List of ongoing studies and topics for a potential test facility and expected benefits for the reference design

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Context

- HEL e-beam has different regime (highly space-charged limited) from existing e-lenses
- Simulations: UltraSAM (Track) CST (WARP)
  - Not yet a direct comparison between different codes, but indications points towards a need for a higher accelerating voltage and magnetic field
  - Need of increasing statistics
- Experimentally we have performed measurements at FNAL test facility
  - Limitations: no bend, ratio beam pipe/beam very far from perveance limit, no compression
  - RHIC e-lens or CERN tests stands
- Need to be confidence in the choice of parameters

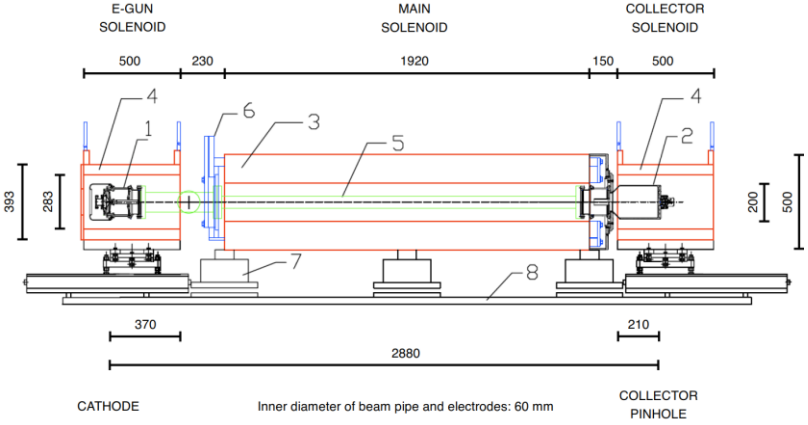
Outline of this talk

- Past and present test stand
- Summary of current measurements at FNAL
- CERN test stand
- RHIC e-lens for tests without ion/proton beam?
- Conclusions

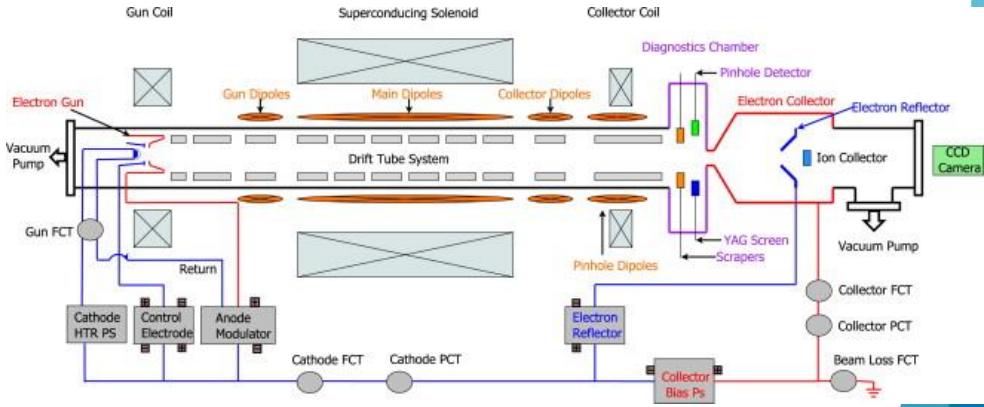
E-lenses test stands: overview

FERMILAB – Tevatron

https://cdcvs.fnal.gov/redmine/projects/elens/wiki/Test_Stand



BNL – RHIC



Operational, up to 10 kV, 8υs x 1Hz pulses (or higher at lower current)
Used to test CERN guns, will be used for testing guns for space-charge compensation at IOTA ring. Could be used to test HF modulators.

