University of Glasgow

E12-06-122
Measurement of the Neutron Spin Asymmetry A_1^n
A Status Report

J.R.M. Annand
University of Glasgow, UK,

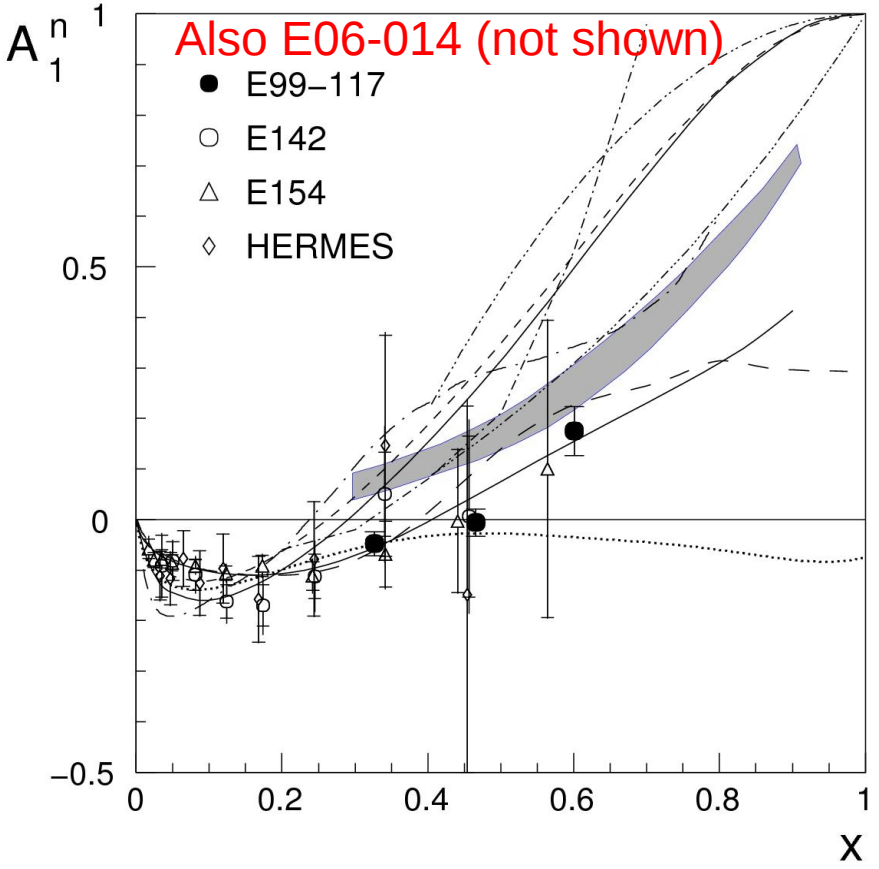
Spokespersons:
JRMA, T. Averett, G. Cates, N. Liyanage, Z.-E. Meziani, G. Rosner,
B. Wojtsekhowski, X. Zheng

A_1^n Motivation

$$A_1(x,Q^2) = \frac{g_1(x,Q^2) - \left[\frac{(2Mx)^2}{Q^2}\right] g_2(x,Q^2)}{F_1(x,Q^2)} \equiv \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}}$$

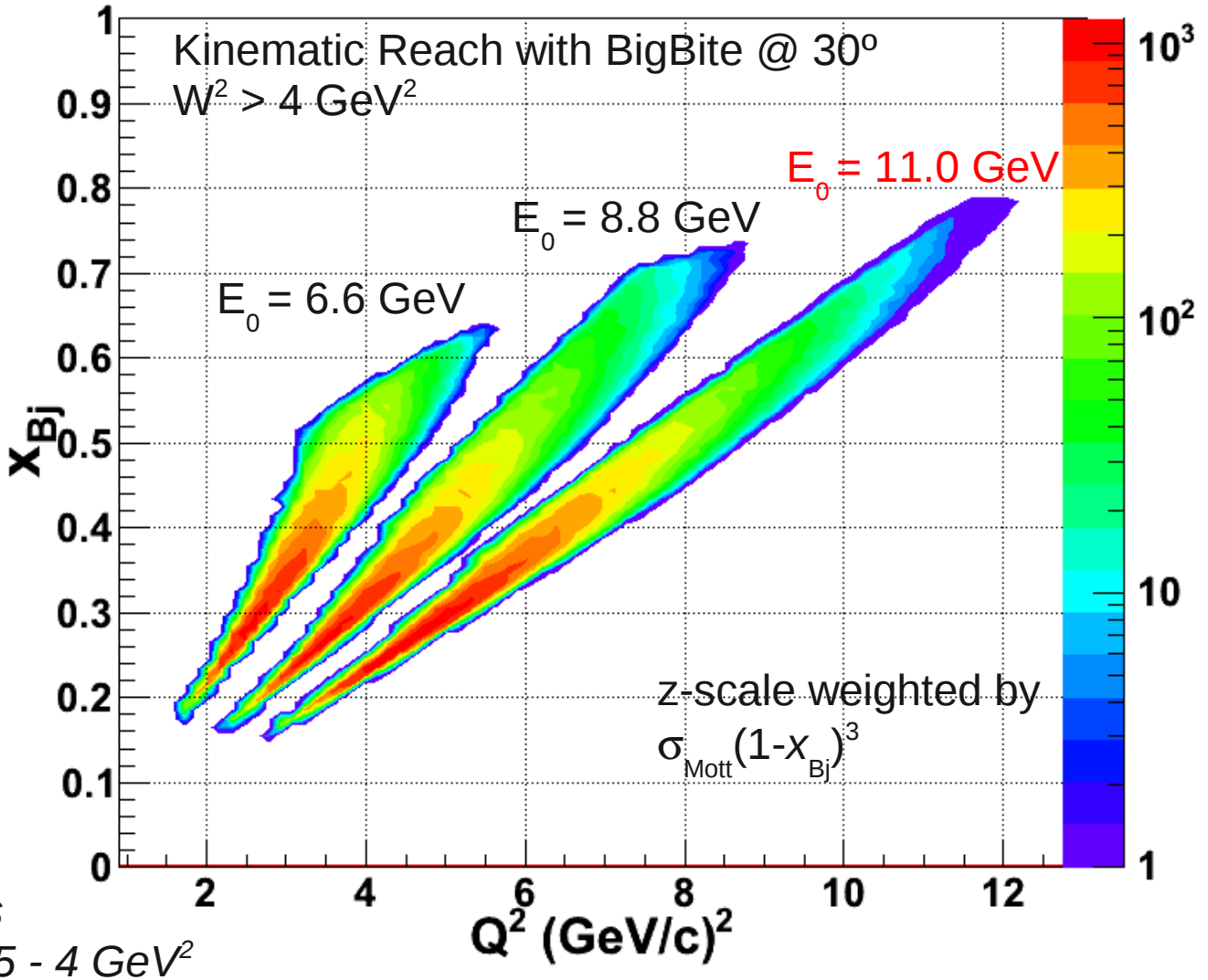
High Q^2 $\quad A_1 \approx \frac{g_1}{F_1} \qquad F_1(x,Q^2) = \frac{1}{2}\sum_i e_i^2 q_i(x,Q^2) \quad g_1(x,Q^2) = \frac{1}{2}\sum_i e_i^2 \Delta q_i(x,Q^2)$

