Setup, beam line and beam properties

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JLAB

HPS review, July 11 (2013)

Outline

- Required beam parameters
- Beam line configuration and detector layout
- HPS in Hall-B
- Expected beam properties
- Beam – detector alignment
- Resources and schedule
- Summary

Beamline design considerations

- HPS – High luminosity (few x10^{34} s^{-1} cm^{-2}/N) electron scattering experiment using a high Z target (W) and multiple beam energies from 1.1 GeV to 6.6 GeV, capable of detecting and identifying leptons (e, μ) at very forward angles, ≥ 15 mrad (the edge of SVT Layer-I is at 500 μm from the beam plane)

Requirements to the beamline:

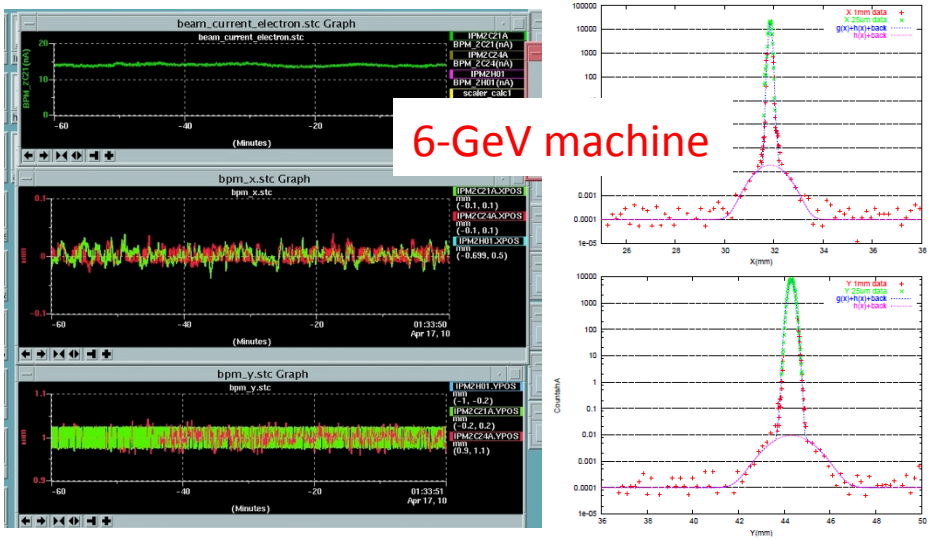
- An asymmetric beam to (a) improve track momentum resolution with small beam size in the non-bent plane (σ_Y < 50 μm), and (b) to avoid overheating the target foil by keeping larger beam size in band-plane (σ_X ~ 250 μm)
- Active (beam halo counters wired into machine fast shutdown system, FSD) and passive (tungsten collimator) protections for SVT to avoid direct exposure to electron beam
- Beam orbit locks with fast feedback to keep beam position stable at the level of ~30 μm
- Vacuum on the way of primary and scattered electron beams throughout the system to keep detector occupancies and trigger rates under the control
- Stable running at low currents (< 10 nA) for detector commissioning and alignment

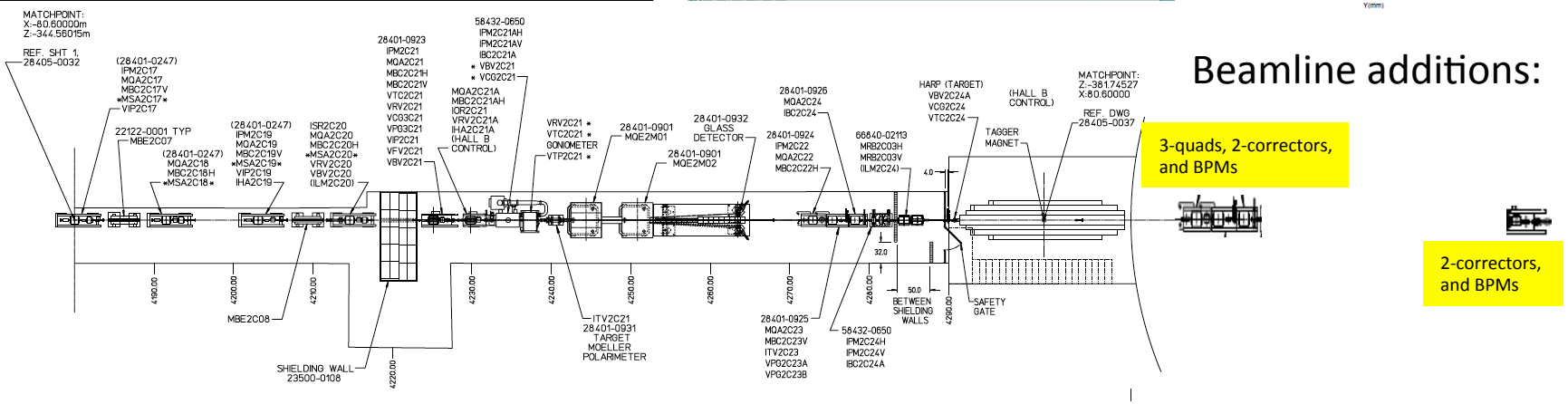
Beam parameters and beam line configuration

