Hall-B Beamline and HPS Experimental Setup

Commissioning plans

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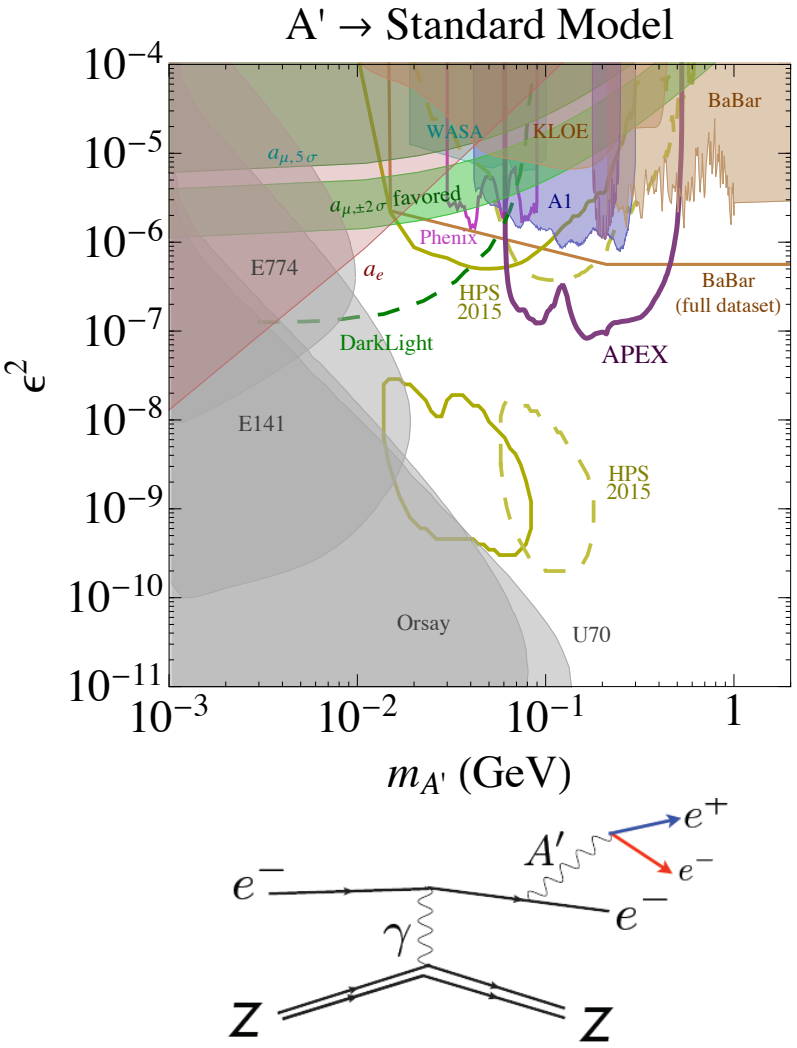
Outline

- HPS experiment
- HPS detector system
- Beam line configuration
  - upstream tunnel
  - in the Hall-B
  - HPS chicane
  - downstream tunnel
- Commissioning plans
- Beamline controls and monitoring
- Summary

Heavy Photon Search Experiment

- **The astrophysical evidence for Dark Matter is compelling,** but so far, there's no proof DM has been produced at colliders, or interacted with sensitive detectors
- **This can make sense if Dark Matter resides in a "hidden sector"** and carries a "hidden sector" charge (analogous to electric charge) which couples to a "heavy photon" (A′)
- **Heavy photons** can couple indirectly to regular electric charge by virtue of their mixing with *the* photon. Accordingly, they can be produced by, and decay into electrons and positrons.
- **The Heavy Photon Search is a search for a massive vector gauge boson** radiated by electron beams, decaying to e^+e^-.

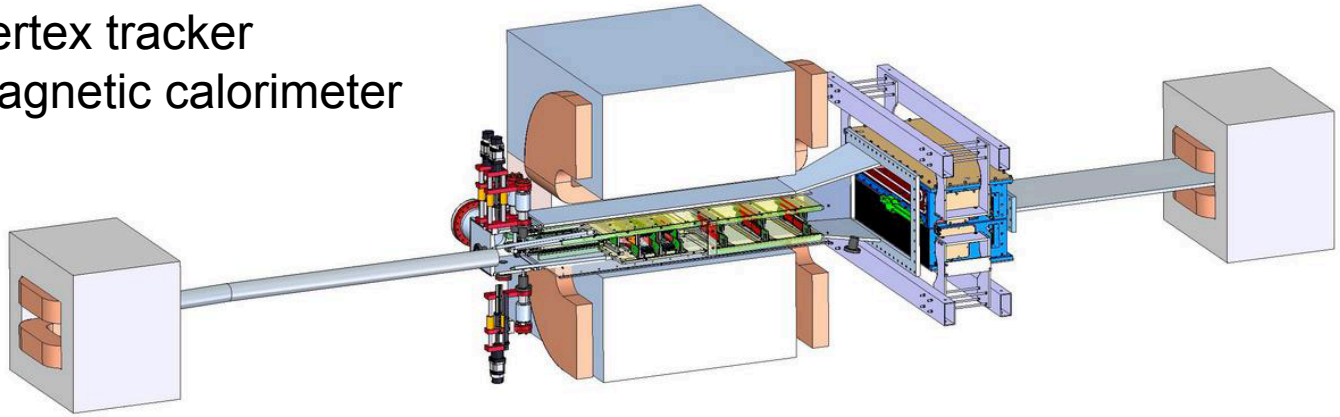


HPS engineering run

- The second stage of an experiment which has already run in Hall B.
- The first stage of HPS, the HPS Test Run, took data in Spring 2012.
- The Test Run experiment incorporated all the critical features needed for HPS, demonstrated its feasibility, and confirmed background estimates.(**arXiv 1406:6115)**

