Coordinate Detector for the SBS Project

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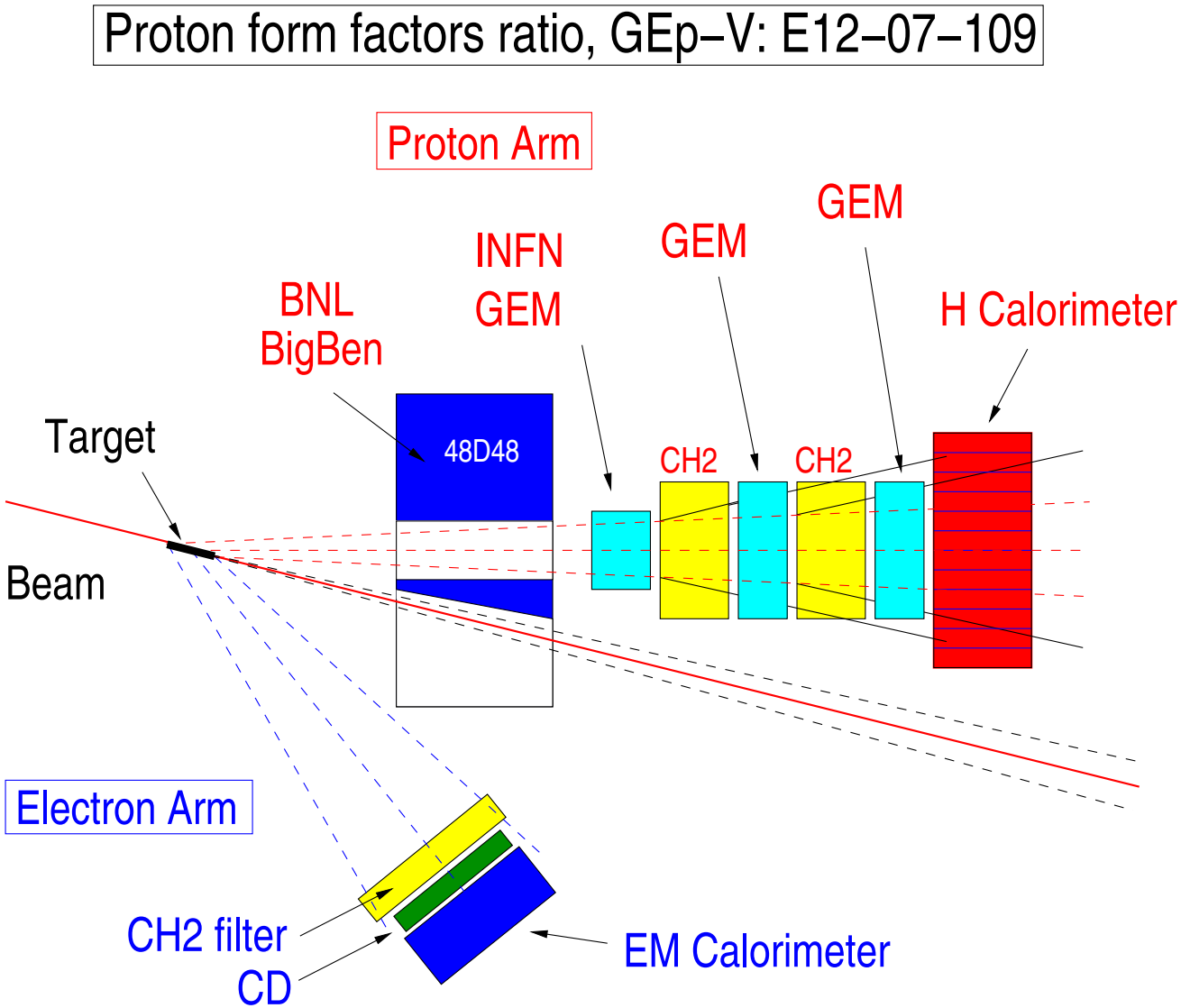
SBS Weekly Meeting / July 24, 2013

Purpose of Coordinate Detector (CD)

- GEp-V takes advantage of kinemagtic angular correlation between elastic electron and recoil proton $\Rightarrow$ allow efficient triggering and pattern recognition in presence of very high background rates in front GEM chambers of SBS.
- Measure very accurately angular correlation between scattered e^- and recoil p; especially, angle between e^- scattering plane and p recoil plane.
- Small size of e^- beam $\Rightarrow$ angles of e^- and recoil p can be determined w/ very good accuracy of ~ 0.5 mrad.
- Corresponding uncertainty in perpendicular momentum balance of ~ 5 MeV/c.
- Typical out-of-plane momentum for inelastic events ~ 150 MeV/c.
- Tight constraint on search region in proton arm $\Rightarrow$ reconstruct proton trajectory w/ efficiencies $> 95\%$.
- Powerful suppression of background events.
- To achieve this, a ~ 1 mm coordinate accuracy is required for scattered e^-.