- Double Polarized DIS ($W^2 > 4$ GeV^2)
- Direct measurement of polarized PDF in high-x_{Bj} valence region
- At high x_{Bj} scattering from high-energy quark
  In principle calculable in pQCD in kinematic domain accessible at JLab
- Previous Measurement in Hall-A
  X. Zheng et al., PRL 92, 012001 (2004),
- 1st observation unambiguous positive signal at high x_{Bj} ~ 0.6
- Consistent RCQM
  (which considered OAM constituent quark)
- Inconsistent pQCD (which assumed HHC)
- OAM is important viz. G_{Ep}, SIDIS
- **Extend x_{Bj} range, finer binning, improve precision**



A_1^n Post CEBAF Upgrade

- Higher energy beam gives access to higher x_{Bj}
- Extension to x_{Bj} ~ 0.7 - 0.8 exceedingly valuable
- Expect a steep rise in A_1^n with increasing x_{Bj}
- Improve precision to constrain theory
- Measure Q^2 dependence... expected to be weak, but has to be known
- Use large acceptance spectrometer...BigBite



- *Can simultaneously access resonance region W^2 : 1.5 - 4 GeV^2*
- *Investigate quark-hadron duality for spin structure functions*
- *Reach higher x_{Bj} than possible in DIS*

The Measurement E12-06-122

PR12-06-122 proposal

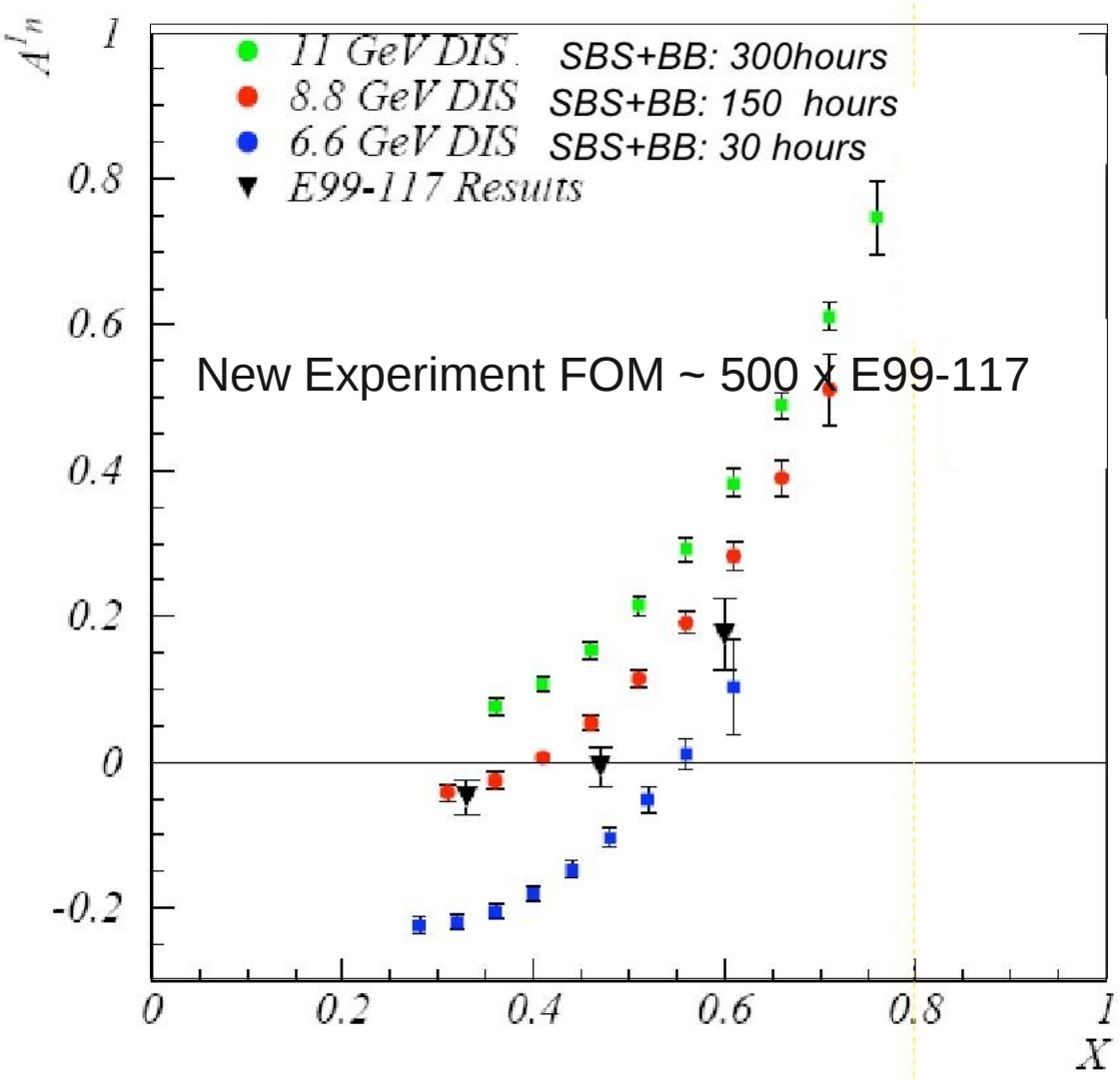
- Beam energy 6.6, 8.8 GeV
- L ~ 5x10^{35,} 30cm 50% pol. target 10 μA
- x_{Bj} up to 0.71 for DIS

Improvements by 2014

- Existing ^{3}He target already achieved ~65% pol. at 12 mA in SIDIS. Polarizations of ~70% achieved
- GEN-II convective target 60cm long, metal walls withstand 60 μA
- Factor ~4 increase luminosity? dependent on other parts of expt.

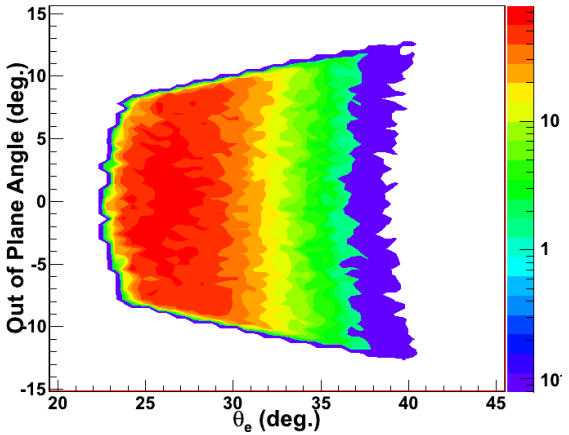
- High luminosity upgrade to BB detect
  New GEM trackers
  New timing hodoscope
  New π^--rejection Cherenkov
- SBS ready to use??
  instead of LHRS at -30º
- Upgrade to DAQ system
- 11 GeV measurement...
  extend to x_{Bj} ~ 0.8 and range of Q^2