25-mm (1-in) Fermilab prototype for LHC (HG1)

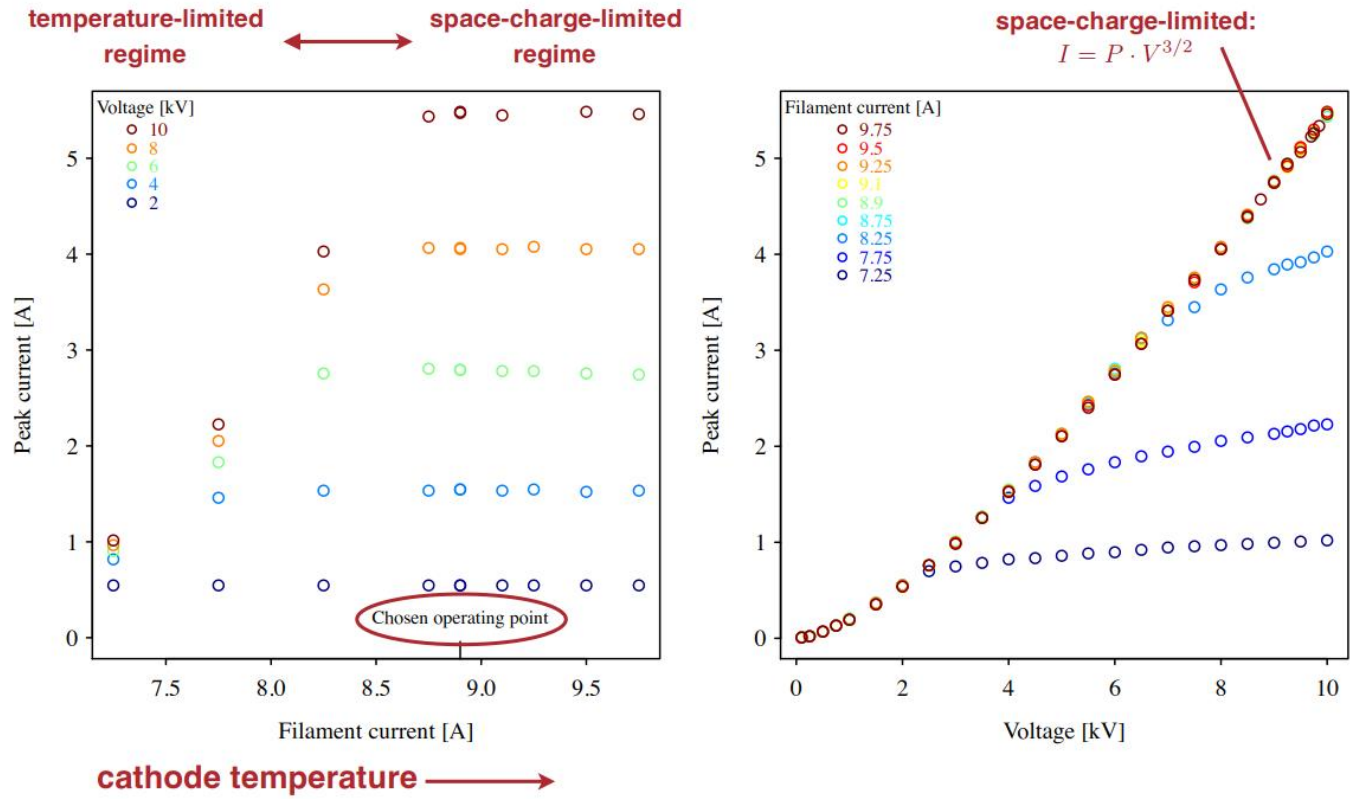
2011-present

HG1: original design

HG1b: added cathode shield