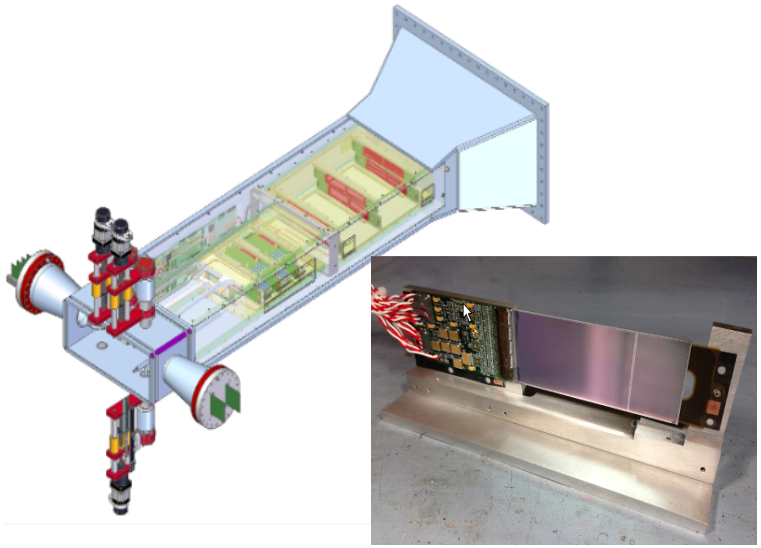
HPS setup for 2014-2015 run will be located in the Hall-B downstream alcove:

- Three-dipole chicane – the same chicane used before in Hall-B experiments, the same power supplies and controls
- Set of vacuum chambers to transport electron beam to beam dump
- Silicon vertex tracker
- Electromagnetic calorimeter



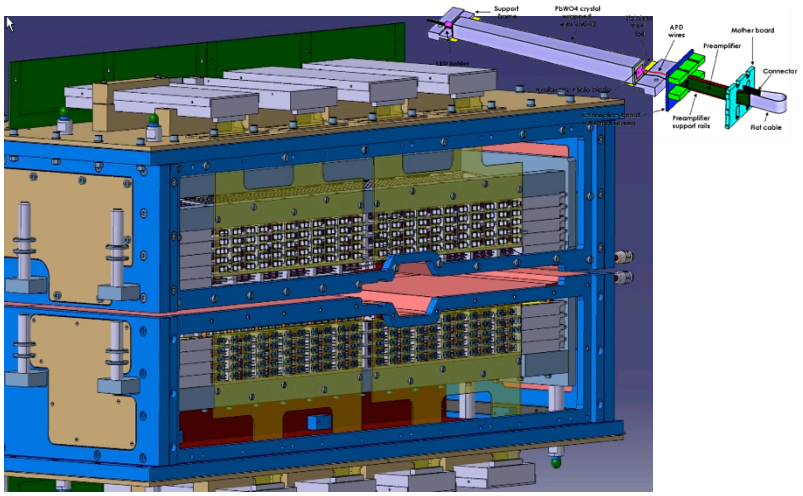
HPS detectors

Silicon Vertex Tracker (SVT)



- **built in two halves, top and bottom**
- **each half with 6 layers, extending from 10 cm to 90 cm downstream of the target**
- **each layer consists of two stereo planes**
- **modules in layers 1-3 have a single sensor, layers 4-6 are double width**
- **high rate DAQ, >50kHz**

Electromagnetic Calorimeter (ECal)

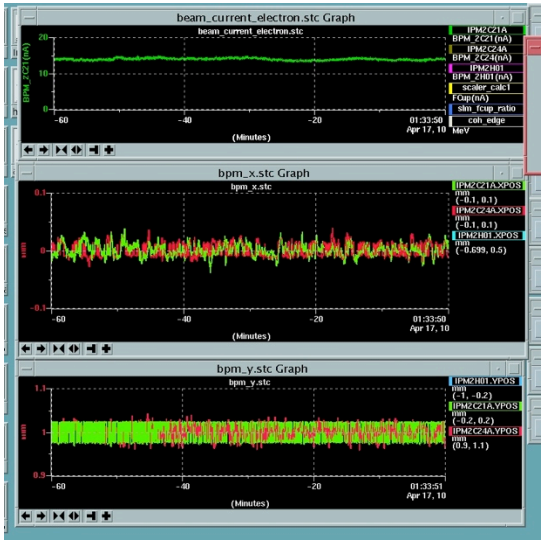


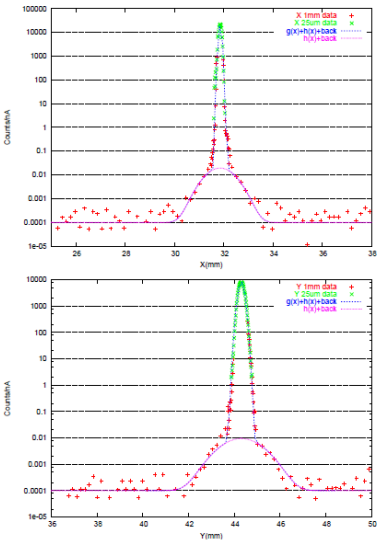
- **built in two halves, top and bottom**
- **each half consists of 221 $PbWO_4$ crystals**
- **readout with large area APDs**
- **modules are assembled inside temperature controlled enclosure**
- **LED based Light Monitoring System**
- **high rate triggering and DAQ, ~50kHz**