Hall-B beam line, with minor modifications will fulfill HPS requirements

Parameter	Requirement			Unit
E	1100	2200	6600	MeV
δE/E		$< 10^{-4}$		
Current	<200	<400	<500	nA
Current Instability		< 5		%
σ_X		< 300		μm
σ_Y		< 50		μm
Position Stability		< 30		μm
Divergence		< 100		μrad
Beam Halo (> 5σ)		$< 10^{-5}$		

Beam current and position position stability, and the beam profile





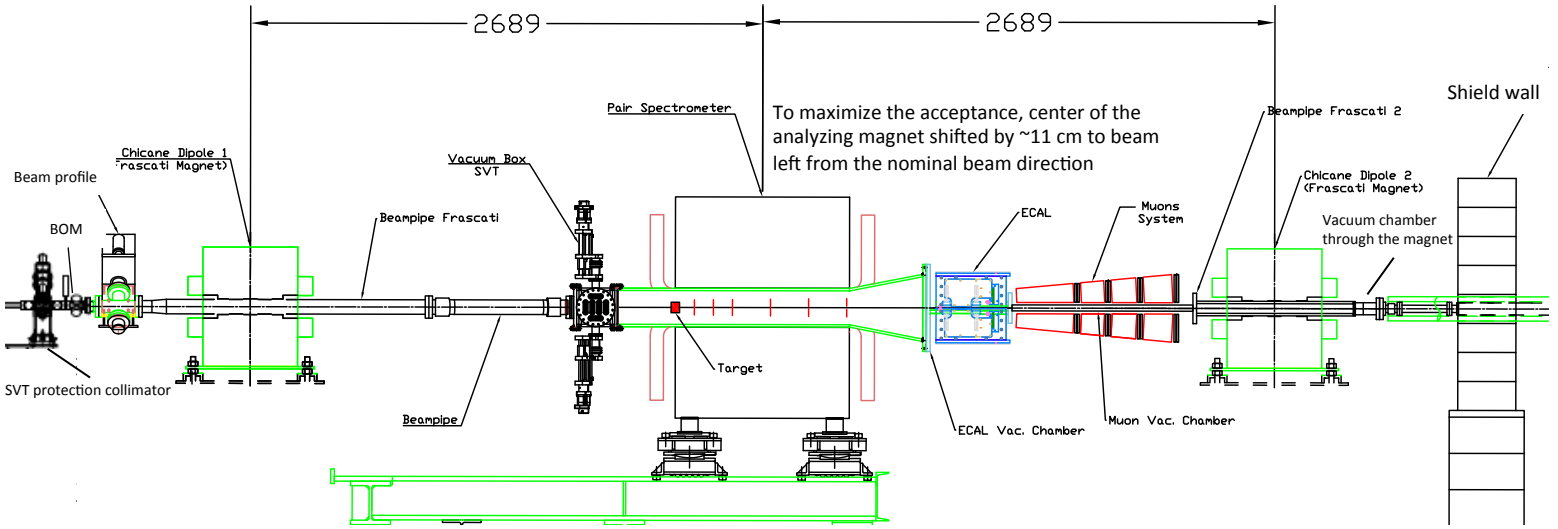
Beamline additions:

3-quads, 2-correctors, and BPMs

2-correctors, and BPMs

Layout of the HPS setup

- HPS will use the three magnet chicane that has been used in Hall-B experiments before
- The Hall B pair spectrometer magnet, an 18D36, will serve as the analyzing magnet. The Hall B "Frascati" H-magnets will be used as the first and the last dipoles of the chicane
- The total length of the system is ~740 cm (without muon system it will be < 650cm)
- The analyzing magnet will be operated at 0.25 T-m/0.5 T-m/1.5 T-m fields for 1.1 GeV/2.2 GeV/6.6 GeV running, respectively

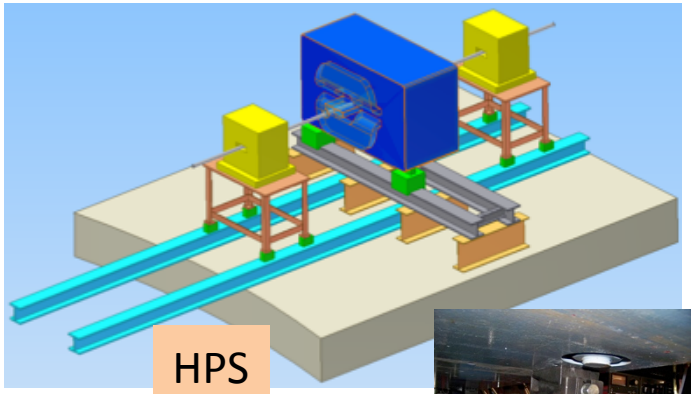


Magnets, magnet power supplies, beam profile scatters, beam halo counters, vacuum chambers, most of beam pipes, and parts of magnet stands do exist