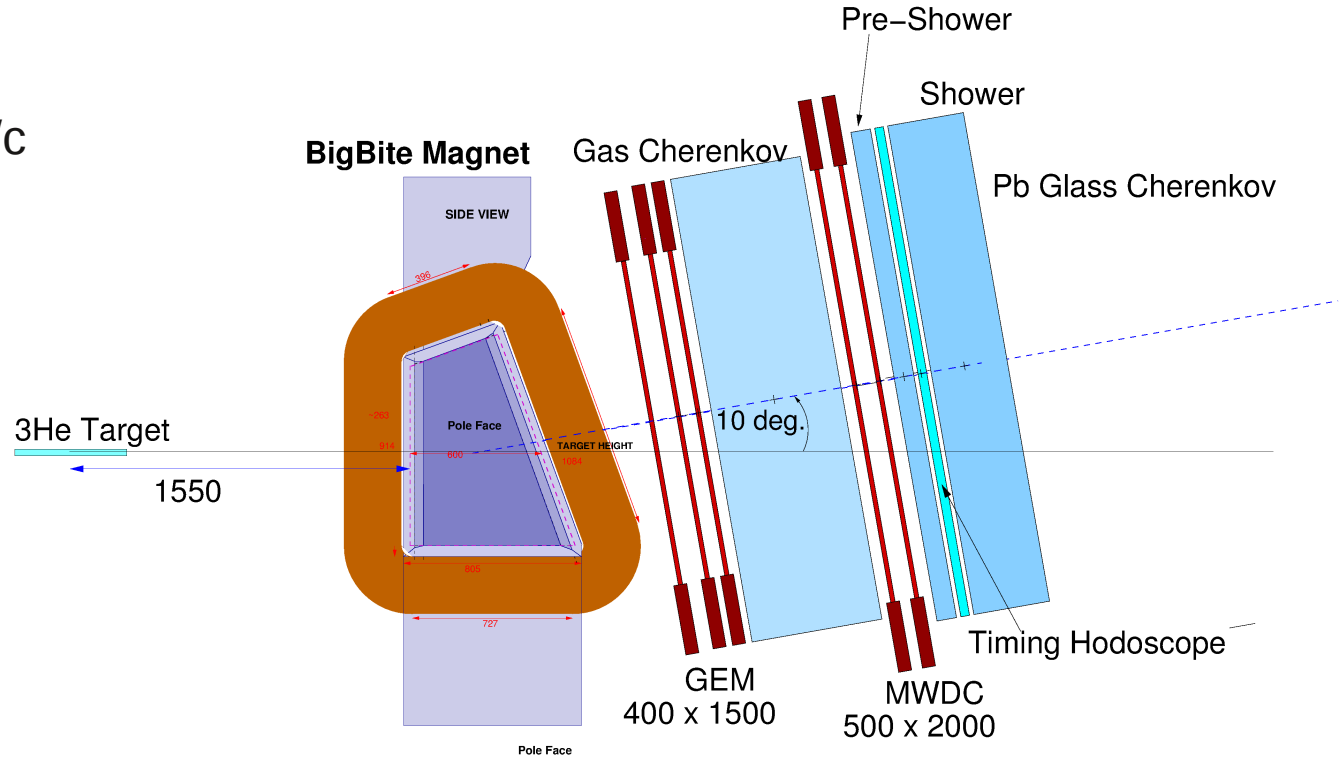
Projected Precision
Nilanga Liyanage, SBS Meeting March 2010



BigBite Detector Apparatus

BB at 30 deg.
B=1.2T
Momentum 1.6 - 3.2 GeV/c





BigBite Electron Arm

- Large acceptance
- Shallow bend angle
- High resolution tracker $\Delta p/p \sim 1\%$
- Pb-glass trigger
  insensitive soft background
  pre-shower/shower π^- rejection
- Gas Cherenkov π^- rejection
- Total rejection factor 10^4

also for G_{En} and G_{Mn} measurements

Upgrade detectors for high luminosity

- GEM chambers replace front MWDCs
- New gas Cherenkov (500 28mm PMT)
- Rear MWDC (6 planes)
- Pre-shower lead glass
- New Timing Hodoscope
- Shower lead glass
- New frame to hold assembly

GEM Chamber Progress

The Front GEM tracker

- Common effort for SBS and BB.
- Same 40x50 cm GEM modules as SBS
- Three GEM chambers 40x150 cm^2.

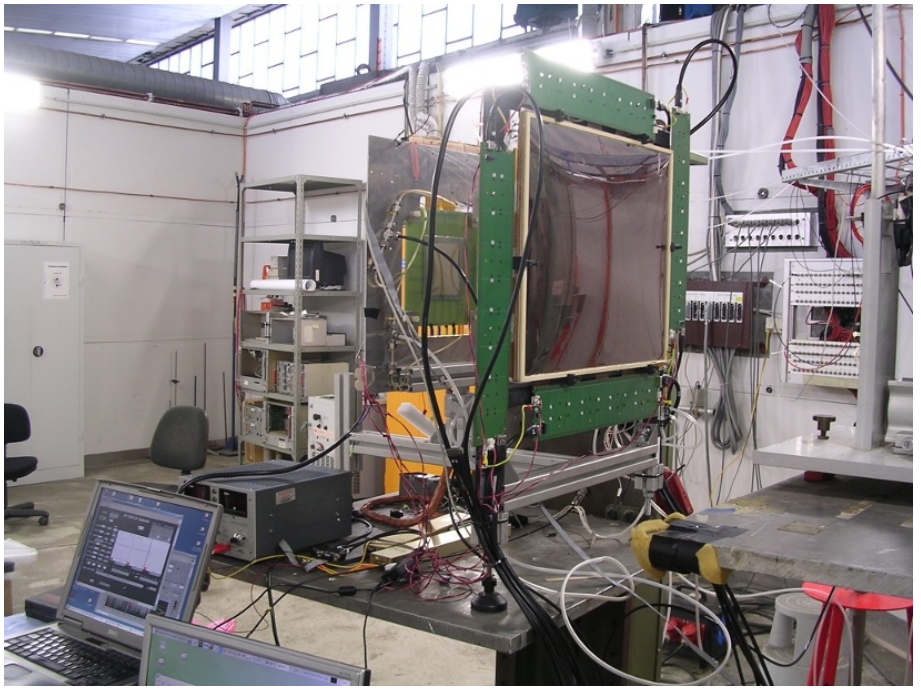
Time Line Projection from INFN Rome

- Chamber production 4/2011 – 3/2012
- Electronics production 5/2011 – 12/2011
- External frames 9/2011 – 3/2012
- Cabling 1/2012 – 6/2012
- Ship JLab 5/2012
- JLab assembly 6/2012 – 9/2012
- Test 9/2012 – 12/2012
- Mount BigBite & test 1/2013 – 2/2013

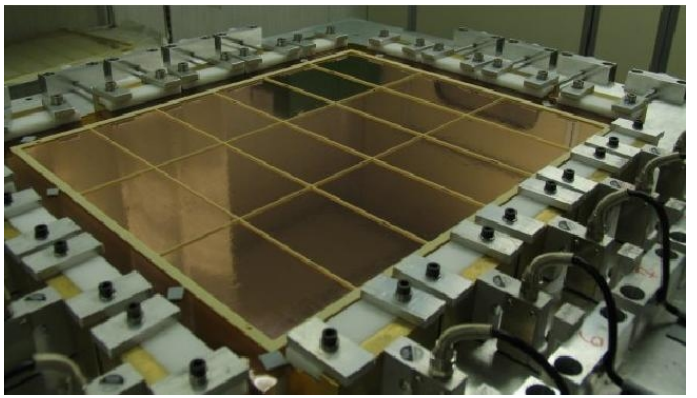
JLab Test 11/2011 (g2p-Gep run)

- UVa 5-layer 10x10 cm^2 prototype
- AVP25 readout
- Compare with Geant-4 simulations background rates....