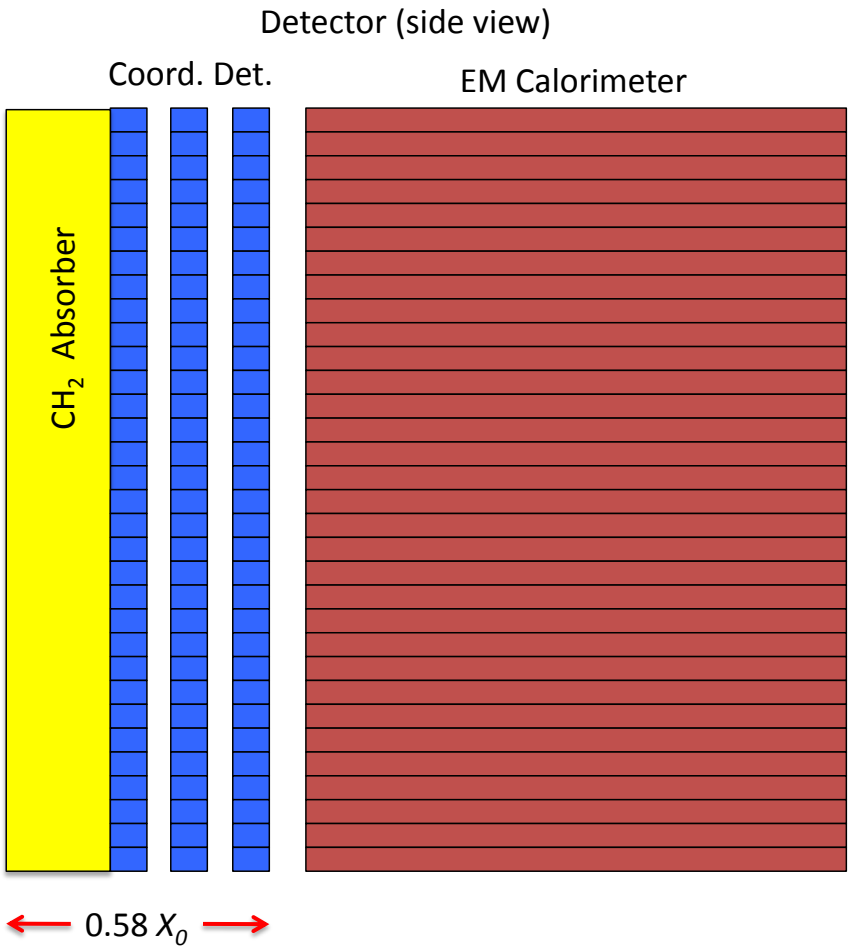
Schematic Layout of GEp-V Experiment



Basic Configuration of CD

- Proposed CD in CDR: 2 planes of GEMs w/ horizontal strips at a 1.0 mm pitch covering 80×304 cm^2 active area of BigCal EM calorimeter w/ a 20 cm thick Al absorber placed in front of GEMs.
- Possible new EM calorimeter (NewCal) using 1728 HERA-B middle section blocks, 5.6×5.6 cm^2.
- Expected size for NewCal 134×402 cm^2 keeping aspect ratio of $\sim 1:4$ horizontal:vertical size for GEp-V kinematics.
- New CD geometry: 2 independent vertical planes (possible inclusion of 3rd plane) of horizontal scintillator bars w/ 15 cm thick plastic shield in front.
- One detector plane consists of 4 sections each covering 104×104 cm^2.
- Each section is a stack of 0.5×3.0 cm^2 scintillator bars, split in half, viewing the target.
- Total number of read-out channels per plane is 1664.
- Light output to PMT via 2.0 mm diameter WLS fibers through central holes along length of the scintillator bars.