HG1c: replaced cathode

Current yield vs. temperature and voltage



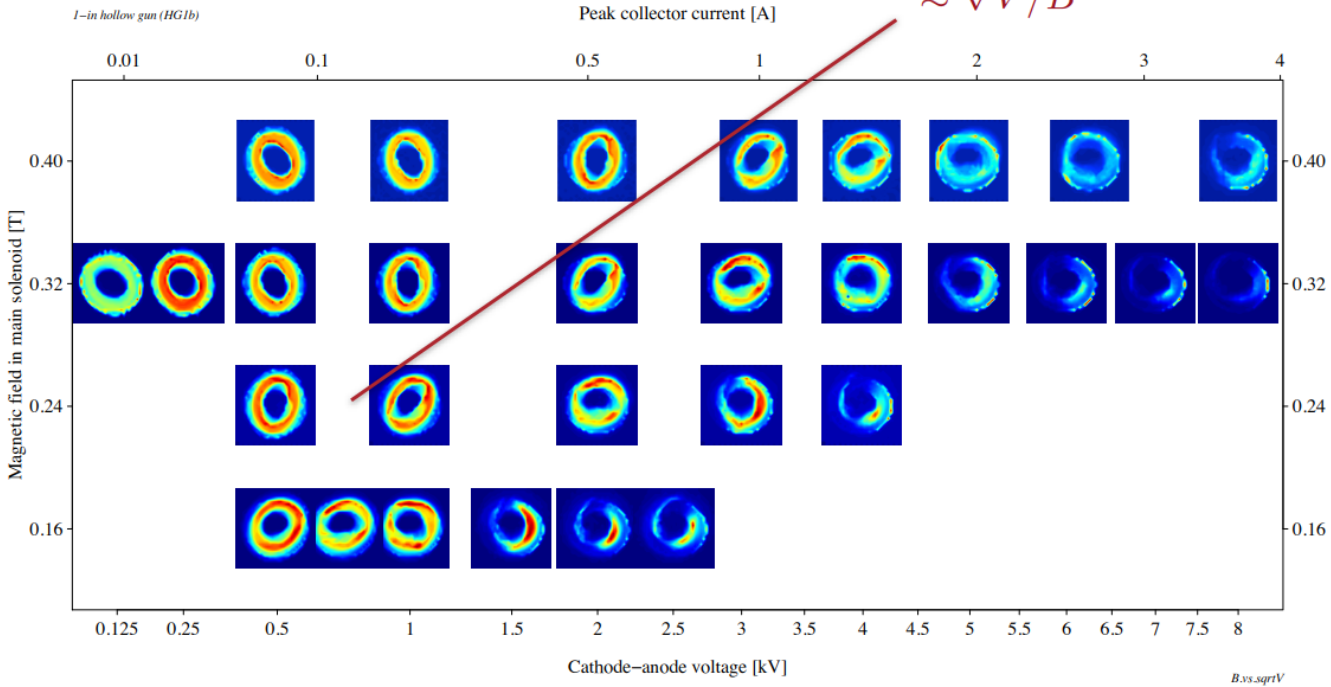
Profile vs. beam current and magnetic field (HG1b)