1st full scale GEM prototype at beam test
from E. Cisbani, INFN Rome



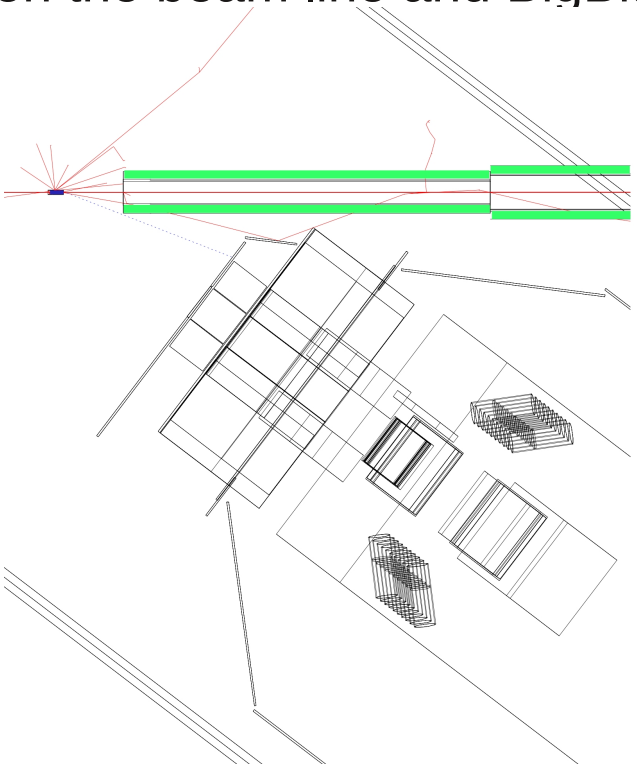
Stretching GEM foil on frame
Reduced spacer material



Gas Cherenkov

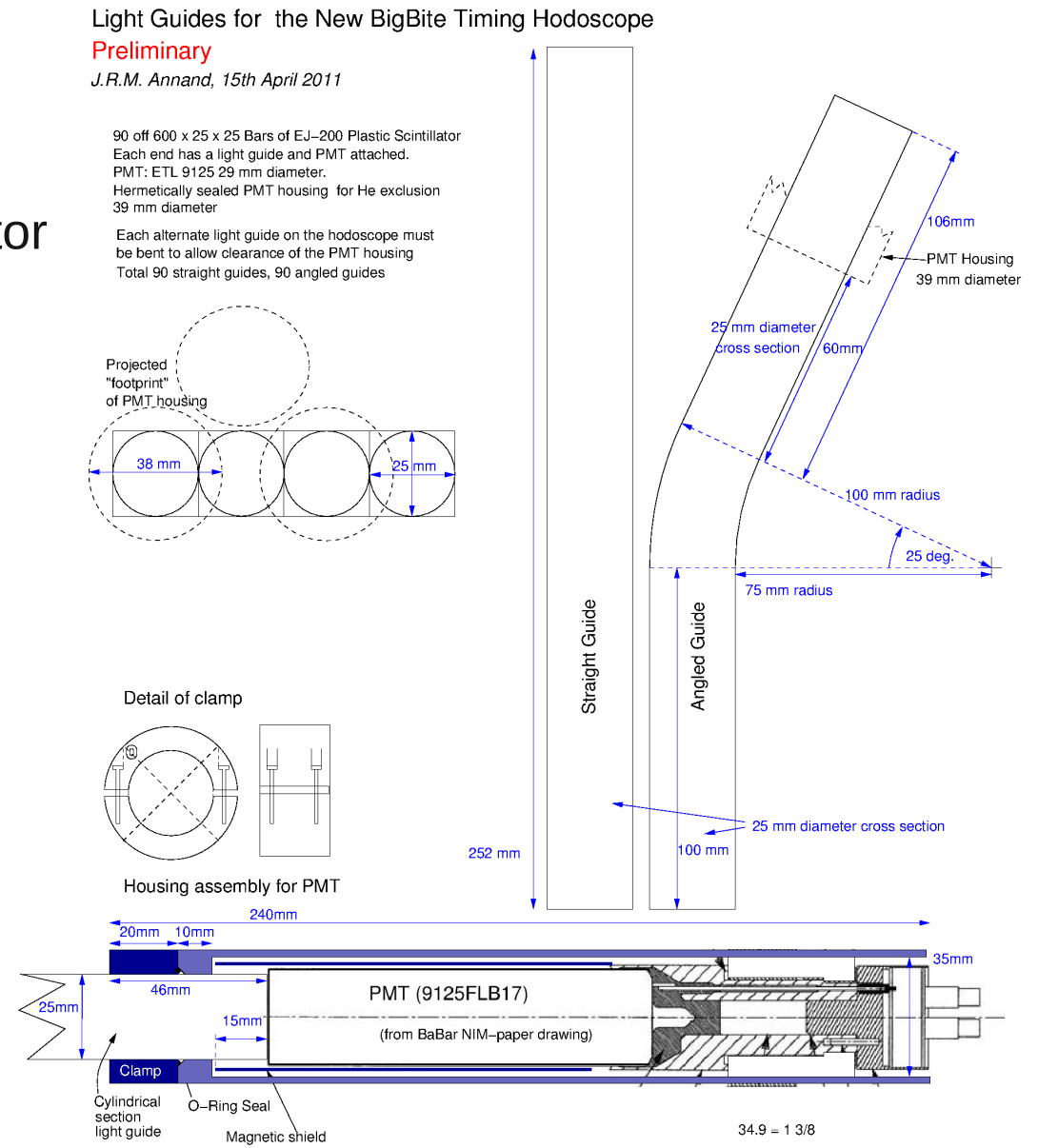
See Todd Averett's Talk from this morning

- The original design had 5” PMTs to record the Cherenkov Light
- High rates observed,
  especially on the side close to the exit beam line
- Soft background was produced in the the beam line
  and secondaries from shielding placed between the beam line and BigBite
- Interacts with the glass window of the PMT
- Switch to smaller PMTs....
  much less glass in front of photocathode
- Originally planned to use 19mm PMT
  from Hermes RICH (SBS)
- Now plan to use PMTs extracted from BaBar
  500 28mm EMI 9125



Timing Hodoscope

- 90 25x25x600 mm plastic scintillator purchased, in JLab
- 90 straight, 90 bent light guides ordered
- 28 mm PMT in JLab
- Hermetic PMT enclosure under design
- Cabling .....under consideration