Required Beam Parameters

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)		$< 10^{-5}$		

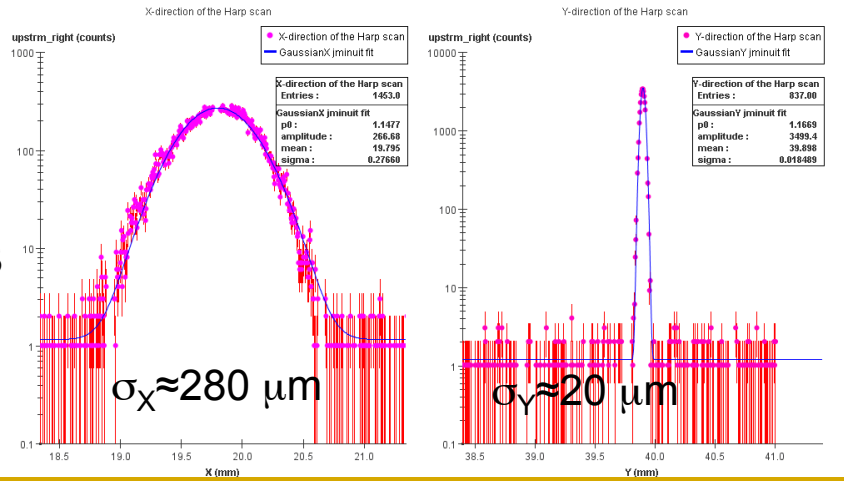
6-GeV machine





- Nothing extraordinary, Hall-B run experiments with close to these requirements
- Optics optimization test showed that stable, "*ribbon*" beams are available for HPS in Hall-B

But, this was in 6 GeV era!



Beamline for the engineering run

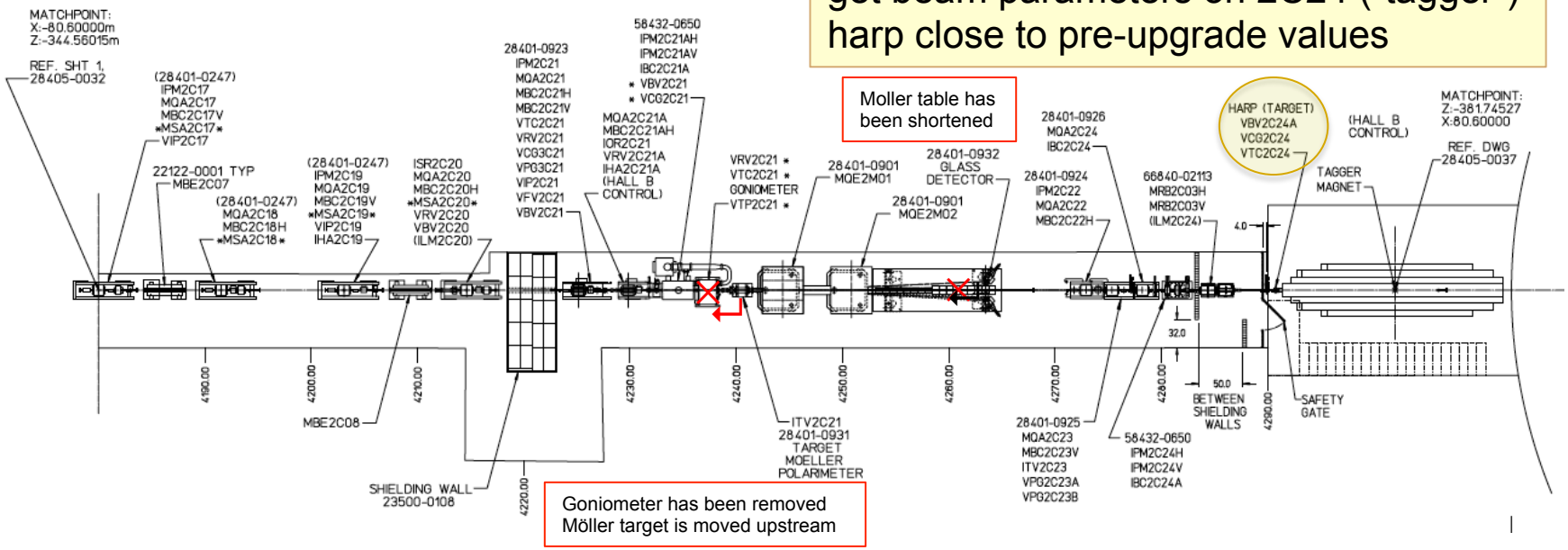
- The required beam parameters are consistent with beams routinely used in Hall-B for 6 GeV experiments:
- For the most part beamline is the same as in 6 GeV era
- The beam line preparations for the run are mostly to restore the 6 GeV beamline, monitoring, and controls
- HPS beamline consists of four major parts:
  - upstream tunnel – unchanged for the purpose of the beam delivery
  - the Hall – two additional girders, removable beam pipes for CLAS12 torus work
  - downstream alcove – HPS setup
  - downstream tunnel – unchanged for the purpose of the beam delivery

