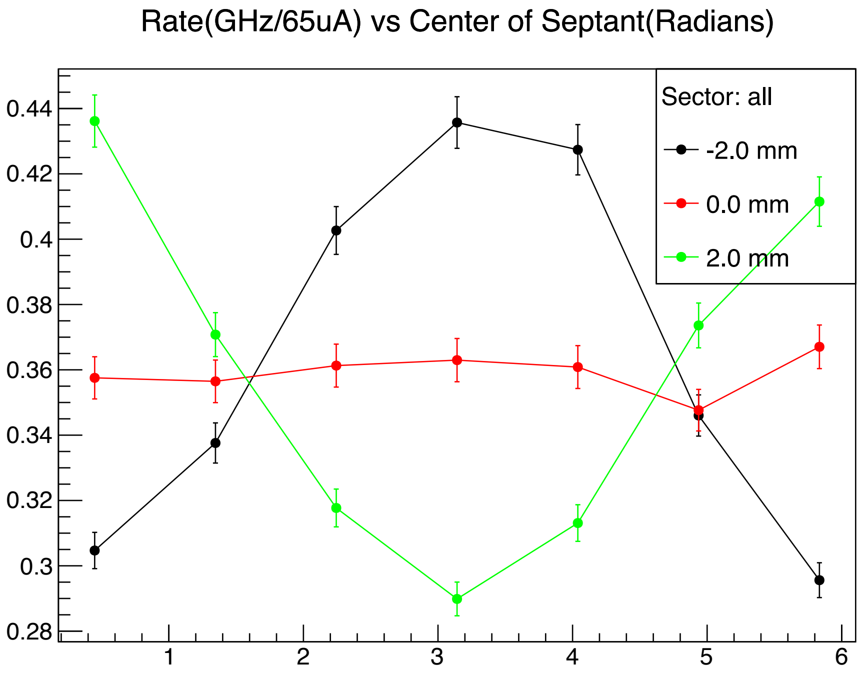
Field ON, raster ON, thick C-target; scintillators, GEMs and main dets (counting) are ON.