PMT from BaBar

EMI 9125 28 mm PMT

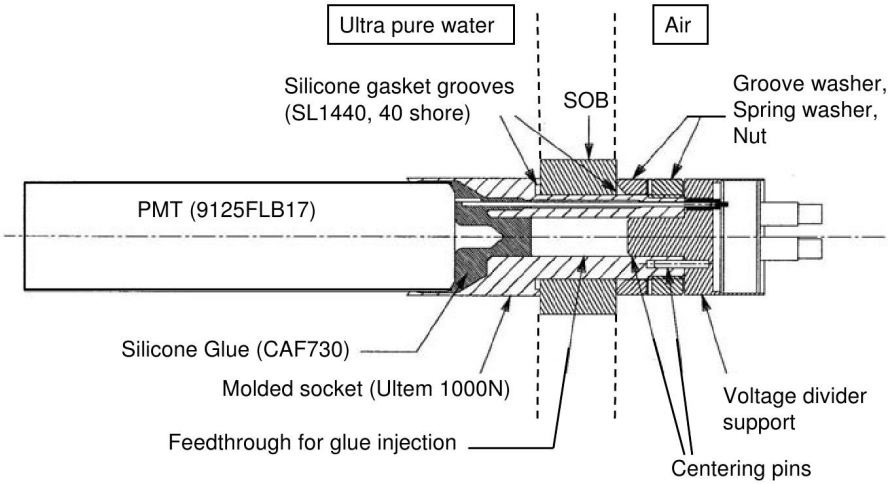
3000 stripped from BaBar DIRC system
and now in JLab

Uses:

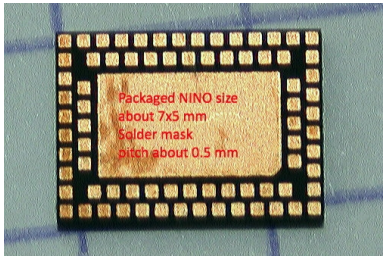
- BigBite Gas Cherenkov (~500)
- BigBite Timing Hodoscope (180)
- Neutron Polarimeter: Analyzer Array (~1000)

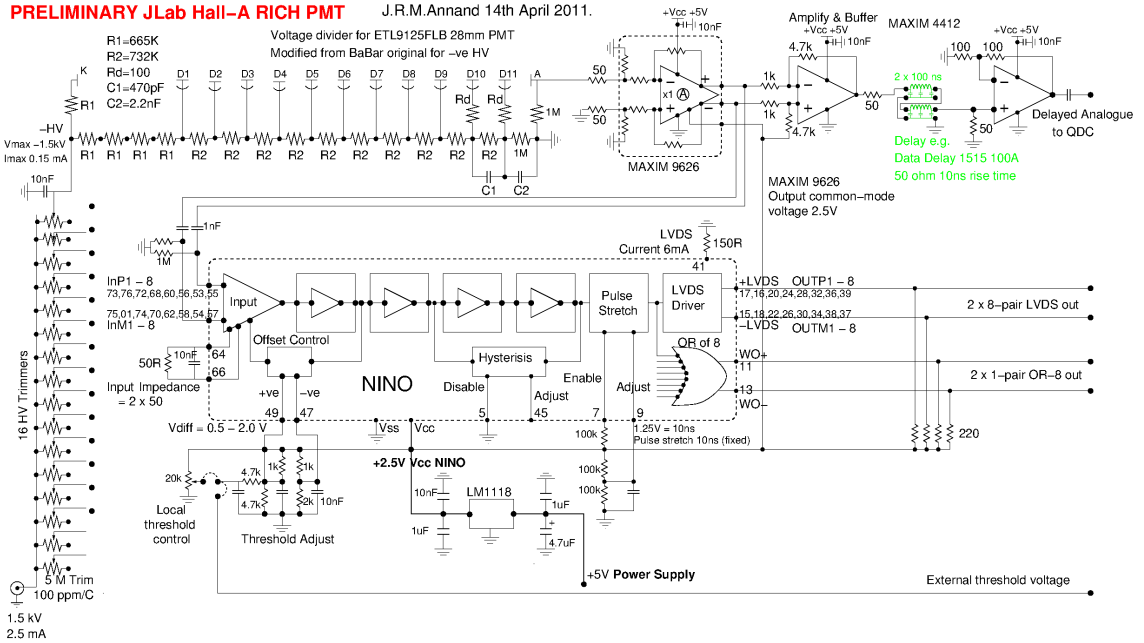
Issues:

- Sensitive to He ingress. PMTs must be isolated from Hall-A atmosphere.
- PMT base configured for +ve HV.
  BaBar PMT operated in H_2O "bath"
- Hall-A HV systems -ve.
  Resolder connections on PCB.
- HV base is low current...fine for Cherenkov.
- Fast-counting scintillator hodoscope may need new design.
- Glass windows "corroded"...
  glue glass disc to face



NINO... for front-end PMT electronics





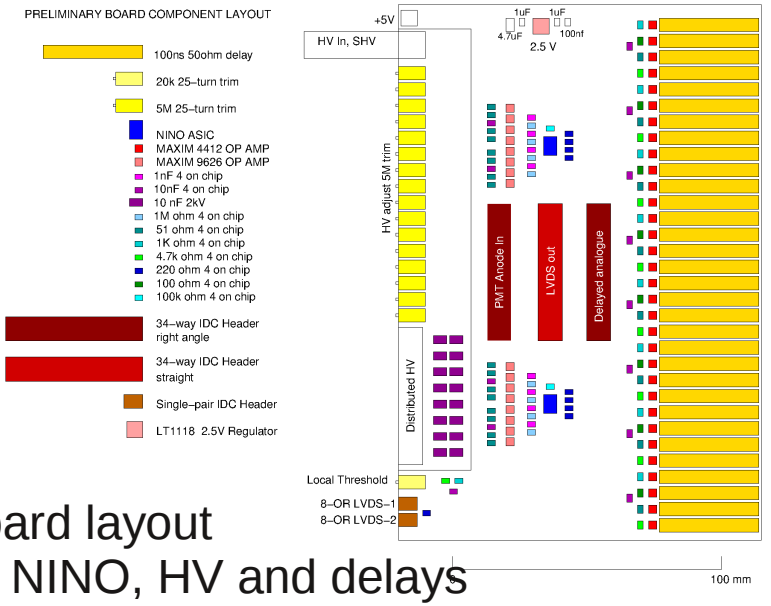
CERN design
ALICE RPC TOF systems

- Excellent timing performance
- 8 amplifier-discriminator channels
- Low power consumption
- Mount close to PMTs
- Differential input...need buffer stage
- Total cost for 1200 chips $18k.

9600 channels.
Uses in Hall A

- G_{En} polarimeter ~ 1000
- SBS RICH ~ 2000
- SBS HCal ~ 250
- **BB Cherenkov ~500**
- **BB hodoscope ~200**
- HRS ~ 2 x 64

Total ~ 4500.