Beamline: Upstream tunnel

- None of beam transport elements have been changed
- Beam diagnostics (harps, BPMs, viewers) are the same as in 6 GeV
- Changes have been made to the Möller polarimeter (will *not be used by HPS*)

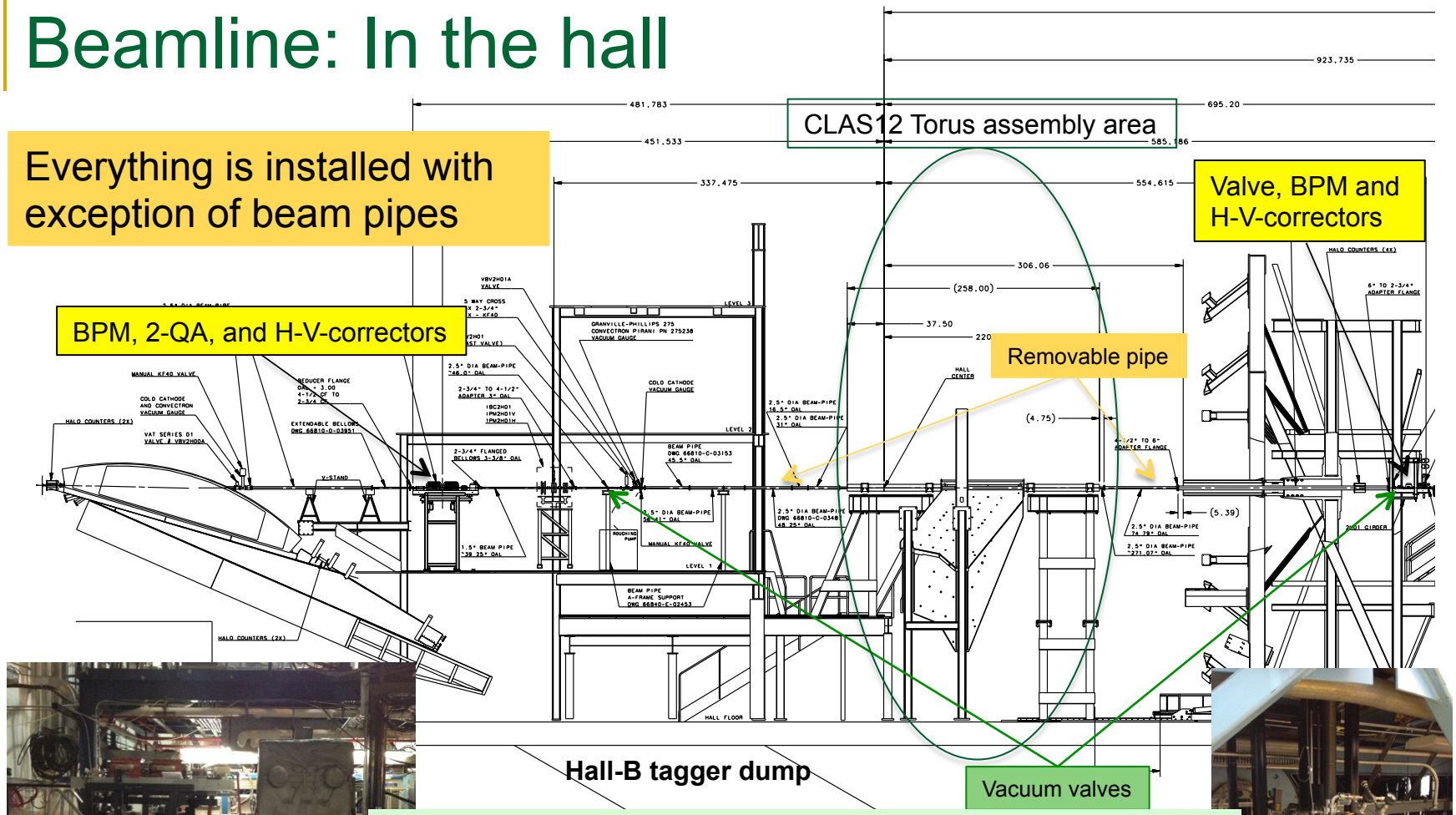
Initial commissioning will be done with the beam to the tagger dump. The same setup as for 6 GeV runs. Beam will not enter into the Hall

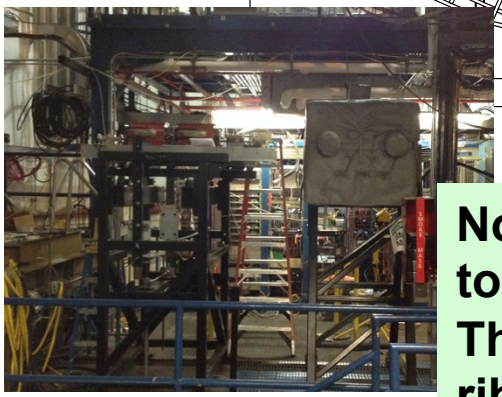
The goal of the initial commissioning is to get beam parameters on 2C24 (“tagger”) harp close to pre-upgrade values