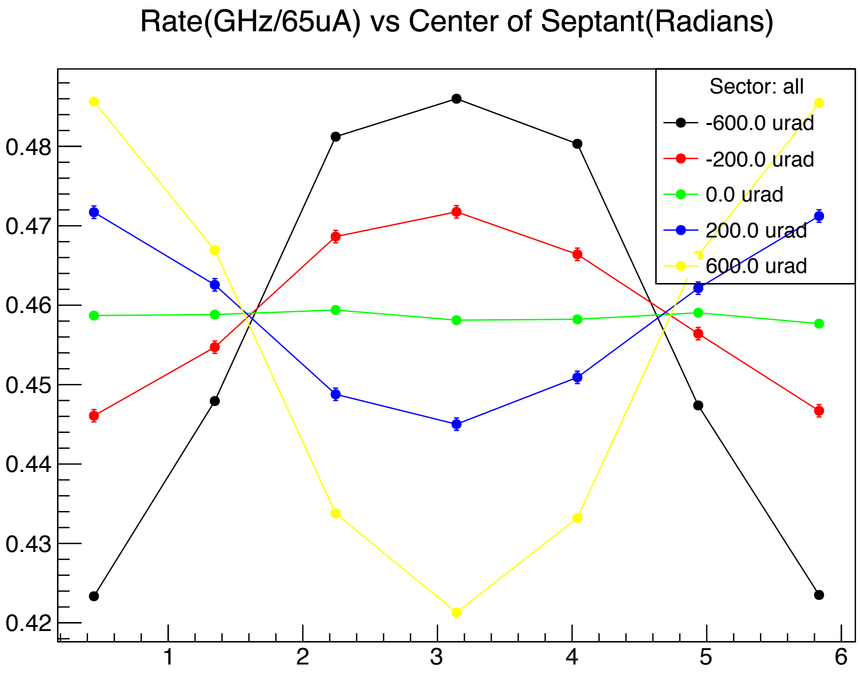


Summary of Sakib's Results in Excel Sheet

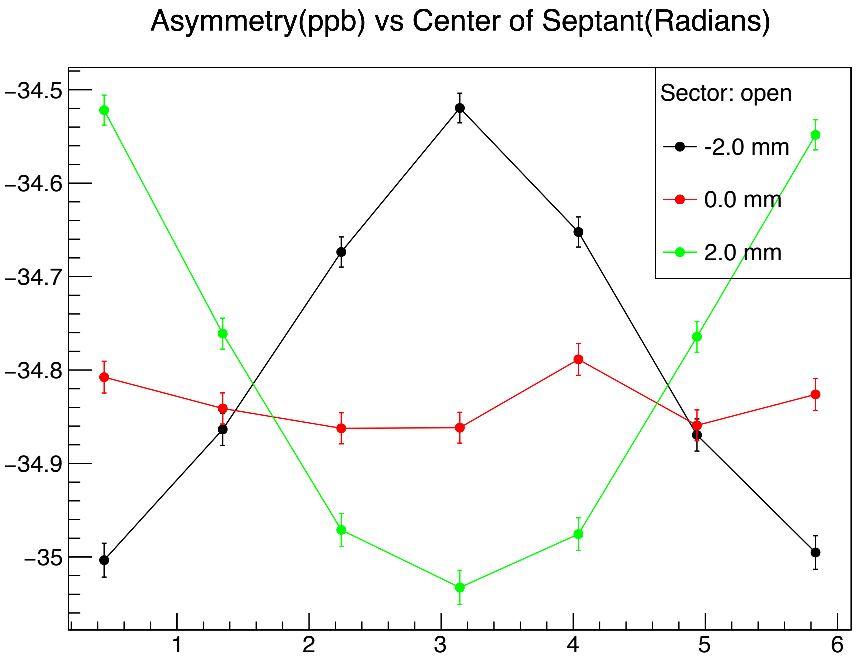
A. Looked at C-12 rate modulation and LH2 asymmetry modulation for position and angle offsets (raster off)
B. Verified original calculations on LH2 and made very important discovery: C-12 rate modulation is far more sensitive (obvious in retrospect)
C. Lots of margin: asymmetry modulation is far less sensitive and therefore our tolerance requirements as well as demands on rate systematics on the tracking detector package are quite conservative
D. Moller scattering reacts quite differently from C-12 scattering: needs further investigation, but likely will allow us to disentangle angle modulation from position modulation

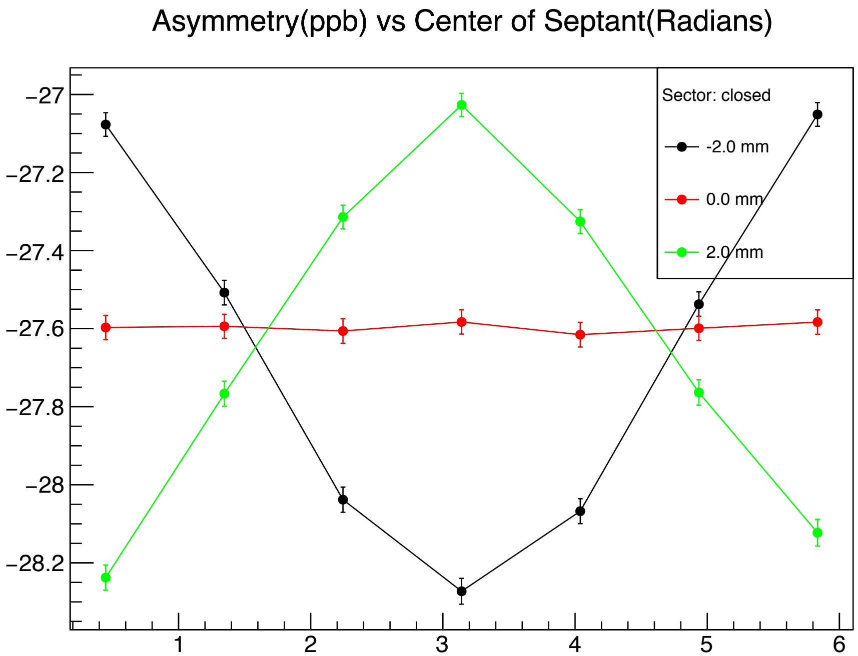
Carbon elastic modulation very sensitive!





