SBS Tracking

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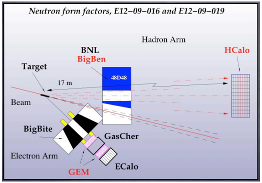
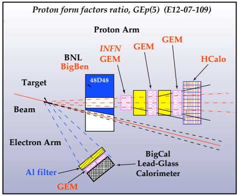
SBS Collaboration Meeting
July 22, 2016

SBS Experiments Overview



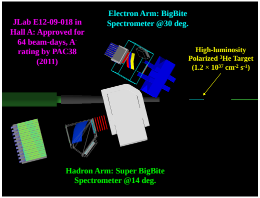
GEn/GMn

- Tracking only in electron arm
- GEM trackers in BigBite



GEp(5)

- 125k GEM channels (65k front, 2×30k back)
- High rates: ≈ 150 kHz/cm^2 charged particles
- CDet/ECAL for electron arm position detection (not tracking)
- Elastic scattering: kinematic correlation between elastic e^- and recoil p



SIDIS

- Tracking both arms, no kinematic correlation
- GEM trackers in BigBite
- GEM planes in hadron arm, like GEp(5) FT
- 40× lower luminosity than GEp(5)

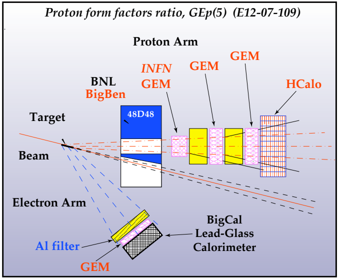
Tracking Requirements

Common: straight tracks (field-free region)

- **BigBite:** GEMs, assisted by ECAL; low rate; BigBite optics
- **SIDIS H-arm:** GEMs, assisted by HCAL; low rate; 48D48 optics
- **GEp(5) front:** GEMs, restricted to narrow search region; very high rate; requires iterative kinematic correlation analysis; 48D48 optics
- **GEp(5) back:** GEMs, similar search region; high rate; requires bridging between tracker regions

Each item involves (somewhat) different reconstruction algorithm.
Significant code sharing possible, if well planned

GEp(5) Kinematic Correlation Analysis



Suggested algorithm (section 9.5.4 of TR2 Response, 13 July 2011):

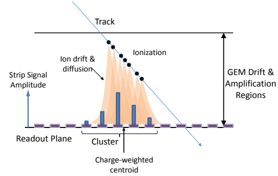
- Identify ECAL and corresponding CDet hit
- Use elastic kinematics to define p-arm search region (200×5 mm^2, 30×2 mrad^2)
- Find track(s) in p-arm search region. Reconstruct vertex(es)
- Identify vertex most consistent with electron hit
- Use vertex position to narrow p-arm search region (30×2 mm^2, 7×2 mrad^2)
- Repeat track reconstruction in p-arm using new search region

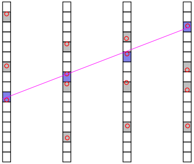
Existing Work

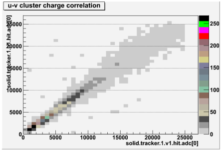
- BigBite track reconstruction based on TreeSearch, for MWDCs (2008)
- GEp(5) tracking feasibility study using TreeSearch for GEMs (2011). Incomplete
- Upgraded TreeSearch library, usable for GEM trackers + calorimeter (or other externally provided search regions) (2014)
- Machine learning approaches (*e.g.* neural network) pattern recognition + Kalman-based track fitter for GEp(5) front trackers (INFN 2015). Work in progress

2011 GEp(5) Tracking Study: Proton Arm GEM Track Reconstruction

- Reconstruction algorithm implemented in 2010/11 based on Hall A BigBite MWDC code
- APV25 decoder & analysis
  - Pulse shape deconvolution
  - Noise rejection
  - Cluster finding
- Pattern recognition: TreeSearch in coordinate projections
  - Very fast recursive template matching algorithm
  - Efficiently finds straight lines of hits (within configurable bin width) → roads
  - Used by HERMES, Qweak, OLYMPUS, . . .
- Correlation of roads from different projections via hit amplitude correlation in shared readout planes
- Simple linear minimization fit of correlated hits in 3D