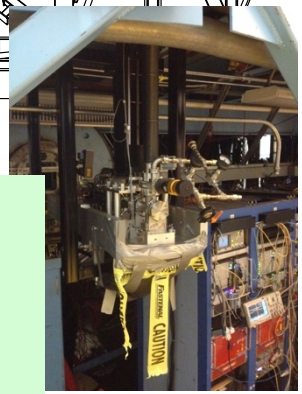


Beamline: In the hall

Everything is installed with exception of beam pipes



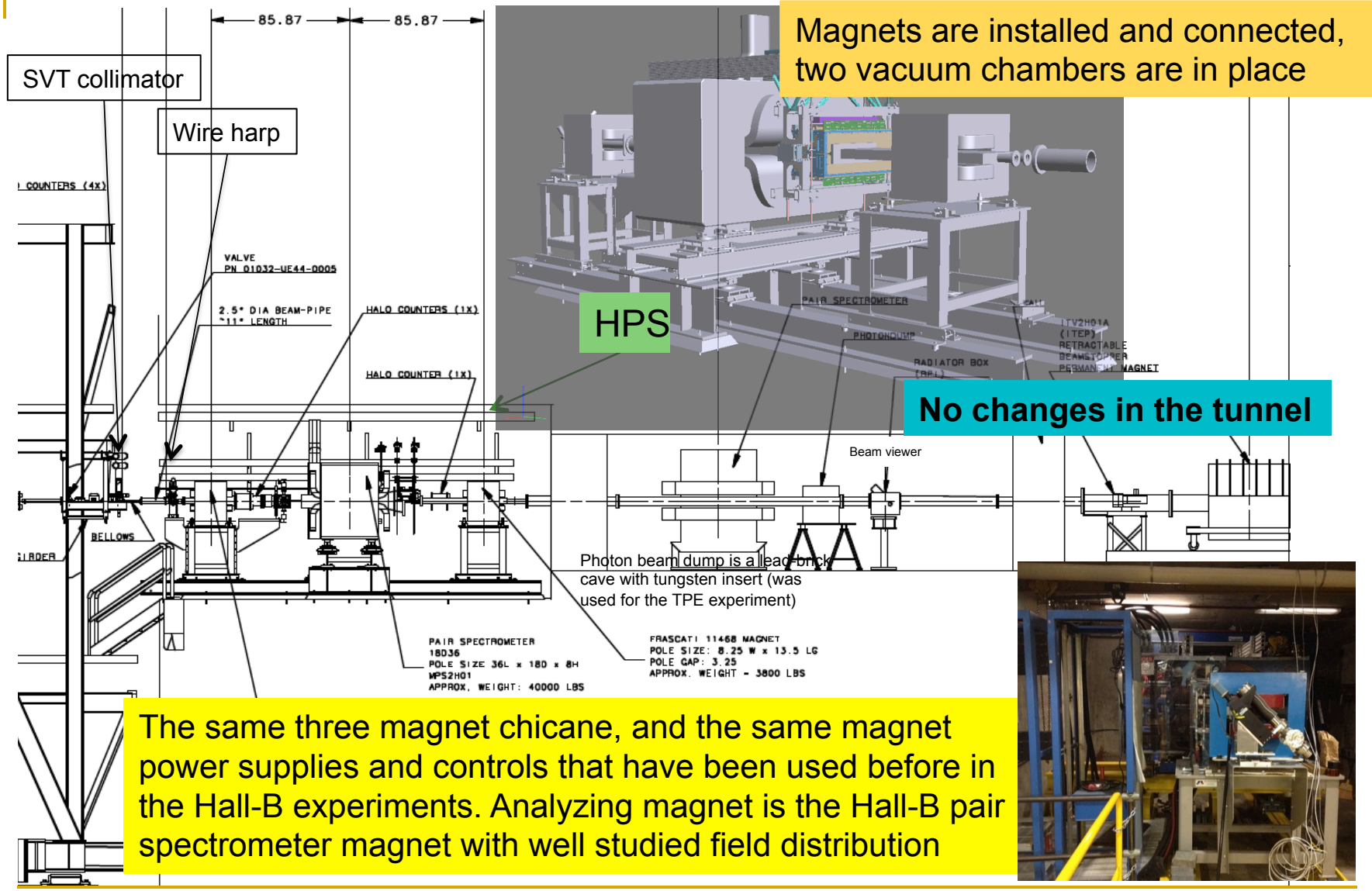




Note: neither of new girders are necessary to run beam safely to the electron dump. They are needed to get a stable, small size ribbon beam on HPS target.

Downstream: HPS and the tunnel

Magnets are installed and connected, two vacuum chambers are in place



The same three magnet chicane, and the same magnet power supplies and controls that have been used before in the Hall-B experiments. Analyzing magnet is the Hall-B pair spectrometer magnet with well studied field distribution

Beamline commissioning

- Procedures to establish physics quality beam to the Hall will be the same as in 6 GeV era – experiment requires low energy beams with beam parameters consistent with what routinely have been used in Hall-B for 6 GeV experiments
- Accelerator OPS is revising beam delivery procedures to Hall-B, with an input from Hall-B/HPS, to better address changes in Hall-B (e.g. no CLAS detector, there are no photon beam devives on the beam line …)
- Detail commissioning plan for HPS has been developed and presented at the Experimental Readiness Review (ERR) on July 10, and is available on the web (on the HPS run page)

https://wiki.jlab.org/hps-run/index.php/Main_Page

- Concerns, raised by ERR committee have been or in the process of being addressed

https://confluence.slac.stanford.edu/display/hpsg/HPS+Readiness+Review+July+10%2C+2014