Layout of CD Configuration



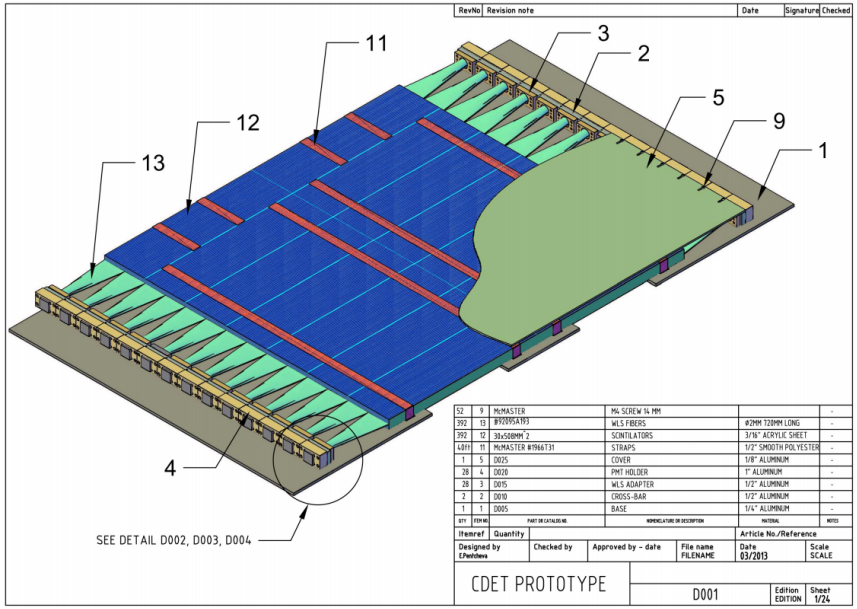
Projected Parameters of Scintillator CD

- Rate of e^- per scintillator bar ~ 500 kHz (w/ 3.5 MeV threshold).
- Required minimum shielding for 20 MeV $e^- \Rightarrow \sim 15$ cm of plastic.
- Time resolution ~ 1 ns.
- Efficiency of 92% per layer $\Rightarrow$ 85% for 2 out of 2 layers.
- Coordinate resolution $\sigma \sim 1.3$ mm for two planes.
- Suppression of photon events by a factor of ~ 2.5.
- Probability of an accidental hit in ± 2.5 calorimeter $\sigma_x = 1.0$ cm is $\sim 5\%$.

PMTs for Scintillator CD

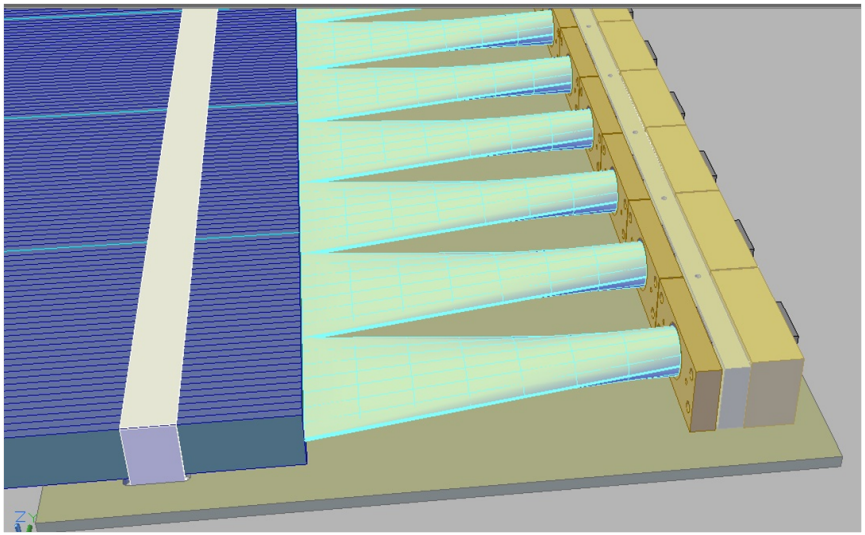
- Multi-anode 16-channel (4×4 matrix) PMTs from CDF at Fermilab.
- 602 PMTs (9,632 channels) from CDF $\Rightarrow$ JLab.
- Two types of MAPMTs:
  - Hamamatsu R5900-M16 w/ Fermilab-built dividers.
  - Hamamatsu H8711 w/ built-in dividers in pom cases.
- High gain (3.3×10^6), high speed response (0.83 ns rise time), low cross-talk (1% typical).
- High rate capability (3 MHz/channel).

