Beam Test Analysis Status

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One Slide Summary



Beam Test Overview

SoLID Director's Review (2021)

- Calorimeter and SPD detectors not tested under high rate / high luminosity environment
- Detector test utilizing a full set of SoLID prototype detectors under "realistic SoLID running condition"

<u>Goals</u>

- 1. Ensuring scintillators and ECal can trigger at high rates
- 2. Identifying MIP signals in ECal above background
- 3. Ensuring GEMs work properly and can find tracks
- 4. Comparison with and benchmark of the SoLID simulation (see Ye Tian's talk)

SoLID Beam Test Timeline

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- XEM 2.

3. Deuteron e⁻ Disintegration

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82°: Low Rate Setting

Goals of Low Rate Setting

- 1. Detector/trigger checkout and optimization
- 2. GEM setup
 - Only single upstream GEM (no tracking)
 - Used to identify clusters

Trigger	Logic	Threshold*	Particle
TS 1	Scin 1 top .and. Scin 2 top	~20 mV	e⁻
TS 2	Preshower Top .and. Shower Top	~20 mV	π
TS 3	Shower Sum	~20 mV	e⁻



e⁻

82°: Low Rate Setting

- Detectors partially blocked when SHMS was below 15° (majority of the run low rate period)
- Recorded waveform information for each event
 - **Offline signal integration** (Jixie Zhang)
- Identified MIP in Preshower
 - Scintillators, SPD, and LASPD
- No MIP in Shower at 82°
 - Agreement with simulation
 Shower spectra used for calibration







7°: High Rate Setting 1

- All 4 GEM layers included
- Removed both scintillators and FASPD
 - Added 4 smaller scintillators
- Remotely controllable threshold
- Dedicated 15 minutes runs each week
 - 3-5 μA (Lowest stable current)
 - Limited data with optimized GEMs
- Experimental dosimetry
 - \circ ~150 kRad



Trigger Name	Logic	Particle	
TS 1	Cherenkov Sum + Shower Sum	e	SoLID e ⁻ trigger
TS 2	Scin D + Shower Sum + Scin B	π	SoLID π like trigger
TS 3	Cherenkov Sum + Scin D + Shower Sum		⅔ Trigger (efficiency)
TS 4	Shower Sum	"clean" e⁻ or photon	
TS 5	Scin B	"clean π "	

Detector layout



18°: High Rate Setting 2

• Data summary

- Beam Current
 - High current: 40 65 μA
 - Low current: 10 μA (Boiling study)
 - Dedicated: 5 µA (short-Detector checkout)
- Targets
 - Deuterium, Carbon, and Dummy
- Experimental dosimetry (on front GEM)
 - 70 kRad

Trigger Name	Logic	Threshold	Particle
TS 1	Cherenkov Sum + Shower Sum	Cherenkov: 2 pe Shower Sum: 0.5 mip	е
TS 2	Scin D + Scin B	0.5 mip	π
TS 3*	Scin A + Scin D		MIP
TS 4	Shower Sum	Variable	High energy e and γ
TS 5	2 out 16 Cherenkov		

*TS 3 was modified due to the high rate in Scin A TS 3 = Scin C + Scin D + Shower Sum

Summary of work since the last collaboration meeting

- 1. GEM optimization
- 2. Beam test comparison with simulation see Ye Tian's update
- 3. SPD timing study (Carter Hedinger)
- 4. Pileup at high current
 - a. Deconvolution algorithm implemented (Jixie Zhang)
- 5. Cherenkov SPE (Zhiwen Zhao & Bo Yu)
 - a. Bench test with JLab Detector Group
- 6. Gain shift in shower pmt
- 7. $\pi^{+/-}$ Rejection of ECal
 - a. Simulation Machine Learning
 - b. Simulation Classical PID
 - c. Data

GEMs



Selecting events (predominantly) in Shower_t,I,r and compare GEM cluster



GEMs



Selecting events (predominantly) in Shower_t,l,r and compare GEM cluster







GEMs



Detector Stability

- Mean energy loss near minimum of (dE/dx)
- Used for gain calibration and stability monitoring of detectors