1st try board layout
Will split NINO, HV and delays to separate boards

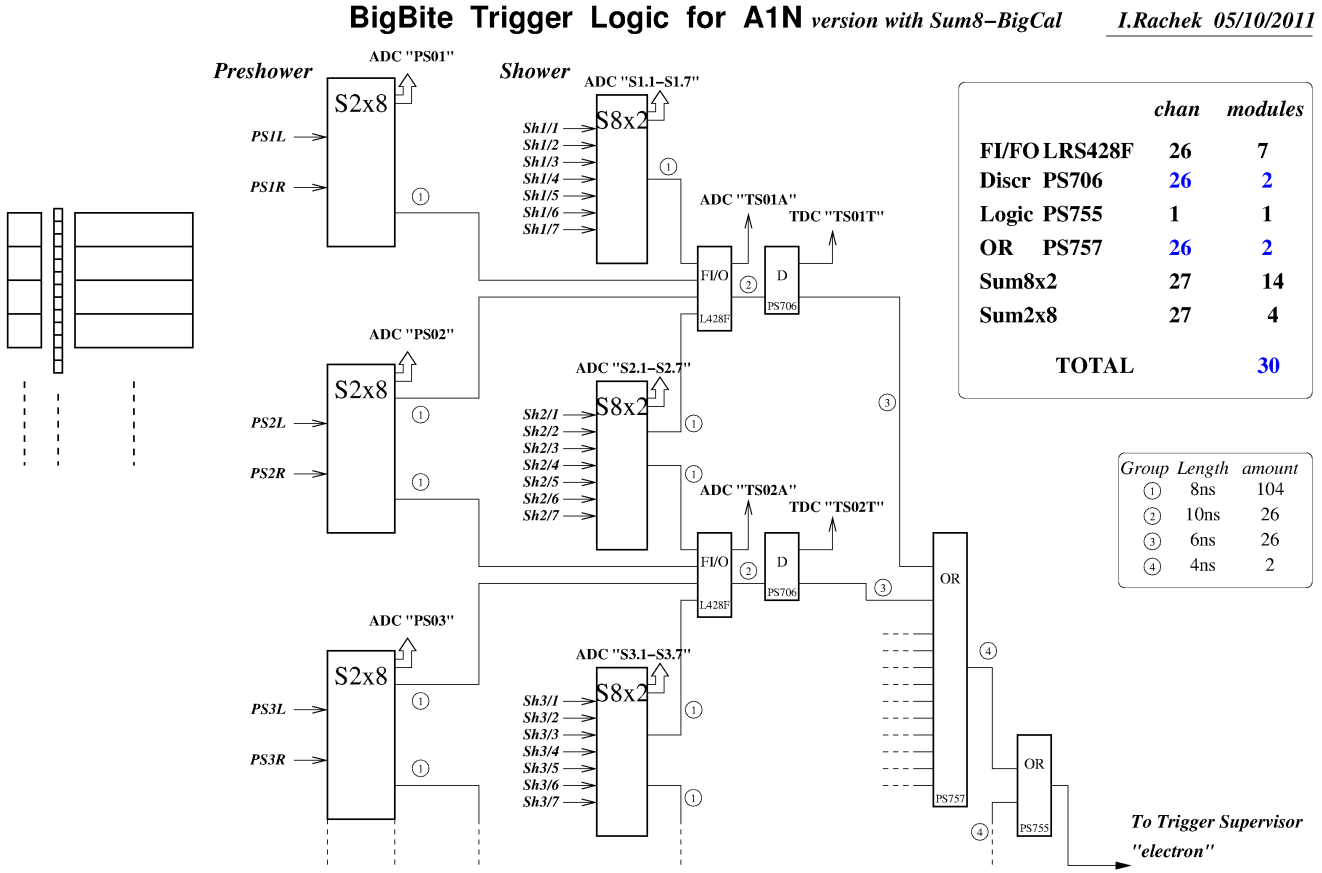
Trigger

Scheme provided by *Igor Rachek*

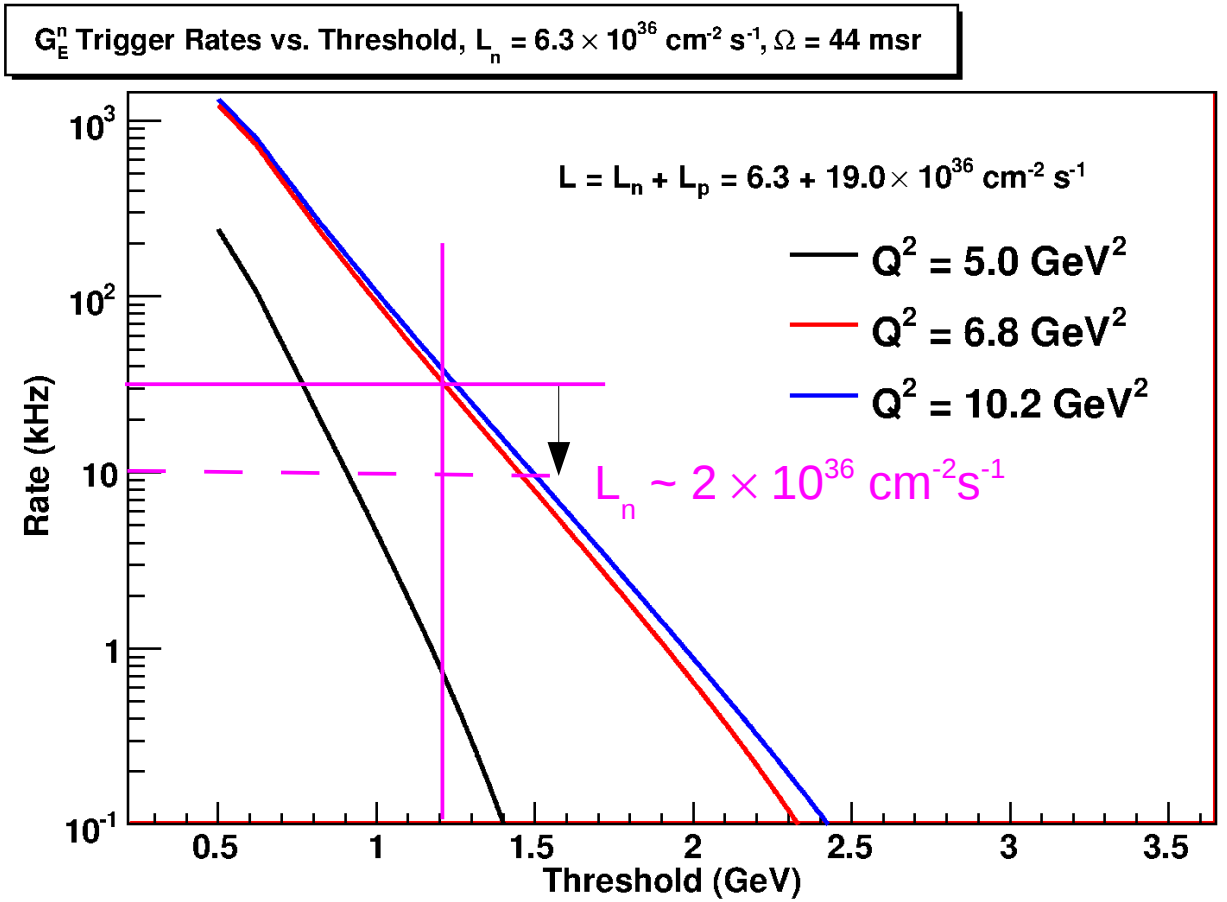
Simple “no-frills” trigger based on the Pb-Glass Shower Counters

If DAQ rate limits the luminosity might consider more sophisticated scheme

e.g pre-shower/shower π^- rejection



BigBite Shower Counting Rate



- Extrapolate from G_{En} calculation
- Shower trigger threshold
  $E_{e'} \sim 1.2$ GeV
- For A_1^n $L_n \sim 2 \times 10^{36}$ cm^{-2}s^{-1}
- Shower rate ~ 10 kHz
- DAQ OK?