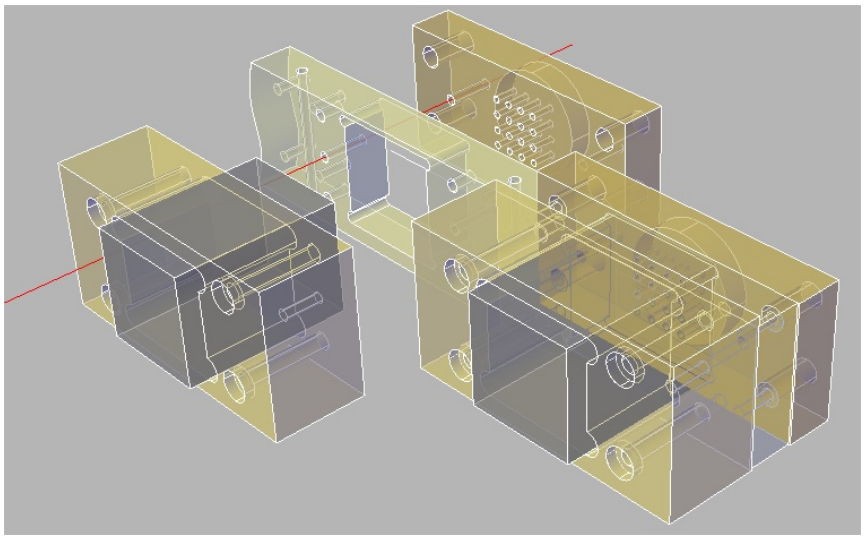
Scintillator CD Prototype Design



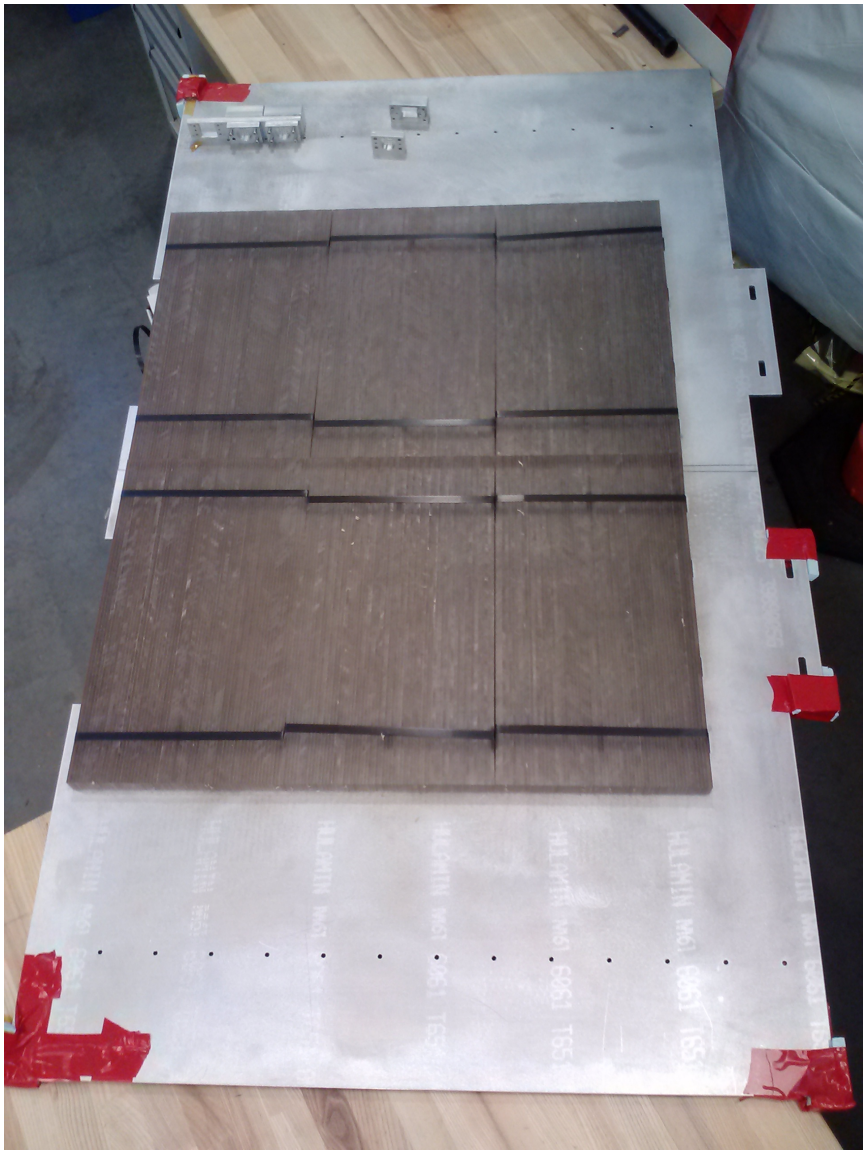
- Detailed engineering design completed for CD prototype including connection between detector sections, WLS fibers to PMT connections, and PMT holder attachments.
- Six vertical stacks (each 32 bars), split in half.
- Each stack strapped to 0.25" Al front plate (not shown) at different positions to make transition between sections.
- Straps run through holes in front plate w/ niches in stacks for straps.
- 2$\times$(4 stacked) sections form one detector plane.