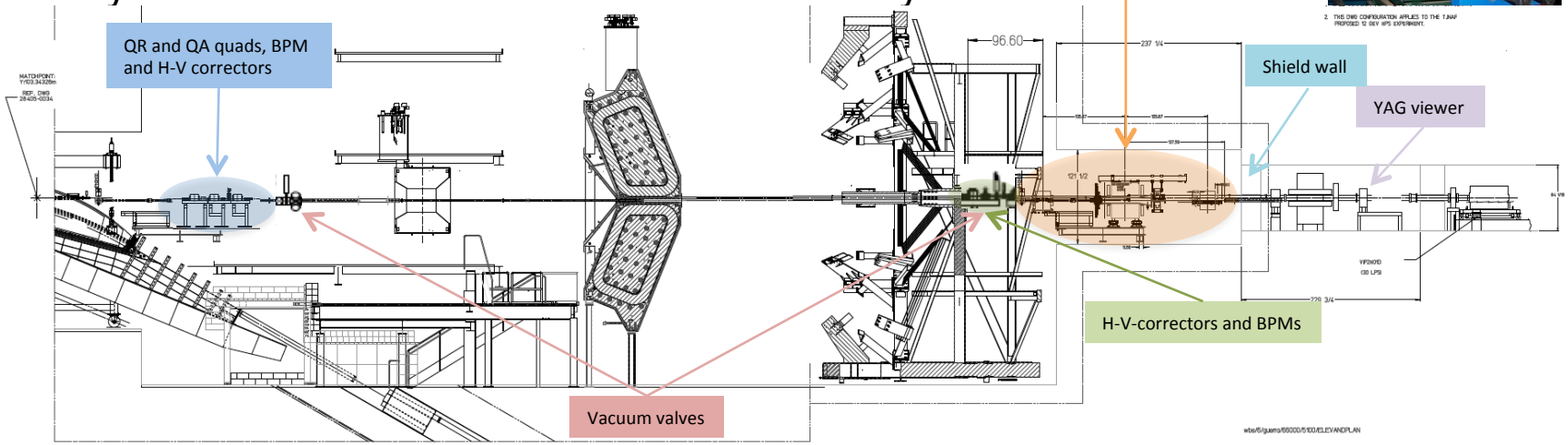
HPS in Hall-B downstream alcove

- Hall-B downstream alcove is 600cm deep, 490 cm wide, enough to house HPS detector system
- Space between upstream end of the HPS setup and the Hall-B forward carriage is ~200 cm and will allow installation of H-V corrector magnets and a BPM
- There will be a 3'' vacuum beam pipe from the Hall-B space frame to the HPS chicane through the CLAS12 systems (torus, solenoid, and the forward carriage)
- No need for additional shielding, additional beam line, and a special photon beam dump after HPS

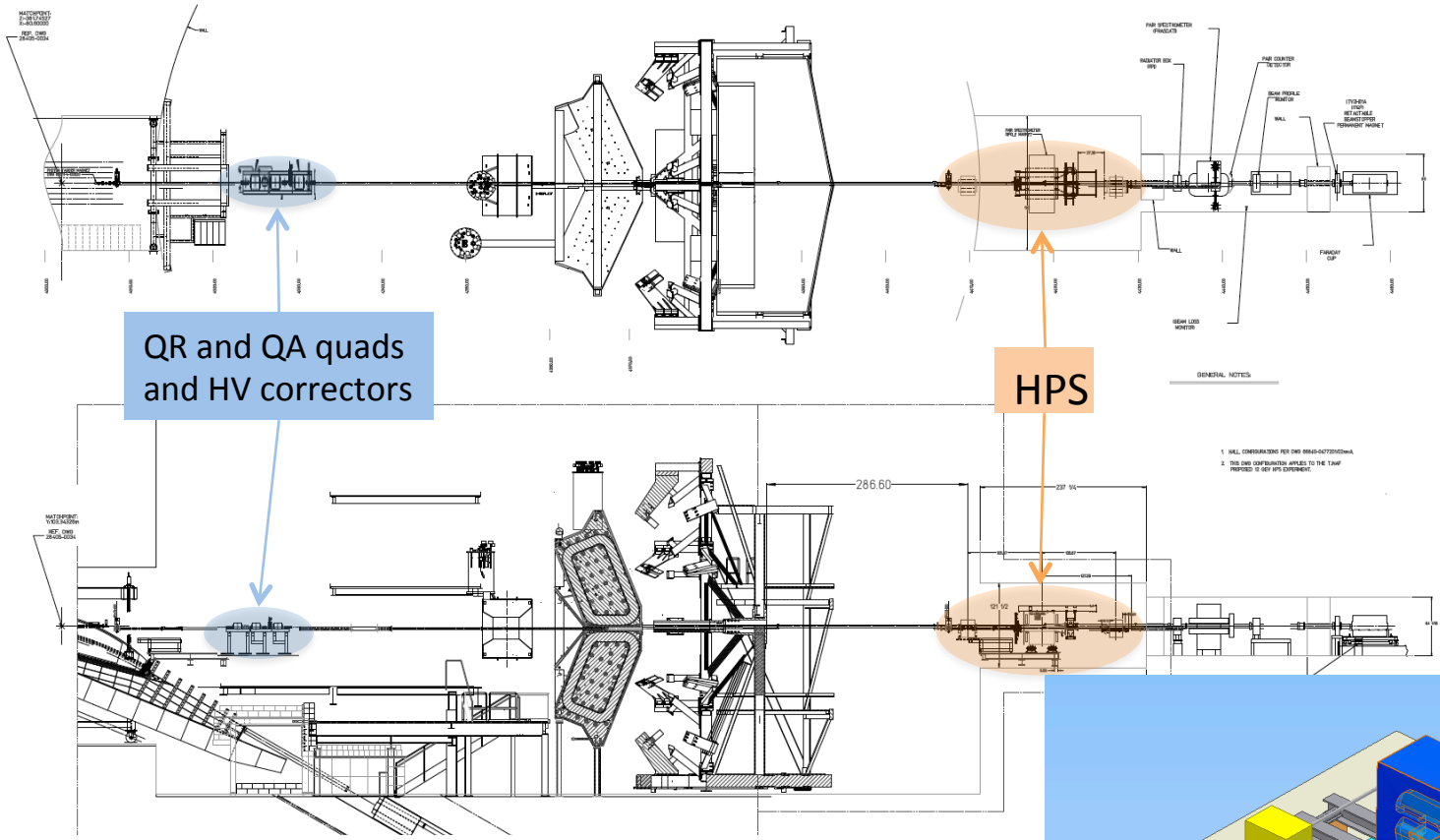
Conceptual design of the HPS magnet supports in alcove. Hilman rollers will allow easy positioning and alignment