Reached 5.2 A @ 10 kV

HG1B ∅25 cathode – ∅63 chamber

Scaling of profiles

$\approx \sqrt{V}/B$

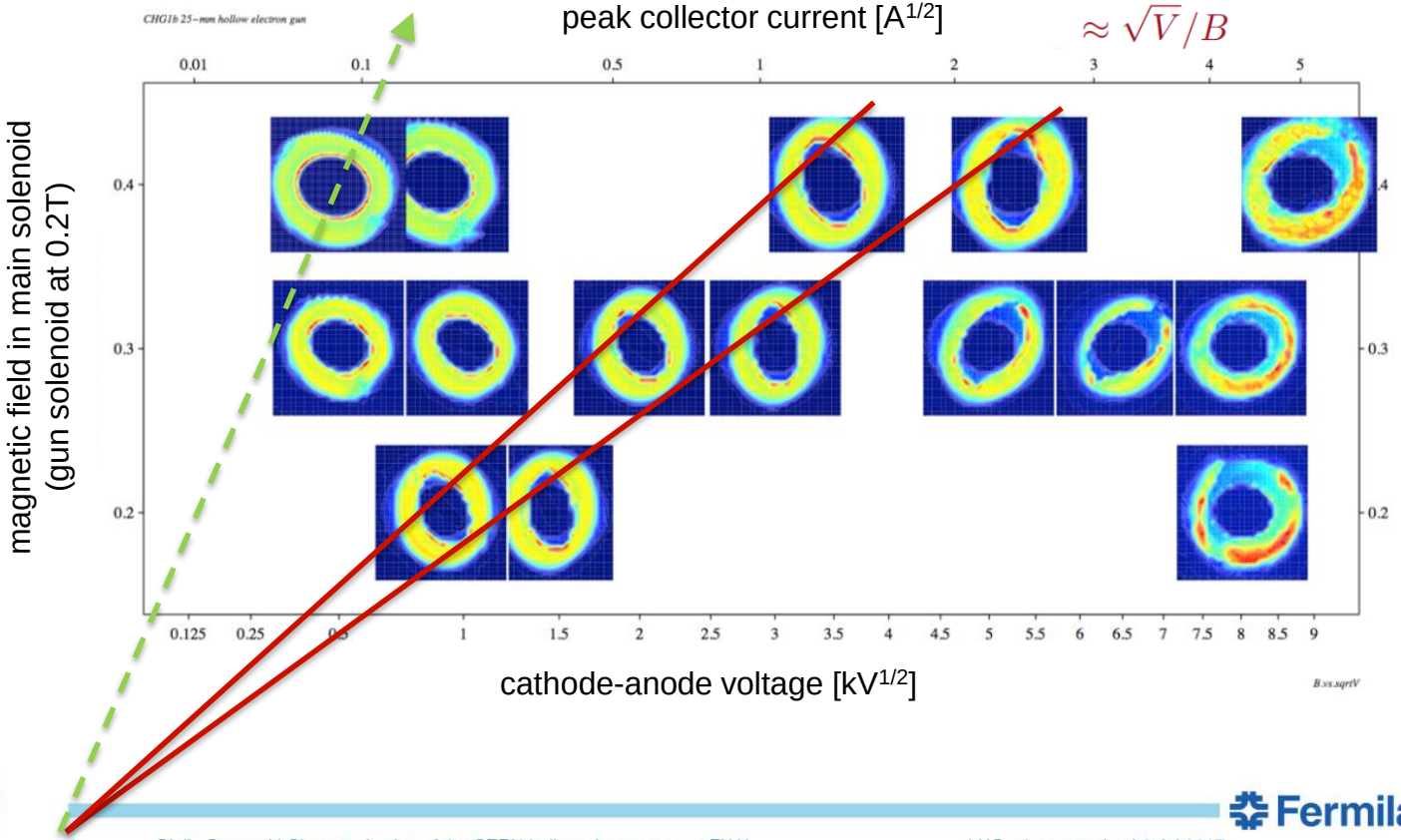


Profile evolution

CHG1B ∅25 cathode – ∅63 chamber

Scaling of profiles

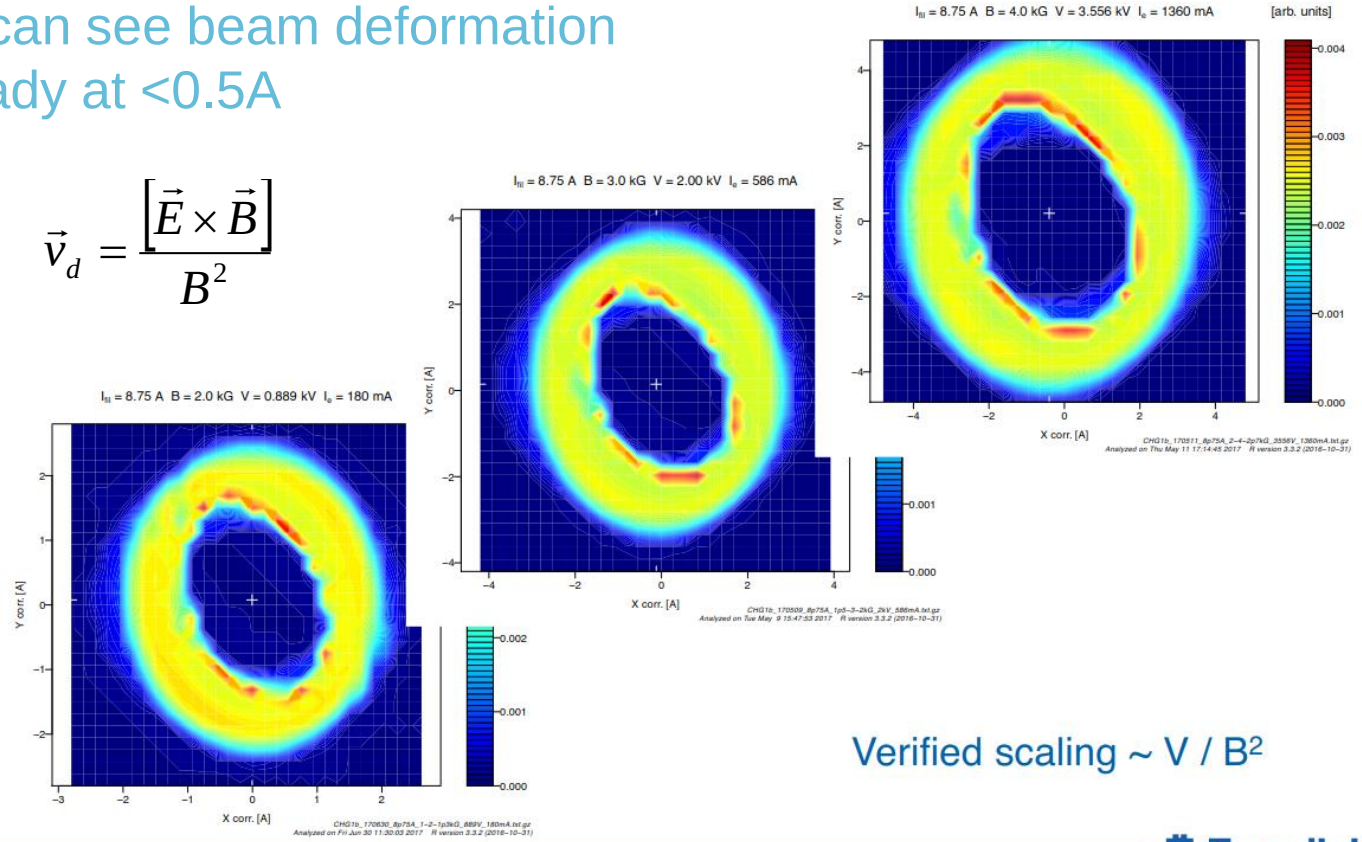
$$\approx \sqrt{V}/B$$



Profile scaling

We can see beam deformation already at <0.5A

$$\vec{v}_d = \frac{[\vec{E} \times \vec{B}]}{B^2}$$

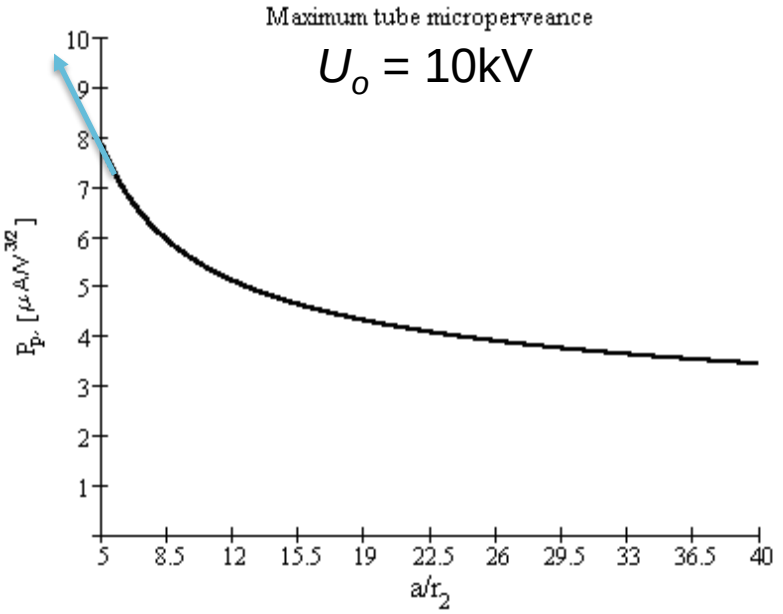


Verified scaling ~ V / B²

Main differences with HEL

- Ratio between the pipe and beam size is ~3
  $\rightarrow$ pipe perveance ~ 10A

- Uniform pipe ∅
- No bends (we cannot see effect of drifts due to B x gradB)



Test facility at CERN (1)

- Foreseen for ARIES studies WP16 – **Intense, RF modulated E-beams (IRME)**
  - Design and build a test stand for testing this gun including instrumentation suitable for measuring the transverse and longitudinal profiles of the RF modulated electron beam
  - Measure the properties of the RF modulated electron beam created by the gun using this test stand

50x70mm oval e-beam, 5-10A, 22kV for the ion beam at the Heavy Ion Synchtron SIS18 (to be used as injector to SIS100) for Space Charge Compensation ⟹ matched transversally and longitudinally