Detector Stability: Shower

- Mean energy loss near minimum of (dE/dx)
- Used for gain calibration and stability monitoring of detectors
- Shower modules experienced a (non-linear) increase in HV with increase in beam current
- Used passive PMT bases



See Richard Trotta's talk on future plans on Ecal & SPD



Detector Stability: Preshower

- Mean energy loss near minimum of (dE/dx)
- Used for gain calibration / stability
- Shower modules experienced a (non-linear) increase in HV with increase in beam current
- Preshower modules appeared stable during 18° setting





Particle Identification: Electromagnetic Calorimeter

e⁻ Efficiency:

Not possible without momentum selection Dominated by low energy background

 $\pi^{+/-}$ Rejection:

Comparison with SoLID simulation Comparison with SoLID pre-CDR



Electron Distribution: Simulation

•	Desired performance	
π^- rejection	≳[50:1]	
e^- efficiency	$\gtrsim 90\%$	
Energy resolution	$< 10\% / \sqrt{E}$	
Radiation resistance	$\gtrsim 400 \text{ kRad}$	
Position resolution	$\lesssim 1 \text{ cm}$	

Sol ID pro CDD



Particle Identification: Electromagnetic Calorimeter

e⁻ Efficiency:

Not possible without momentum selection Dominated by low energy background

$\pi^{+/-}$ Rejection:

Comparison with SoLID simulation Comparison with SoLID pre-CDR

Analysis Effort Tasks

- 1. Detector stability completed
- 2. $\pi^{+/-}$ Rejection will be completed in ~ 1-2 weeks

•	Desired performance	
π^- rejection	≳[50:1]	
e^- efficiency	$\gtrsim 90\%$	
Energy resolution	$< 10\% / \sqrt{E}$	
Radiation resistance	\gtrsim 400 kRad	
Position resolution	$\lesssim 1 \text{ cm}$	

Sal ID pro CDD

<u>Cuts</u> Cherenkov • Cherenkov SPE < 5 Scintillator Coincidence timing • Scin D and Scin B Scintillator cuts • Scin D > 3000 and Scin D <5000 Preshower vs. Shower: 2-d cut (slope = -0.85)

Cut adapted from PID on Simulation

Summary and Conclusion

- Recent beam test has provided opportunity to
 - Study detector performance in high luminosity + background environment
 - Make comparison with SoLID simulation
- Shower base exhibited current dependent behavior
 - Due to passive PMT base
- Preshower stable during 18° setting
- Particle ID studies largely complete $\sigma \pi^{+/-}$ Rejection of Ecal
- Documentation and summary report
 - Technical notes summarizing work and analysis
- Test data provide foundation for possible future AI/ML PID work

Thank You

Hall A/C staff, Hall C Technical Staff, Hall C Engineering Staff, RADCON, and (all) the running experiments

MIP Summary

- Shower modules experienced a (non-linear) increase in HV with increase in beam current
- Behavior was observed in test for NPS passive PMT bases (2012)
 - Passive bases used in beam test shower modules
- Left shower module (closest to beamline)
 - Started to fail around 60 μA
 - Recovered and continued to work properly at low currents
- Possible future bench test to further understand behavior with these bases

New Photomultiplier Active Base for Hall C Jefferson Lab Lead Tungstate Calorimeter

¹Vladimir Popov, ²Hamlet Mkrtchyan

¹RADCON/ESH&Q, Thomas Jefferson National Accelerator Facility, Newport News, Virginia, USA
²A. I. Alikhanyan National Science Laboratory (Yerevan Physics Institute), Yerevan, 0036, Armenia.



Fig. 6 Normalized gain as a function of pulse repetition rate of PbWO₄ scintillator similar LED light source.

Active base, initial amplitude: — 300mV; — 600mV; – 1000mV Passive base, initial amplitude: … 300mV; … 600mV