DAQ Systems

Goal 10 kHz, 90% Live time

3 Front GEM Chambers ~20k readout strips 0.4mm pitch

- AVP25 "3-sample" → VME64x MPD (16 AVP25) *128 x 3 samples @ 40 MHz takes 10 μs*
- MPD: 200 MHz flash ADC, Ped-subtraction, zero suppression FPGA firmware
- Firmware processing < 10 μs (not yet demonstrated)

Other Components: FASTBUS electronics from Cornell and KEK

- FASTBUS 1877S Multi-hit TDCs, 500ps resolution (20k channels)
  program short gate for common-stop mode
- FASTBUS 1881 QDCs, 9 μs conversion
- KEK amplitude-to-time convertors (possible use with 1877s)

F1 TDC (100ps resolution) probably not necessary for single-arm experiment

Breakdown FASTBUS Readout (from Igor Rachek)

Subsystem	#Chan	Readout	Rate/Chan	Rate/Total	T_{gate} (ns)	Hits/event
Gas Cher	500	TDC + QDC	1 MHz		50	25+25
Pb Glass	243	QDC			100	39
Pb Glass Σ	26	TDC + QDC		10 kHz	100	2+2
Hodoscope	180	TDC + QDC	500 kHz		50	5+5
MWDC	1200	TDC		120 MHz	250	30
Total						**133**

10 kHz DAQ rate → 5.3 Mb/s

Projected Effort

Detector and Tasks	Start	End	Duration (Days)	% Complete	Working Days	Days Complete	Person Days
1. Gas Cherenkov Detector	1-Mar-11	5-Mar-13	735	0%	526	0	**351**
1.0 Conceptual design	1-Mar-11	7-Jun-11	98	0%	71	0	36
1.1 Outer shell contruction	7-Jun-11	22-Nov-11	168	0%	121	0	91
1.2 Mirror	7-Jun-11	30-Aug-11	84	0%	61	0	31
1.3 Gas Handling	7-Jun-11	30-Aug-11	84	0%	61	0	31
1.4 Prototype and grade PMT	1-Mar-11	24-May-11	84	0%	61	0	46
1.5 Construct sub-frame	22-Nov-11	14-Feb-12	84	0%	61	0	31
1.6 Assemble Detector	14-Feb-12	8-May-12	84	0%	61	0	61
1.7 Cosmic ray test	19-Jun-12	17-Jul-12	28	0%	21	0	11
1.8 Incorporate in BigBite	12-Feb-13	5-Mar-13	21	0%	16	0	16
2. Gas Cherenkov Readout	1-Mar-11	19-Jun-12	476	2%	341	10	**241**
2.1 Prototype 1 construct & test	1-Mar-11	16-Aug-11	168	10%	121	16	61
2.2 Prototype 2 construct & test	16-Aug-11	8-Nov-11	84	0%	61	0	31
2.3 Production of cards & cables	8-Nov-11	24-Apr-12	168	0%	121	0	61
2.4 Test electronic cards	20-Dec-11	5-Jun-12	168	0%	121	0	30
2.5 ID trigger & readout elect.	16-Aug-11	11-Oct-11	56	0%	41	0	8
2.6 Design and construct mounting	16-Aug-11	8-Nov-11	84	0%	61	0	31
2.7 Mount electronics on Cherenkov	24-Apr-12	19-Jun-12	56	0%	41	0	21
3. Front GEM tracker	1-Mar-11	12-Feb-13	714	3%	511	17	**507**
3.0 GEM system conceptual design	1-Mar-11	24-May-11	84	30%	61	25	31
3.1 GEM module production & test	5-Apr-11	20-Mar-12	350	0%	251	0	126
3.2 Readout elect. Production & test	10-May-11	20-Dec-11	224	0%	161	0	81
3.3 Sub-frame to hold front tracker	6-Sep-11	6-Mar-12	182	0%	131	0	131
3.4 Production of cabling	3-Jan-12	19-Jun-12	168	0%	121	0	30
3.5 Ship GEM modules to Jlab	10-Apr-12	15-May-12	35	0%	26	0	7
3.6 Assemble GEM subsystem	19-Jun-12	11-Sep-12	84	0%	61	0	61
3.7 Source & cosmic ray tests	11-Sep-12	4-Dec-12	84	0%	61	0	15
3.8 Mount on BigBite frame	8-Jan-13	12-Feb-13	35	0%	26	0	26
4. Trigger Timing Hodoscope	1-Mar-11	21-Aug-12	539	12%	386	62	**237**
4.0 Conceptual design	1-Mar-11	26-Apr-11	56	40%	41	22	21
4.1 Prototyping	26-Apr-11	11-Oct-11	168	10%	121	16	30
4.2 Test and grade PMT	26-Apr-11	24-May-11	28	0%	21	0	5
4.3 Manufacture & test scintillators	11-Oct-11	3-Jan-12	84	0%	61	0	61
4.4 Construct sub-frame	11-Oct-11	3-Jan-12	84	0%	61	0	31
4.5 Manufacture cabling	3-Jan-12	27-Mar-12	84	0%	61	0	31
4.6 ID and assemble electronics	3-Jan-12	28-Feb-12	56	0%	41	0	21
4.7 Assemble hodoscope	27-Mar-12	8-May-12	42	0%	31	0	16
4.8 Cosmic ray tests	8-May-12	31-Jul-12	84	0%	61	0	15
4.9 Mount on BigBite frame	31-Jul-12	21-Aug-12	21	0%	16	0	8

Detector and Tasks	Start	End	Duration (Days)	% Complete	Working Days	Days Complete	Person Days
5. Pb-Glass shower counters	1-Jun-12	29-Mar-13	301	0%	216	0	**213**
5.1 Check and treat Pb-Glass	1-Jun-12	16-Nov-12	168	0%	121	0	30
5.2 Test and grade PMTs	1-Jun-12	24-Aug-12	84	0%	61	0	31
5.3 Test & repair cabling	24-Aug-12	16-Nov-12	84	0%	61	0	31
5.4 Check/Modify sub-frame	24-Aug-12	5-Oct-12	42	0%	31	0	31
5.5 Identify trigger & readout elect.	1-Jun-12	13-Jul-12	42	0%	31	0	3
5.6 Reassemble shower detectors	16-Nov-12	8-Feb-13	84	0%	61	0	61
5.7 Cosmic ray tests	8-Feb-13	8-Mar-13	28	0%	21	0	11
5.8 Mount on BigBite frame	8-Mar-13	29-Mar-13	21	0%	16	0	16
6. Rear MWDC tracker	1-Jun-12	17-Sep-13	473	0%	338	0	**151**
6.1 Chamber care and maintenance	1-Jun-12	24-Aug-12	84	0%	61	0	31
6.2 Test/replace front-end electronics	1-Jun-12	24-Aug-12	84	0%	61	0	31
6.3 Test/repair/replace cabling	1-Jun-12	24-Aug-12	84	0%	61	0	31
6.4 Check (and modify) sub-frame	1-Jun-12	27-Jul-12	56	0%	41	0	21
6.5 Reassemble MWDC subsystem	24-Aug-12	19-Oct-12	56	0%	41	0	21
6.6 Source & cosmic ray tests	19-Oct-12	16-Nov-12	28	0%	21	0	11
6.7 Mount on BigBite frame	16-Nov-12	7-Dec-12	21	0%	16	0	8
7. Dipole & Main Support Frame	24-May-11	17-Sep-13	847	0%	606	0	**183**
7.1 Frame conceptual design	24-May-11	16-Aug-11	84	0%	61	0	31
7.2 Frame construction	16-Aug-11	31-Jan-12	168	0%	121	0	61
7.3 Frame assembly	8-Jan-13	25-Jun-13	168	0%	121	0	61
7.4 Dipole care & maintenance	25-Jun-13	23-Jul-13	28	0%	21	0	11
7.5 Spectrometer Movement	23-Jul-13	20-Aug-13	28	0%	21	0	11
7.6 Sieve slit etc.	20-Aug-13	17-Sep-13	28	0%	21	0	11
8. Data Acquisition	24-May-11	26-Mar-13	672	0%	481	0	**206**
8.1 Conceptual design	24-May-11	8-Nov-11	168	0%	121	0	61
8.2 Test old hardware	8-Nov-11	24-Apr-12	168	0%	121	0	36
8.2 New hardware (GEM related)	8-Nov-11	24-Apr-12	168	0%	121	0	36
8.3 Slow control, HV, FPGA etc.	24-Apr-12	9-Oct-12	168	0%	121	0	36
8.4 Online data display	9-Oct-12	26-Mar-13	168	0%	121	0	36