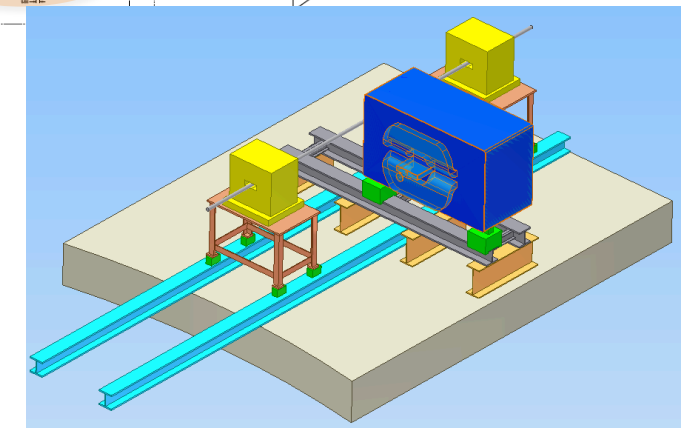


Layout of Hall-B for CLAS12 Torus assembly



HPS with CLAS12 running





- New girder on space frame will stay and will be used for CLAS12 experiments
- Analyzing magnet with SVT and ECal will be rolled away (to beam right) to allow vacuum beam line to FC

Additional girders

What	MyName	Distance to first HPS dipole (m)	Distance to Tagger harp (m)
nA Beam Position Monitor	IPM2H01	27.505	12.914
Beam Position Monitor?	IPM2H02	27.255	13.164
Quadrupole	MQA2H02	26.905	13.514
Quadrupole	MQR2H03	26.305	14.114
Quadrupole	MQA2H04	25.705	14.714
Vertical Corrector	MBC2H04V	25.180	15.239
Horizontal Corrector	MBC2H04H	24.98	15.439
Beam Position Monitor	IPM2H04	24.905	15.514
CLAS Target	ETACLAS	15.415	25.004
Center of HPS 1^{st} Dipole	MBX2H90	0	40.419

Girder-I:

- total length ~2.5 m, will be installed on the platform where Hall-B pair spectrometer magnet is currently located
- will be useful for any Hall-B experiment