Layout of CD WLS Fibers and PMT Attachments



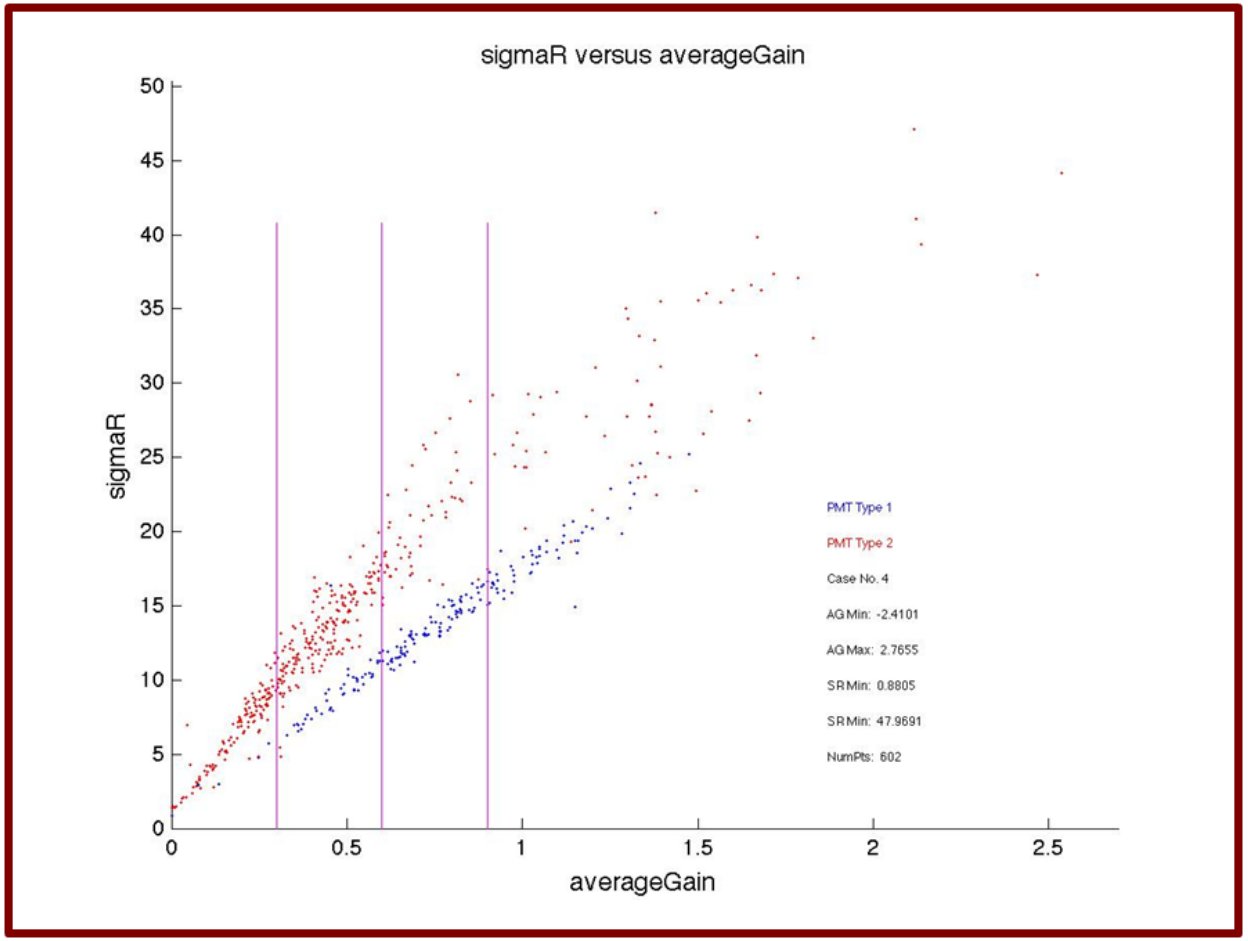


Construction of Prototype CD at JLab



Tests of Multi-anode PMTs

- Detailed testing and characterization of all 602 multi-anode PMTs (9,632 pixels) carried out at JLab by Saint Mary's University students.



Performance Comparison for CD

- Detailed simulations of the CD were carried out to study the background rates, detector efficiency and resolution to optimize the geometry for two planes of GEMs and scintillators.

	GEM CD	Scintillator CD
Position resolution (mm)	1.8	1.3
Time resolution (ns)	10	1.0
Rates per strip/bar (kHz)	550	500
Probability of Accidentals in BigCal (%)	30	5

- Advantages of Scintillator CD over GEMs:
  - Significantly better time and position resolutions.
  - Not sensitive to low energy photons/e^-.
  - Minimum thresholds and much less sensitive to backgrounds.
  - No aging of detector problems.
  - Covers larger area with minimal gaps between detector sections.
  - ~ 5 times better overall performance and significantly cheaper.
  - Very reliable and well established technology.

Budget Comparison for CD

- GEM (2 planes) : 40×50 cm^2 modules$\times 24$ covering 80×304 cm^2 area of BigCal.
  Scintillators (2 planes): 104×0.5 cm^2 bars$\times 624$ covering 104×312 cm^2 area of BigCal.
- All listed prices are from quotations of direct costs to vendors.

GEM CD		Scintillator CD		
Item	Cost (k$)	Item	Source	Cost (k$)
Frames construct. (3)	30	Scintillators	FNAL	70
FEC cards (94)	51	WLS Fibers	St. Gobain	10
MPDs (7)	44	NINO Frontend Boards (178)	U. Glasgow	21
Back planes (19)	2	Level translators	Hall A HRS	no cost
HDMI cables (66)	4	HV mainframes/cards	CDF	no cost
GEM foils (72)	86	Multi-anode PMTs and base	CDF	no cost