E12-06-122 can be one of the
1st post-upgrade experiment to run in Hall-A
BigBite systems ready and tested by early 2014

Collaboration Effort

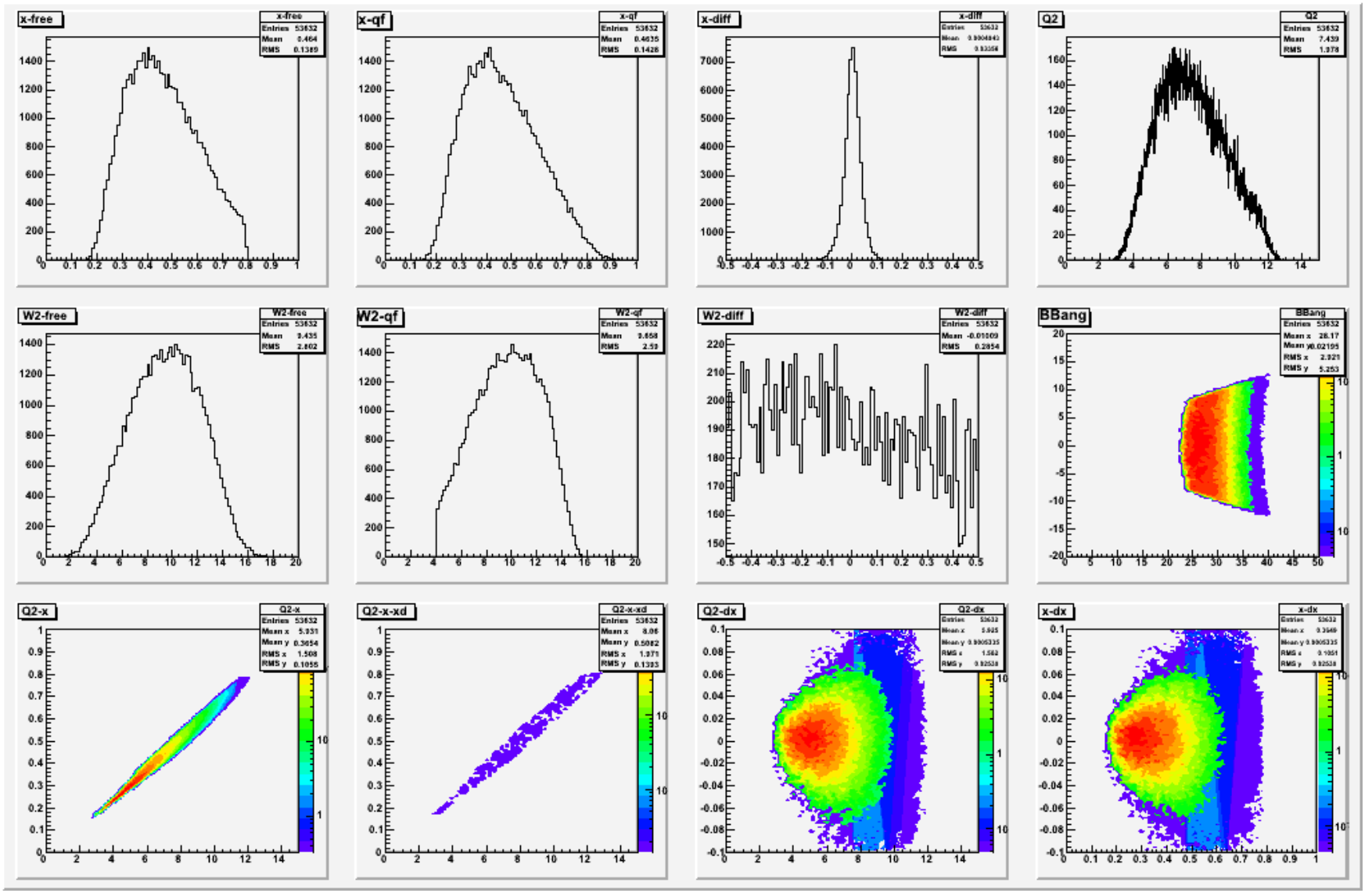
- Cal. State — Mechanical engineering
- Glasgow — Timing hodoscope, front-end electronics development
- INFN Rome — Forward GEM chambers, GEM read electronics
- JLab — MWDC, mechanical engineering, BB dipole, DAQ, Target
- Rutgers — Electronics, mechanical engineering
- UVa — Polarized ^{3}He target, GEM production/development
- W&M — Gas Cherenkov

A_1^n Planning Meeting June 15th, 11.00 - 13.00 EST, Room F224

Interested ?

Contact: bogdanw@jlab.org, john.annand@glasgow.ac.uk

Backup: 11 GeV Kinematics



Backup: Variables

$$A_{\parallel} = \frac{\sigma^{\downarrow\Uparrow} - \sigma^{\uparrow\Uparrow}}{\sigma^{\downarrow\Uparrow} + \sigma^{\uparrow\Uparrow}} \quad A_{\perp} = \frac{\sigma^{\downarrow\Rightarrow} - \sigma^{\uparrow\Rightarrow}}{\sigma^{\downarrow\Rightarrow} + \sigma^{\uparrow\Rightarrow}}$$

$$A_1 = \frac{A_{\parallel}}{D(1+\eta\xi)} - \frac{\eta A_{\perp}}{d(1+\eta\xi)}$$

$$D = \frac{(1-\epsilon E^{'}/E)}{(1+\epsilon R)} \quad d = D\sqrt{\frac{2\epsilon}{(1+\epsilon)}} \quad \eta = \frac{\epsilon\sqrt{Q^2}}{(E-E^{'}\epsilon)} \quad \xi = \frac{\eta(1+\epsilon)}{2\epsilon}$$

$$\epsilon = \left[1 + 2(1+1/\gamma^2)\tan^2(\theta/2)\right]^{-1} \quad R = \frac{\sigma_L}{\sigma_T}$$

$$\frac{g_1}{F_1} = \frac{A_{\parallel} + A_{\perp}\tan(\theta/2)}{D^{'}} \quad D^{'} = \frac{(1-\epsilon)(2-y)}{y(1+\epsilon R)} \quad y = \frac{\nu}{E}$$