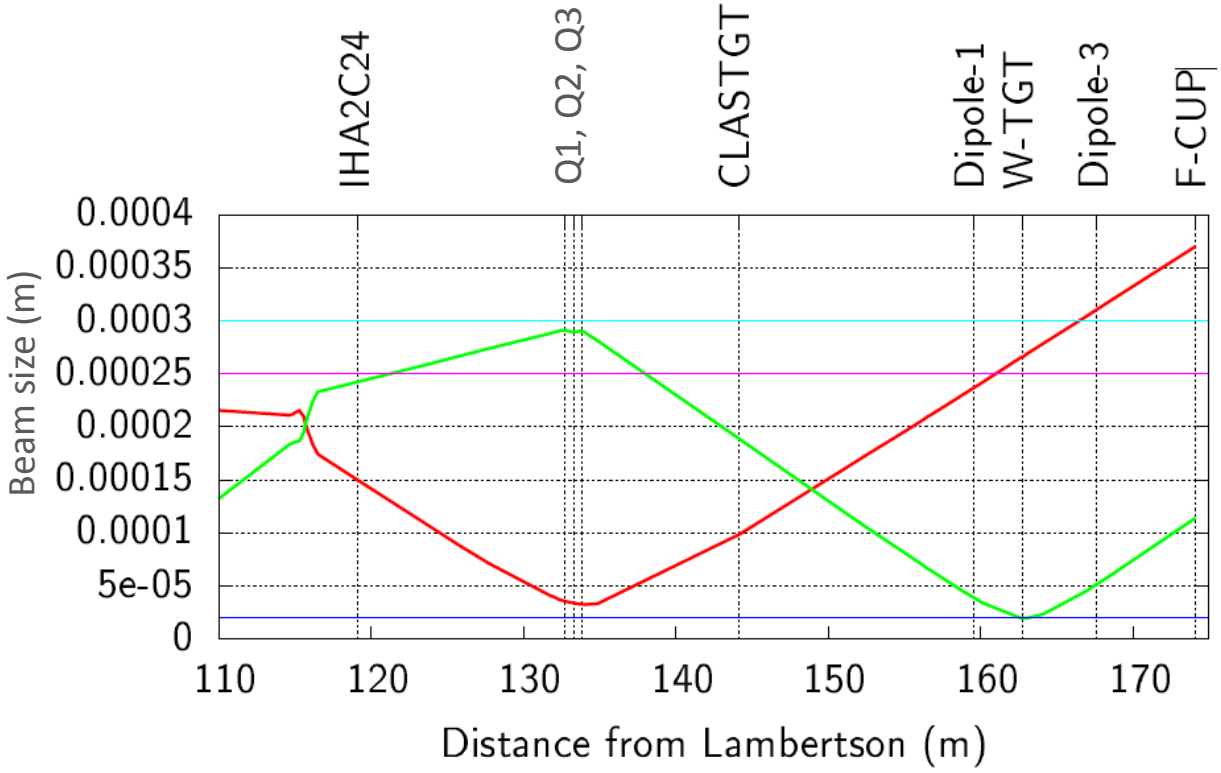
What	MyName	Distance to first HPS dipole (m)	Provenance
Vertical Corrector	MBC2H08V	2.5	New
Horizontal Corrector	MBC2H08H	2.35	New
Beam Position Monitor	IPM2H08	2.075	New
Drift			
Beam Viewer	ITV2H09	0.89	ITV2H01?
Wire Scanner	IHA2H09	0.69	IHA2H00
Beam Position Monitor	IPM2H09	0.5	New
Center of HPS 1^{st} Dipole	MBX2H90	0	Frascati

Girder-II:

- total length <2 m, will be installed on the forward carriage
- correctors can be used by CLAS12 experiments to correct beam trajectory after the central solenoid or target fields

Beam profile

Optimization of the Hall-B beamline with expected changes for 12-GeV operations, with 12-GeV machine design parameters, and with proposed additional two girders has been done using optics algorithm "*elegant*" (ELEctron Generation ANd Tracking)



HPS Requirements:

- horizontal ribbon beam
- 250μm < σ_X < 300μm
- σ_Y < 40μm

Fit Convergence Criteria:

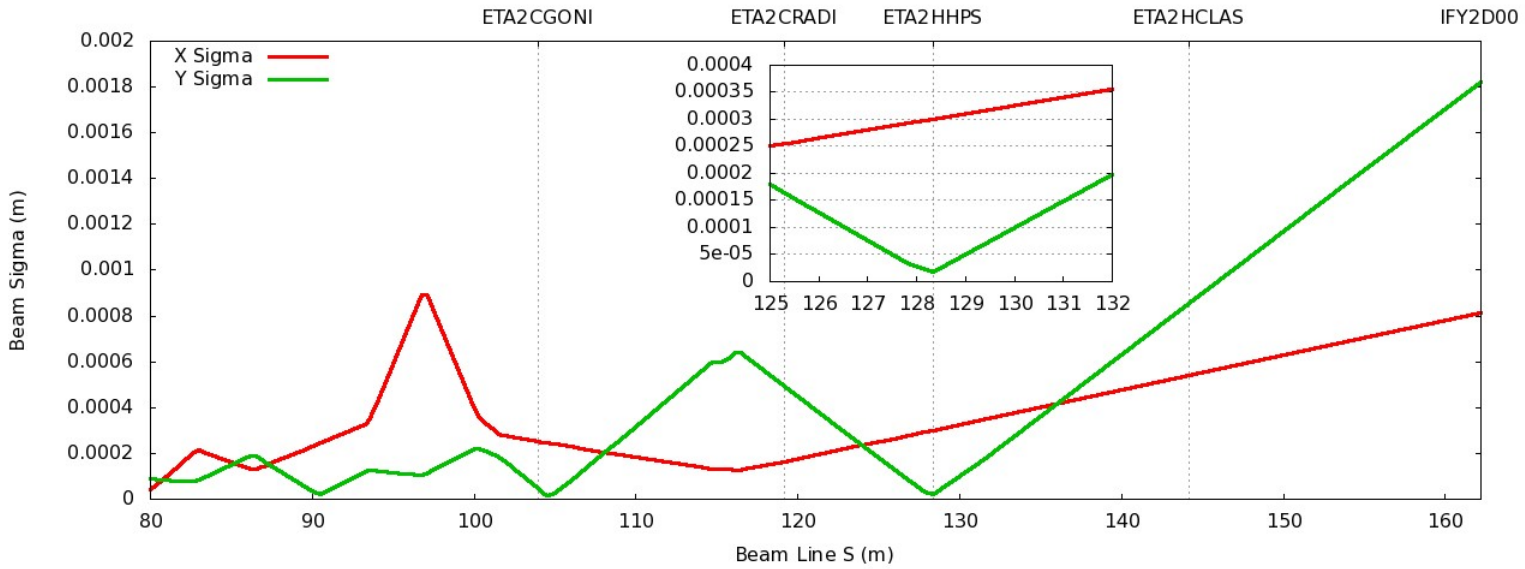
- 250μm < σ_X < 300μm
- σ_Y < 20μm

The factor of two on σ_Y is a safety factor

Test of the optimization of beam optics

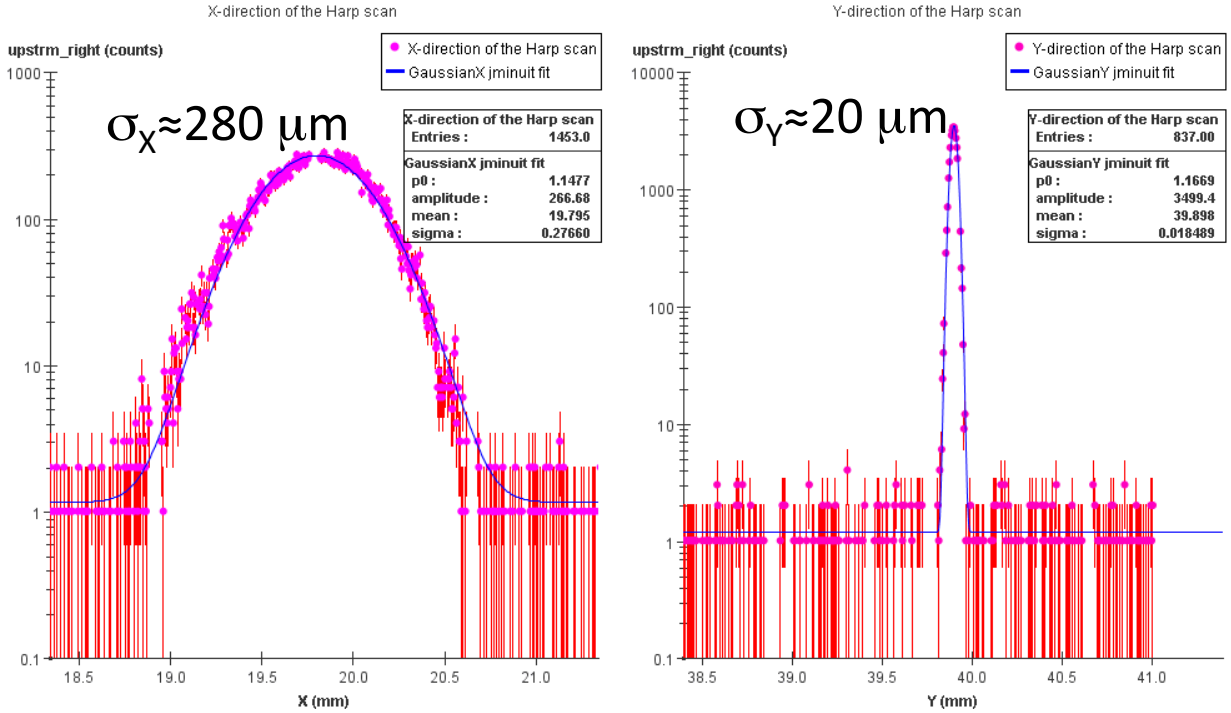
- Optics optimization with “elegant” was tested during the Hall-B TPE experiment using the 2.2 GeV (2 pass) electron beam
- Parameters were set for a beam profile of $\sigma_X \approx 300$ μm and $\sigma_Y \approx 10$ μm at the Hall B ”tagger” beam profiler (~1 meters downstream of the Hall-B tagger dipole)

Arne Freyberger

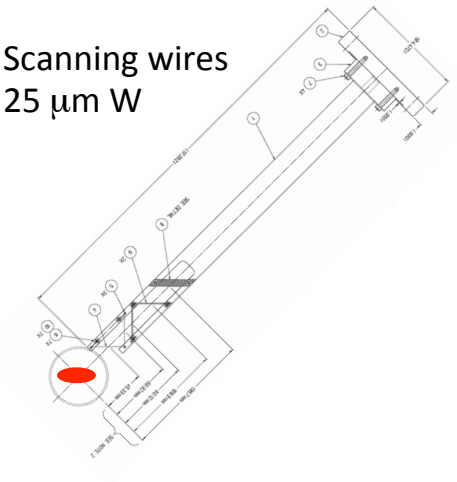


Optics optimization tests (February 2011)