Beamline commissioning plan

Hall-B/HPS beamline commissioning will have several stages

- Stage-I, establish physics quality beam to the Hall-B tagger dump – executed by Accelerator OPS (MCC)
  - The Hall-B tagger dipole is energized, beam will not enter into Hall-B
  - Perform Hall-B beamline commissioning
  - Tune physics quality beam at 2C24 (tagger) wire harp

Goal: get the beam parameters close to the values obtained with 6 GeV machine

- Stage-II, transport physics quality beam to the Hall-B electron dump – executed by Accelerator OPS (MCC). *HPS chicane is OFF, detectors are retracted*
  - Beam to downstream dump, observe beam on the downstream beam viewer. *This will be possible without using the two new girders*
  - Establish physics quality beam at 2H02 wire harp
  - Perform current calibration of BCMs using the Hall-B Faraday cup

Hall-B/HPS will monitor beam quality by measuring beam profile with wire harps

Beamline commissioning (cont.)

- Stage-III, establish HPS quality beam (ribbon) at the 2H02 harp – executed by Accelerator OPS (MCC)
  - With help of new quads on 2H00 achieve required beam profile at 2H02 harp
  - Center beam on the Ecal vacuum chamber. *Ecal is ON*
- Stage-IV, establish beam through the HPS chicane – executed by Accelerator OPS (MCC) and Hall-B
  - Energize chicane dipoles to the nominal settings for the given beam energy
  - Correct currents if needed using rates on Ecal, downstream halo counters, and the position on the downstream viewer
- Stage-V, establish beam for the HPS detector checkout – executed by Accelerator OPS (MCC) and Hall-B/HPS
  - Center the beam relative to SVT using SVT wires
  - Check the beam stability at the nominal production
  - Setup the trip levels for BLMs and halo counters in FSD

Beam controls

- The beam is controlled by Machine Operations (MCC)
- Hall-B receives information from machine controls (BPMs, trim magnets, vacuum, BCMs …), monitors beam quality (wire harps, halo counters) and communicates issues with the MCC
- The only control Hall has on the beam delivery is through the beam fast shutdown system (FSD) designed to terminate beam delivery if conditions are not right – bad beam that may effect the data quality or may cause damage to the detectors
- From Hall-B/HPS, inputs to FSD are:
  - Chicane magnet power supplies
  - Beam halo counters
  - Beam lost monitors (BLM)
  - SVT motor limit switches
  - Vacuum gauges and valves
  - SVT protection collimator position

Beamline monitoring

The Hall-B beamline monitoring, as well as monitoring and control of other devices used for HPS, will be done using EPICS

No changes in Hall-B beamline monitoring since the 6 GeV:

- three wire harps (two in the upstream tunnel, one in front of the HPS chicane)
- nA BPMs with new lock-in amplifiers (2 in the upstream tunnel, one on the space frame)
- two beam viewers (in the tagger dump and in the downstream tunnel, before the electron dump)
- 11 halo counters spread out along the beamline from the tagger to HPS
- Faraday cup (will be used to calibrate BPMs). During the production running FC will be blocked to prevent overheating (the same setup used for previous high current runs in Hall-B)

All EPICS controls and GUIs for beam line devices, magnet power supplies, voltage controls …, already exist.

Run documentation and organization

- There is Hall-B run page: http://www.jlab.org/Hall-B/run-web/, with links to the current run information:
  - formal documentation
  - information on the collaboration
  - shift schedule (not yet generated)
  - logbook entries
  - experiment run page (https://wiki.jlab.org/hps-run/index.php/Main_Page)
- The required formal documentation, COO, ESAD, RSAD, and ERG, is ready and posted on the web, including checklists and TOSP for the SVT
- Collaboration adopted a shift policy (similar to what Hall-B run for 15 years) – 2 man shifts, expert and worker, 8 hour shifts with staggered start time for overlap
- List of shift and detector subsystem experts is defined
- Detector experts will commission subsystems and will be available on-call during the normal running periods to help
- Training of personnel will start some time in September

Hall B Checklists - Preparing for Beam

System	Contact	Initial
Call list	Hall B PDL	
Beamline and Magnets	S. Stepanyan	
Magnets swept for magnetic material		
All magnets turned on and in remote		
GUIs exercised, IOCs up		
Beam halo PMTs turned on		
FSD system operational		
Radiator, collimator out of beam		
BPMs operational		
Viewer screens on video		
LCW flow rate turned up	D. Tilles	
Valves checked for extraneous lock outs		
Fire Safety Inspection	D. Tilles	
Remove cables above all crates in racks		
Remove all transient trash		
Remove all transient ignition sources		
Test the fire early-warning system		
Final house keeping	D. Tilles	
Grounding straps to fwd carriage and clam shell		
VESDA ok?		
Final walk-through	B. Manzlak	