Moller asymmetry much less sensitive





Simulation studies

A. Review studies of power deposition on Col1.
    a. SAM rates/scanner rates (slit scattering) with field off?
    b. [Is there any sensitivity to conceivable mis-alignment of Col1? Study in sim?]
B. Field off: ee, epE (1e7 events each), beam (1e8 events)
    a. Distributions of rates at the scanners. Distributions of rates at tracking planes.
    b. Find edges from collimator 2.
    c. Compare to beam offset or angle. (1mm-2mm. 300-600 urad.)
C. Field on distributions: ee, epE (1e7 events each), beam (1e8 events)
    a. Distributions of rates at the scanners. Distributions of rates at tracking planes.
    b. Compare to beam offset distributions (1mm, 2mm?)
    c. Compare to angle offset distributions (300urad, 600 urad)
D. [Realistic window and beam offset analysis (1e8 event beam generator with field off)]
    a. 15mm diameter thin Al window and thickener outer region
    b. Check distribution at end of target (interception with nipple)
E. Simulation with only US magnet on
    a. Can you see a difference in the scanners?
F. Tungsten in front of scanners with a thick C target; 100% field we should still be able to “see” the photon edge
G. Distributions at GEM planes for magnet steps
H. Collimator centering simulation: beam simulation, virtual planes in coll1 bunker, power deposition
I. Analyzing power re-evaluation for position and angle misalignments

Need for counting DAQ group

- Four scanners and scintillators for the counting DAQ -earlier there were three & only in the integrating mode.
- Pulser trigger capabilities for the all detectors - to make deadtime uniform for the rate modulation on the detector plane.
- Should have a sophisticated software package that will allow us to calculate r-phi rate modulation on the detector plane.
- Monitoring the dipole-field using blocker & with target- particles will be pulled out by the magnetic field (around the magnets region) and reach to the tracking detectors - software required for tracking those high angle particles and infer about the dipole field (may be with some simulation backing)
- SAMs rate differences to infer about beam and magnetic axis of the spectrometers.

- **Beam Trajectory Requirements (Draft)**
    - *Rastered beam must be fully contained in the front and back target endcap nipples:* It is expected that the nipples are at least 15 mm in diameter, so there is freedom at the level of +/- 2 mm over and above a 1 mm transverse tolerance specification.
    - *Beam centered on collimator 2 within 1 mm:* This is the most important physics specification. Diagnostics are built in to be able to determine this without spectrometer fields being energized. The goal will be to get within the tolerance here while staying within the target nipples and cleanly transporting the exhaust beam to the beam dump.
    - *Beam power in collimator 1 relatively uniform*: Once the above is accomplished, this should be simply a verification step as a 1 mm tolerance entering the collimator (which is rigidly connected to collimator 2) should achieve the desired uniformity
    - *High power beam transported safely to beam dump:* the goal is to maintain all the criteria above as well as clean transport to the dump after the magnets are fully energized.
    - *Hybrid dipole field backgrounds in SAM region considered acceptable for physics:* Once the ideal trajectory has been defined above, diagnostics studies using the full blocker should be able to determine whether the backgrounds from fringe fields in the detector region are under control.

Task Force Agenda and Plan

- **Beam Trajectory Requirements**
- **Collimator/Spectrometer Tolerance Requirements**
- **…**