- Several beam profile scans with different speed of the wire scanner (0.1 mm/s to 0.5 mm/s) and data readout (0.014s to 0.7s) have been performed during 1 hour of tests
- Measured position and widths of X and Y projections suggests:
  - no beam motion faster than 1 Hz
  - beam position stability is better than 20 μm



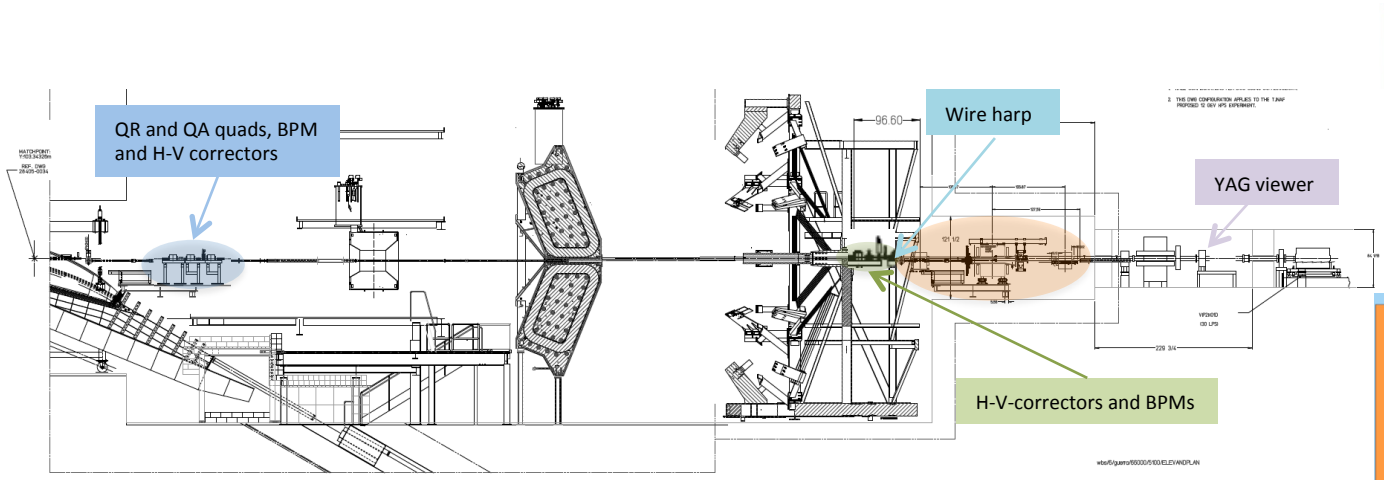
Scanning wires
25 μm W

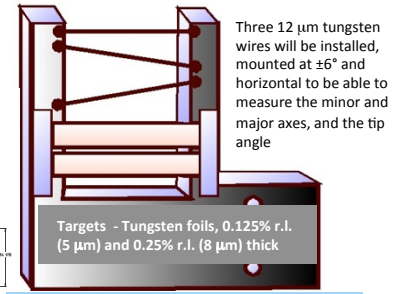


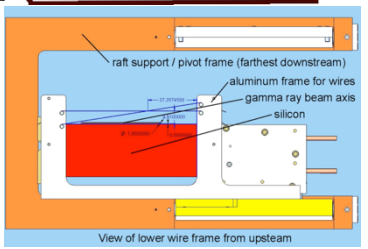
Current version of the wire harp has a third wire, strung perpendicular to the fork, to allow measurement of beam tilt

Beam tune and beam-detector alignment

- Initial beam tune will be performed according to standard procedures for Hall-B using low current beams (< 10 nA) directed to the Hall-B tagger dump, and two wire harps located in the upstream tunnel
- Without energizing the HPS chicane, tuned, low current (< 10 nA) beam will be directed to the Hall-B downstream electron beam dump. More tuning will be done with new sets of quads and correctors using wire harp located just upstream of the first chicane dipole
- After desired beam profile is achieved, chicane magnets will be energized. Analyzing magnet will be set to its nominal value for a given beam energy, while currents on "Frascati" H-dipoles will be varied to optimize counts on downstream halo counters and to have the same beam position on the YAG viewer
- Final adjustments of the beam profile and position will be done using wires mounted on the HPS target
- SVT protection collimator will be positioned on the beam before aligning the first three layers of SVT on the beam using beam-fiducial wires mounted immediately in front of SVT planes







Resources

- Engineering and design will be done at JLAB, SLAC, and ORSAY
- Hall B engineering group will be involved in coordinating of the design and engineering efforts from contributing institutions, and in integrating of various new elements into the beam line
- Installation and the commissioning of the new girders will be done by accelerator engineering group
- Key personal for beam line design, installation, and operations are:
  - A. Freyberger (5%), F-X Girod (50%), and S. Stepanyan (50%) at JLAB, K. Moffeit (20%), T. Maruyama (20%) and C. Field (20%) at SLAC, P. Rosier (10%) and E. Rindel (10%) at Orsay
  - beam diagnostics and slow controls - N. Gevorgyan (25%) (YrPhI) and H. Egiyan (20%) (JLAB)