Chamber frames (24)	41	1877S TDC modules (70)	BELLE	no cost
1D read-out (20)	8	FASTBUS (6)	BELLE/Hall B	no cost
Chamber supplies	12	DAQ CPU (6)	GE	21
Chamber support (7)	20	DAQ SFI (6 maximum)	Struck	54
Chamber mechanics (6)	30	Detector frames	Vendor	12
UG student (1)	4	Cables/Connectors	(estimate)	30
GEM CD Total	332	Scintillator CD Total		218

Organizational Aspects of CD

- Participating institutions:

  JLab, Idaho State University, Saint Mary's University, University of Glasgow.

- Task force team:

Bogdan Wojtsekhowski	-	the concept and guidance
Mahbub Khandaker	-	overall coordination of entire CD project
Adam Sarty	-	design details/construction schedule/manpower
Lubomir Pentchev	-	design details/MC simulations
Mark Jones	-	MC simulations
John Annand	-	NINO electronics
Alexandre Camsonne	-	DAQ: FASTBUS/CPUs/CODA

- Institutional MOUs in place:

  JLab - Idaho State University
  JLab - Saint Mary's University
  JLab - University of Glasgow

- Funding support acknowledgements:

Hall A	-	items for CD prototype
Vina Punjabi	-	student and material support
Todd Averett	-	machine shop time support

Summary

- Scintillator-based coordinate detector for the SBS project.
- Definite advantages of Scintillator CD compared to GEM-based CD:
  - Significantly better time and position resolutions
  - Much less sensitive to low energy backgrounds
  - Much better overall performance
  - Significantly cheaper
  - Very reliable and well established technology
- Project well underway in establishment of design parameters and prototype construction.
- Significant progress in acquisition and testing of detector electronics.
- Scintillator CD project awaits inclusion into SBS Project Management Plan!