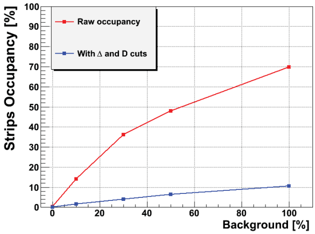




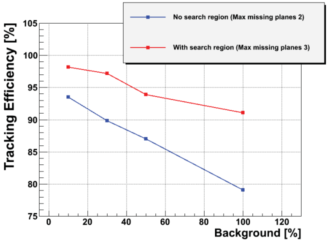


2011 GEp(5) Tracking Study: Results (with Vahe Mamyan, CMU)

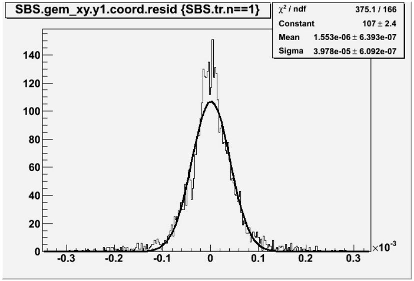
Front tracker GEM strip occupancy



Tracking Efficiency



Track reconstruction accuracy



- Realistic digitization of GEM & electronics response
- Simplifying assumptions made (see next)
- $>$ 90% tracking efficiency
- 5% ghost track probability
- $\approx$ 40 μm track position resolution

2011 GEp(5) Tracking Study: Shortcuts Taken

- Very limited simulation (Geant4)
  - Only central front tracker GEM detectors (*i.e.* no HCAL, analyzers, back trackers, CDet, ECAL). No magnet
  - Only small central region illuminated
  - What backgrounds included/missing?
  - Limited statistics
- Simplified reconstruction
  - No target reconstruction
  - No actual kinematic correlation analysis performed
  - Static search window, estimated from MC
- Limited performance characterization
  - "Tracking efficiency" defined via comparison with MC truth data (should be via reconstructed quantities)
  - Ghosts not identified via MC truth data
  - Ghost elimination procedure via χ^2 needs verification

Status of TreeSearch Library

- 2013/2014 Improvements (for SoLID)
  - GEM-related algorithms fully implemented
  - Support for "virtual planes" (*e.g.* calorimeter, kinematic r.o.i) to pre-select search regions(s)
  - MC truth data available for reconstructed hits and tracks
  - Support for vertex reconstruction via user-supplied algorithm
- Library in present state should be directly usable for any GEM tracker system plus optional calorimeter, provided the planes and readout coordinates are parallel
- Possible future improvements
  - Better track fitter (*e.g.* Kalman filter). Requires availability of full detector geometry (materials) in tracking code
  - Deterministic annealing algorithm for road clustering (used in OLYMPUS)

Preparing for Software Review

- 4th JLab 12 GeV-era software review scheduled for Nov 10–11, 2016
- SBS specifically targeted for review (as part of Hall A)
- Don't have to show readiness, but present a realistic plan how to get there
- Define requirements, *e.g.*
  - configurations to be supported, order of experiments
  - performance parameters
  - software components, analysis needs
  - data management, computing requirements/resources
- Present plan
  - code design, algorithms
  - simulations, testing and validation
  - alignment and calibration procedures
  - manpower
  - timeline
- Need to discuss actual practicable solutions. No feasibility studies and proposal-style estimates

Ideally: Create computing document

Possible Milestones

- Near-term (before review)
    - Collect requirements (info mostly exists)
    - Start implementing decoders for new electronics (in progress)
    - First shot at realistic GEp(5) tracking simulation with full input (all essential detectors) & kinematic correlation. Digitization can still be incomplete/approximate.
    - (Realistic BigBite tracking simulation, if needed for upcoming ERR)
    - To-Do list for next 2 years
- By late 2018 (before beam)
    - Improve reconstruction code based on results of simulations
    - Thoroughly test decoders with real hardware
    - Develop other necessary algorithms (calorimeter clustering, RICH PID, GEp(5) polarimetry)
    - Test INFN machine learning codes within simulation framework
    - Develop SIDIS tracking (likely not needed until later)