Summary

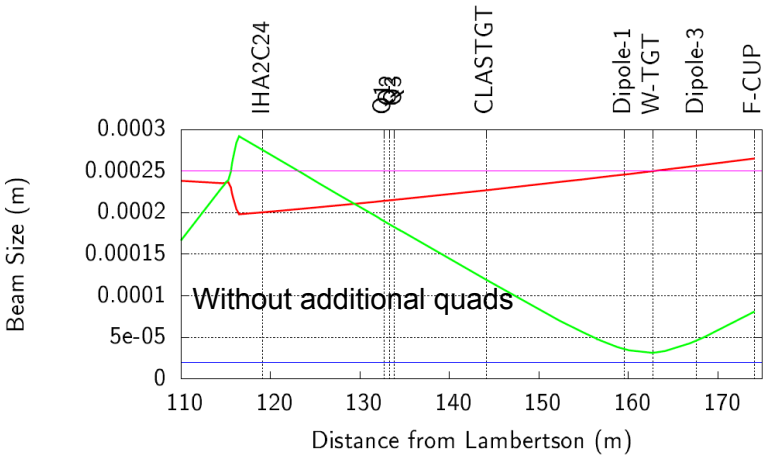
- The Hall-B beamline and the HPS detector configuration for the upcoming engineering run is defined
- The 6 GeV era beamline and controls will be used without major modifications
- Ownership of the beamline elements and detector subsystems are defined
- Detailed beamline commissioning plan has been developed
- All the beamline elements are in place, surveyed, and ready to be connected
- The required documentation (COO, ESAD, RSAD, and ERG) is ready
- Shift takers manuals and procedures are also ready
- Shift policies are set, training of personnel will follow

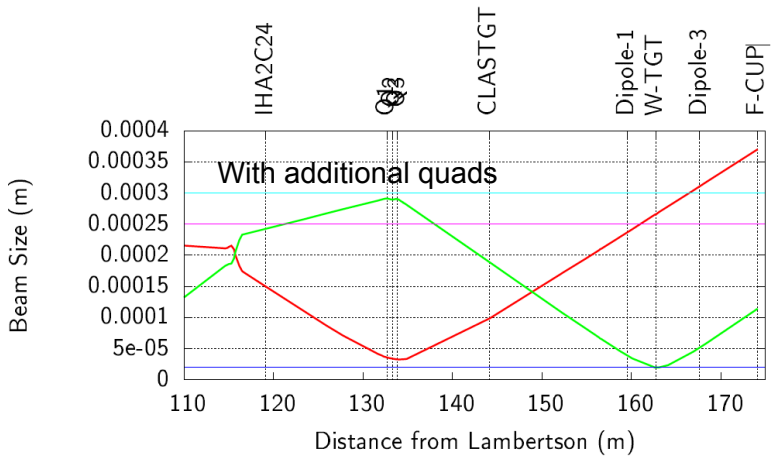
Full installation and hot checkout of the beamline is expected by end of September, HPS will be ready for beam in October

Additional slides

HPS Beamline Simulations

- Optics simulations ("*elegant*") have been performed with 12-GeV machine design parameters, to define required optics changes
- A set of quads has been added on the Hall-B space frame to "beef-up" optics to accommodate somewhat distant target and possible additional focusing needs with the new machine





HPS Requirements:
- horizontal ribbon beam
- 250μm < σ_X < 300μm
- σ_Y < 40μm

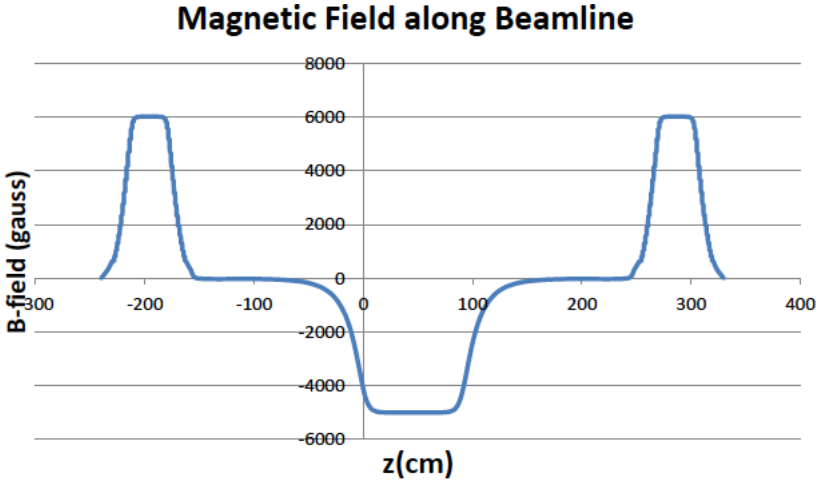
Fit Convergence Criteria:
- 250μm < σ_X < 300μm
- σ_Y < 20μm

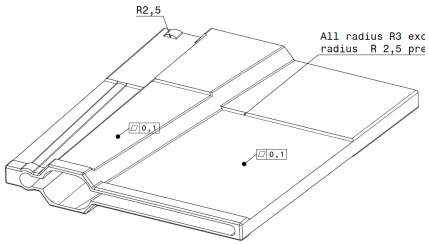
The factor of two better in σ_Y is a safety factor