Beamline Downstream - ALCOVE	Labor	M&S	Total
Refurbishing of the Alcove	$202	$118	$320
Platform in the Alcove	$57	$53	$110
Magnet Power	$9	$26	$35
Beamline controls	$136	$39	$175
Beamline Upstream (Proposal)	**Labor**	**M&S**	**Total**
Items not required in the Alcove	$8	$65	$74
Vacuum beam line downstream of chicane	$0	$19	$19
Frascati Vacuum Chamber	$0	$19	$19
Photon Dump & Shielding	$8	$27	$35

Increase $320k -

Saving $74k =

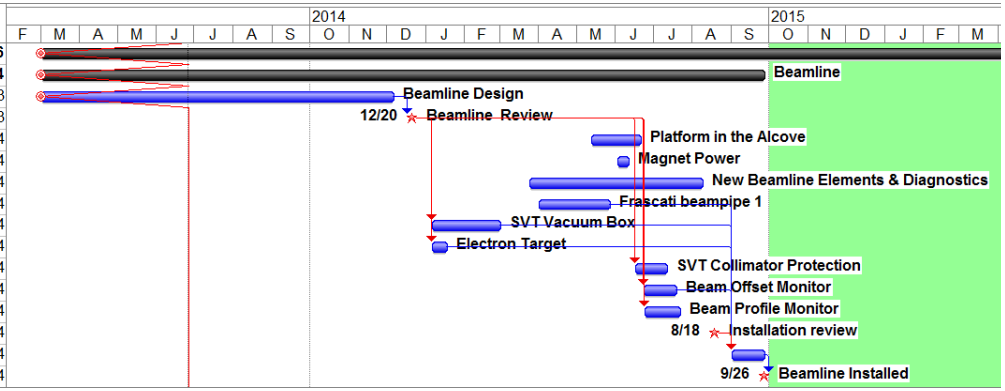
Net Incr. $246k

The additional costs to refurbish the Alcove are considered HPS Infrastructures

Schedule

- HPS beamline installation will be performed in two steps:
  I. installation of the chicane in alcove, 6 weeks during Q2 and Q3 of FY14
  II. installation of the beamline (including vacuum chambers) and beam diagnostic devices, 4 weeks in August – September of 2014
- Installation will require efforts from HPS, Hall B and accelerator engineering groups
- Beamline will be surveyed before detectors are installed. HPS detectors can be installed after magnets and vacuum chambers are surveyed
- Final beam line and detector survey will be done after after everything is installed

WBS	Task Name	Duration	Start	Finish
1	**HPS**	**889.13 days?**	**Fri 3/1/13**	**Thu 8/25/16**
1.1	**Beamline**	**401 days?**	**Fri 3/1/13**	**Fri 9/26/14**
1.1.1	Beamline Design	10 mons	Fri 3/1/13	Thu 12/5/13
1.1.2	Beamline Review	1 day	Fri 12/20/13	Fri 12/20/13
1.1.3	Platform in the Alcove	6 wks	Mon 5/12/14	Fri 6/20/14
1.1.4	Magnet Power	7.5 days?	Mon 6/2/14	Wed 6/11/14
1.1.5	New Beamline Elements & Diagnostics	20 wks	Mon 3/24/14	Fri 8/8/14
1.1.6	Frascati beampipe 1	8 wks	Tue 4/1/14	Mon 5/26/14
1.1.7	SVT Vacuum Box	8 wks	Mon 1/6/14	Fri 2/28/14
1.1.8	Electron Target	10 days	Mon 1/6/14	Fri 1/17/14
1.1.9	SVT Collimator Protection	4 wks	Mon 6/16/14	Fri 7/11/14
1.1.10	Beam Offset Monitor	4 wks	Mon 6/23/14	Fri 7/18/14
1.1.11	Beam Profile Monitor	4 wks	Tue 6/24/14	Mon 7/21/14
1.1.12	Installation review	1 day	Mon 8/18/14	Mon 8/18/14
1.1.13	HPS Beamline Installation	4 wks	Mon 9/1/14	Fri 9/26/14
1.1.14	Beamline Installed	0 days	Fri 9/26/14	Fri 9/26/14



Summary

- HPS experiment will be located in downstream alcove of the experimental Hall B at JLAB, and will utilize standard beamline of Hall-B, with minor additions
- The three-magnet chicane has been used successfully before, magnets and power supplies do exist, and relocation of only one of PS's is needed for HPS in alcove
- Requested beam parameters are comparable to ones routinely delivered to Hall-B in 6-GeV era. It is expected that 12-GeV machine will behave similarly, especially at low energies (below or at 3 pass)
- Critical beam optics parameters have been simulated using design parameters of the 12-GeV machine. Simulation algorithm has been tested with 6-GeV machine
- Installation of the chicane in alcove will be done during Q2-Q3 of FY14
- Beam line commissioning for HPS is planned during Q1 FY15
- Design of new beam line elements started, critical parts have workable solutions
- Existing manpower is adequate for timely completion of the design, fabrication, test and installation of the beamline