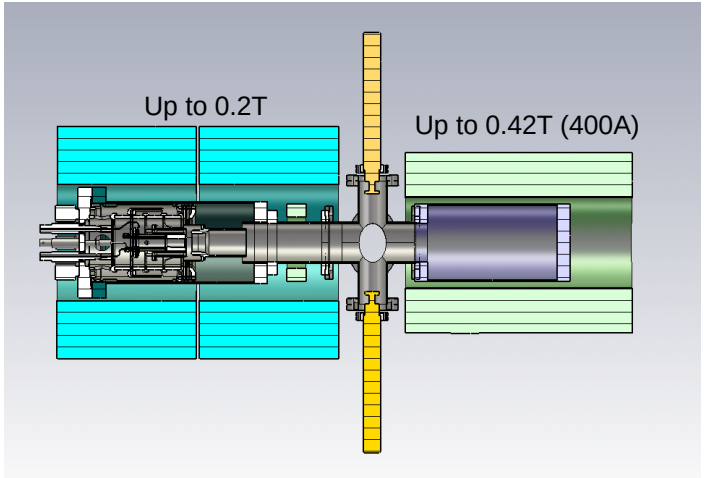
Test facility at CERN (2)

- Foreseen to test high intensity e-gun for **Beam-Beam Long Range compensation**
  - Few mm round e-beam, up to 20A, 20-35kV
  - Modulated at 40MHz for bunch by bunch
  - Could be modulated at 4MHz (**102nd HiLumi WP2 Meeting** https://indico.cern.ch/event/662031/)
- If **HEL** becomes baseline tests **at CERN**
  - beam instrumentation, modulators, interlocks,
  - understanding safety and technical aspects of e-lenses operation
  - preparation infrastructure for test and commissioning of components of HEL@LHC

Test-stand development at CERN:

Example of diagnostic box at RHIC e-lenses

Basic configuration – stage 1



Gun solenoid (twins), collector solenoid, diagnostic box (pin-hole Faraday cup + YAG screen monitor), HV system.

magnets at CERN

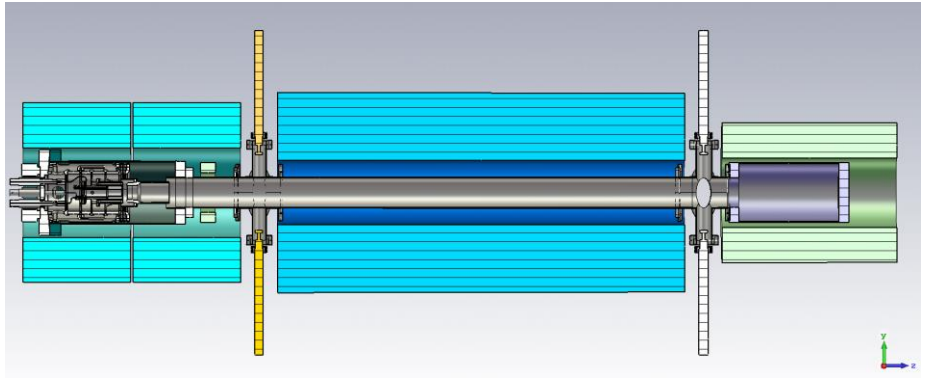
Purpose of this stage:

- Preparation:
  - Commissioning diagnostic procedures (current, profile, position)
  - Commissioning HV system
  - Safety and technical aspects of operation

- Electron gun tests: characterization & simulations
- Design diagnostic box
- Tests with Beam Gas Curtain monitor