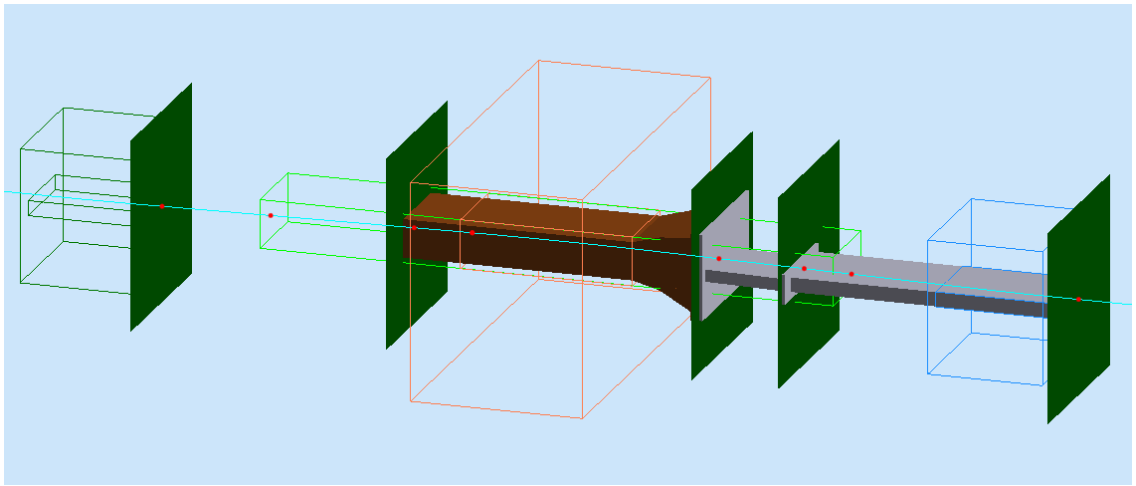
Chicane simulations in GEMC

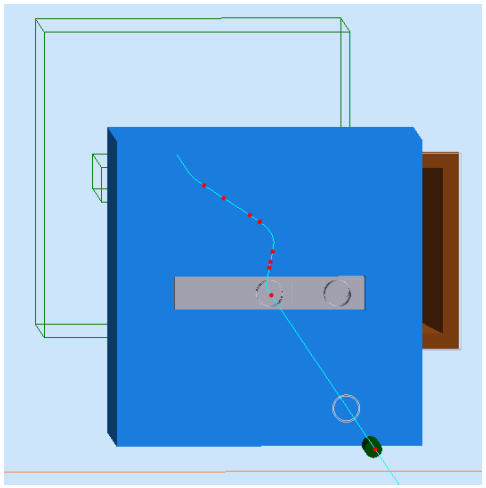
Beam trajectories and the chicane settings have been simulated in GEANT4 using the HPS GEMC setup.

Vacuum chambers have been designed based on background simulations using GEANT4 and EGS5

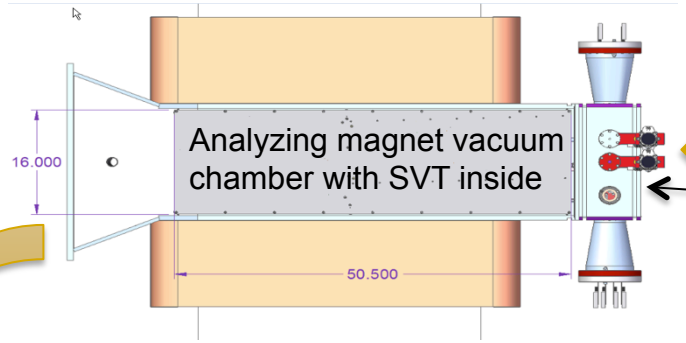




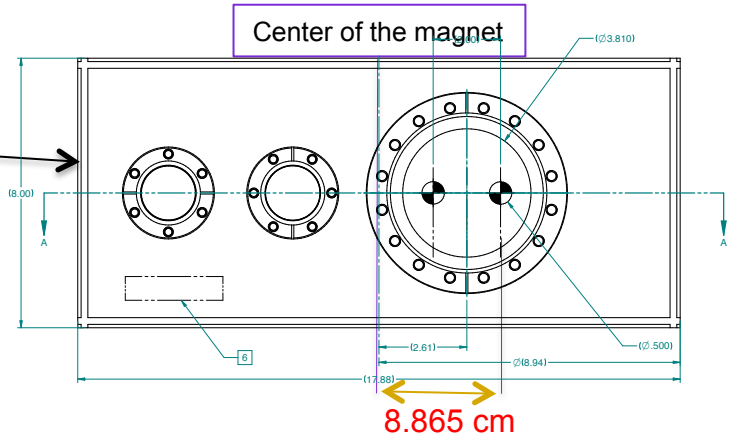


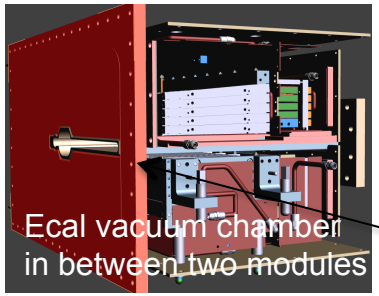


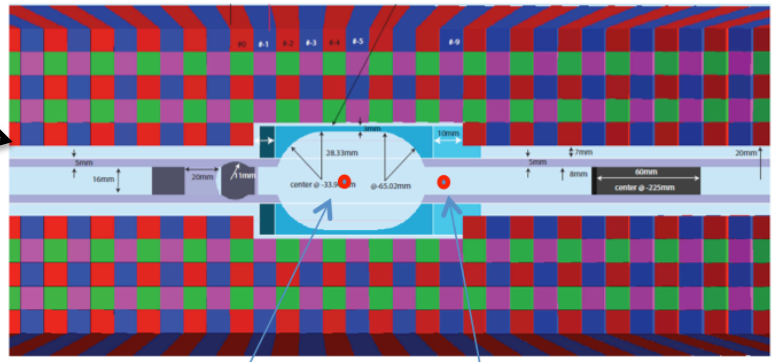
HPS Vacuum Chambers



Beam







Photon beam to be terminated with Kapton window and continued in He bag

Electron beam to be connected to the downstream vacuum line