Test-stand development at CERN. Upgrade

Addition of main solenoid – stage 2

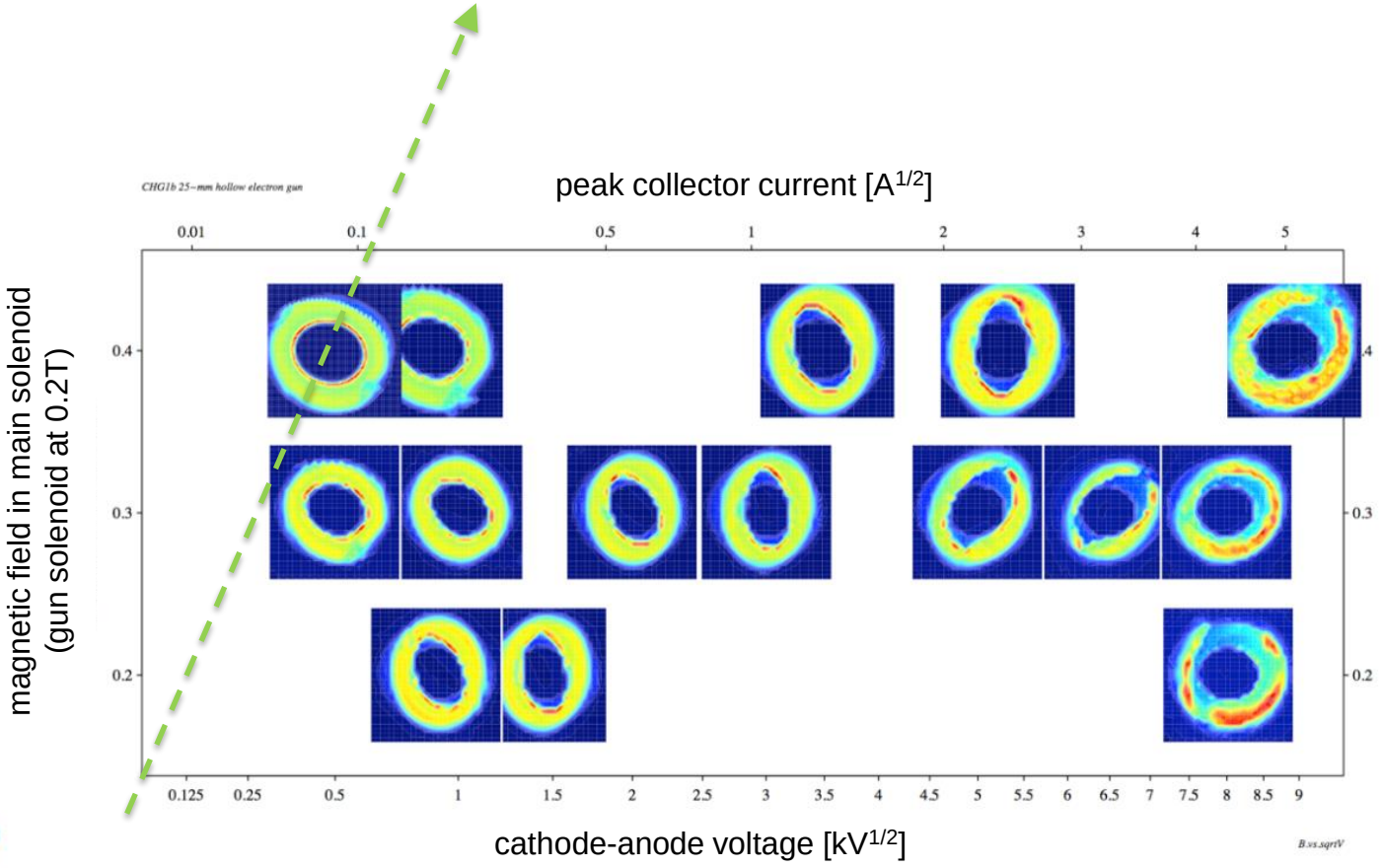


Main solenoid could be 0.4-0.5Tx1m or higher (in the latter case a dry SC solenoid may be cheaper and would expand range of investigation)

Purpose of this stage:

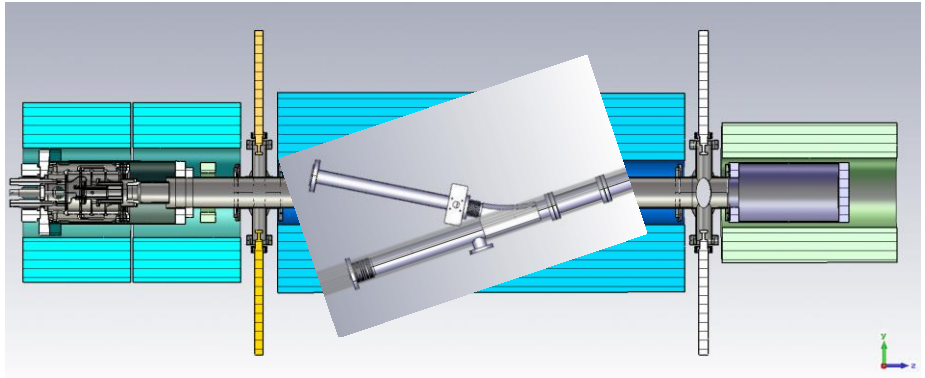
- Allow drift and see beam deformations/rotations/…
- Test Beam Position Monitor ‘shoe-box’ with very HF modulation
- Test effect of very HF modulation (%current) on beam dynamics (microbunching?)
- Study electron beam dynamics in regime close to virtual cathode
- Computer model validation
- Study electron beam dynamics with compression

Test-stand add on with upgrade



Test-stand development at CERN. The future!

Addition a bend – stage 3



Purpose of this stage:

- Measure effect of B x gradB on deformation of beam with high current density
- Computer model validation

RHIC

- RHIC will be used to test effect of hollow e-beam: hollow electron gun in construction
- RHIC e-lens has all features to be the ideal test stand for hollow electron beam

RHIC e-lens TEST STAND!

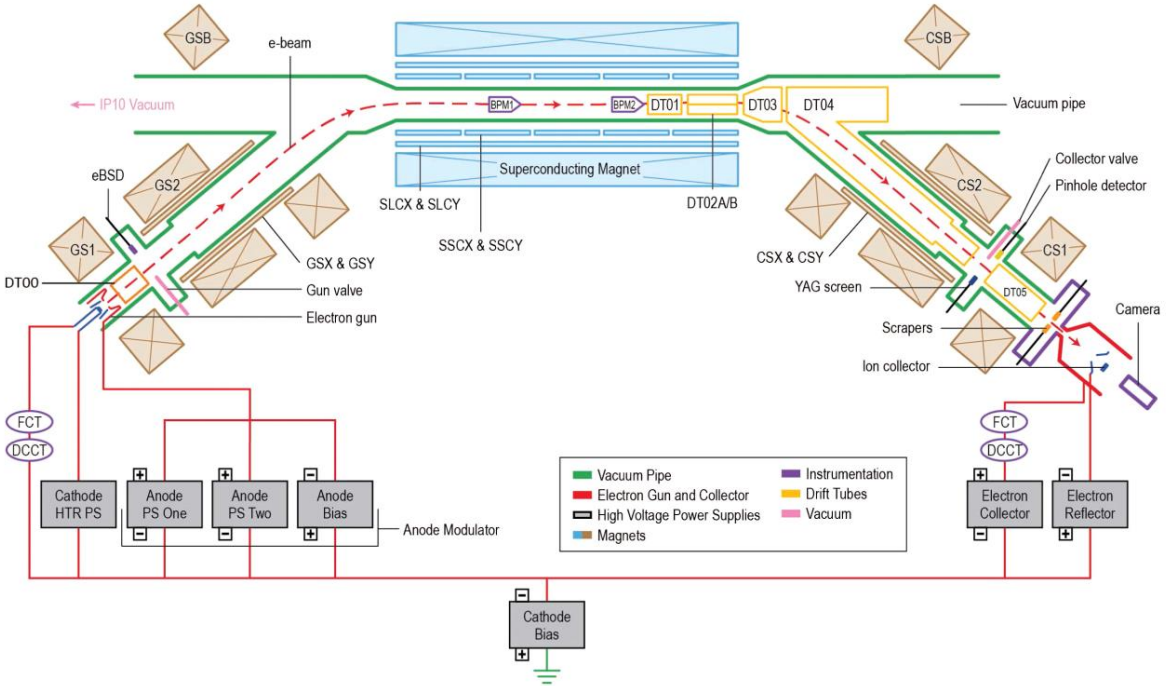


FIG. 3. Schematic layout of the RHIC electron lens.

Conclusions: a test stand at CERN

- Studying/characterisation e-lenses's modules:
  - E-gun (5A DC - 20A DC),
  - Modulator of electron beam
  - Beam diagnostics: profile, position, …
  - Prototype of collector
  - * Compatibility with elliptical beams
- Investigate electron dynamics
- Testing computer models and studying beam dynamics
  - UltraSAM, Trak, CST, WARP
  - LHC e-lenses simulation
- Understanding safety and technical aspects of e-lenses operation
  - Software control (correctors, etc.)
  - Interlocks
- Preparation infrastructure for test and commissioning of components of HEL@LHC

Thank you

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