Update on of the Hollow e-lens and e-beam

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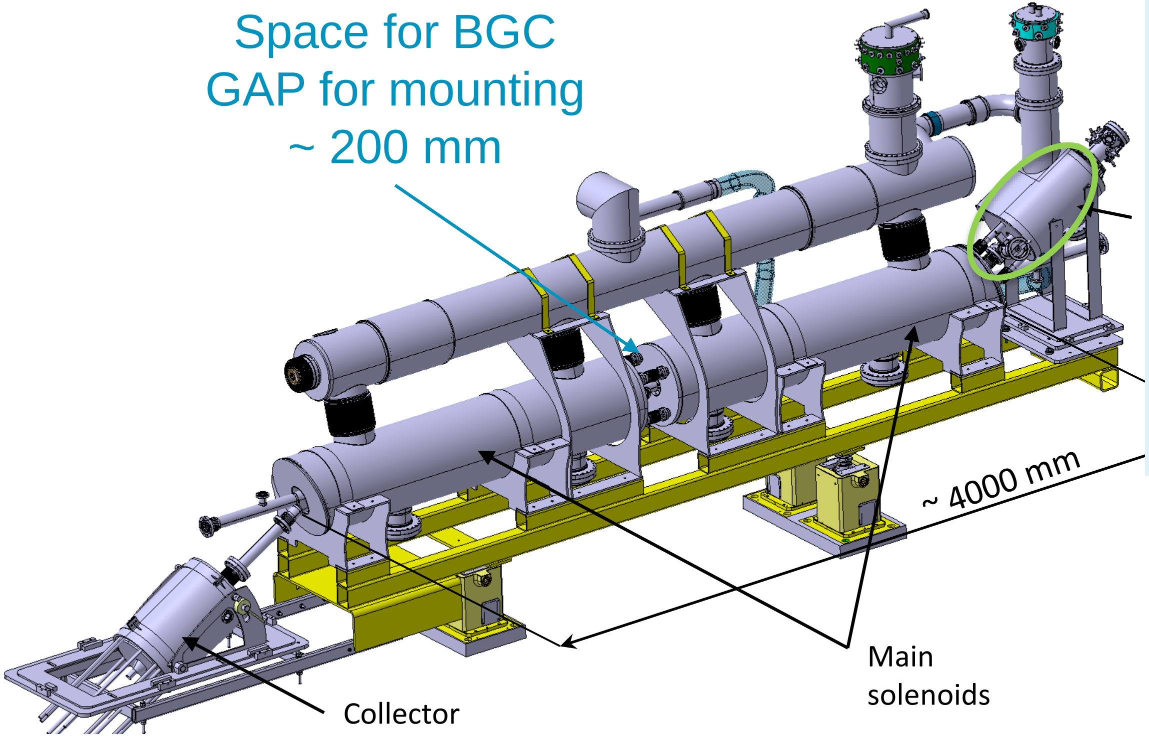
BGC Collaboration Meeting – CERN – 27 November 2018

HEL 3D drawing

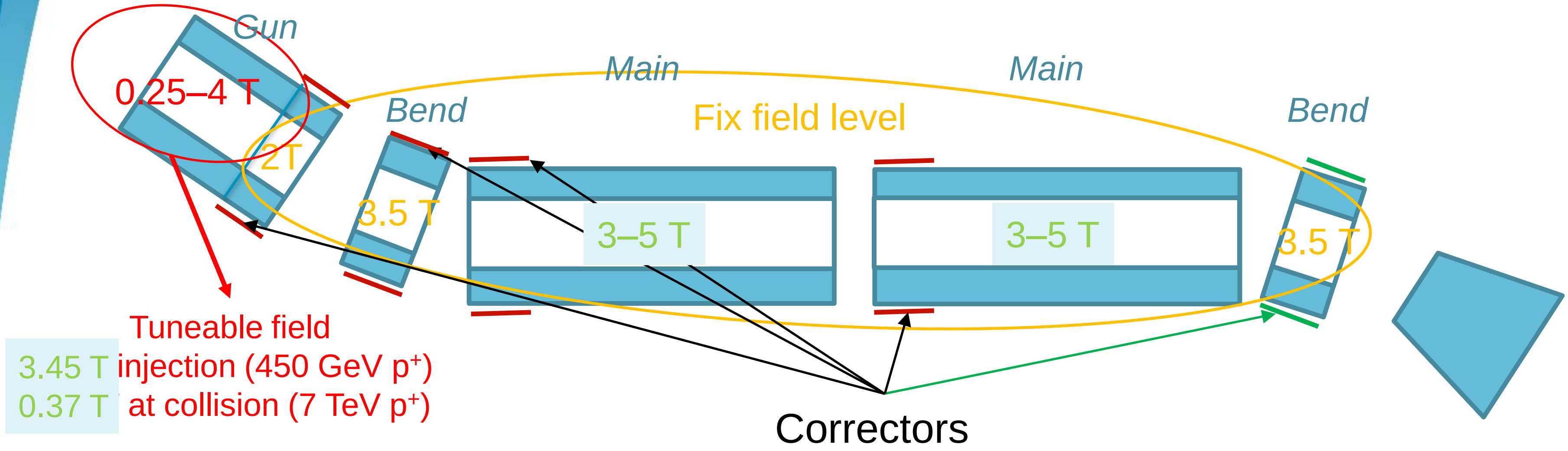


Gun valve (∅40mm) NOW between 2 gun solenoids.

Advantages:

- Better mechanical supported
- Higher B field = smaller e-beam at valve
- Gap gun-bend distance can be shorter = higher B field and smaller e-beam in injection arm

Magnetic fields



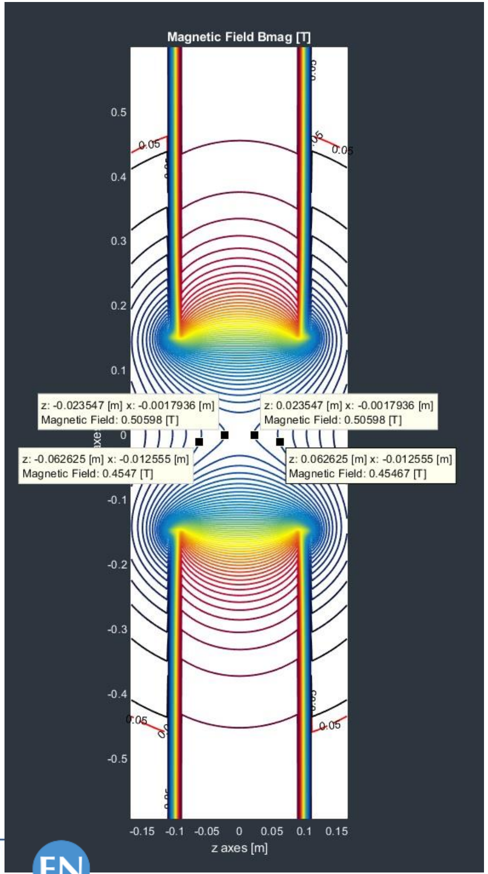
Since proton beam optics changed from 200 to 280m beta at HEL, the field in the main solenoid will actually vary with proton beam energy

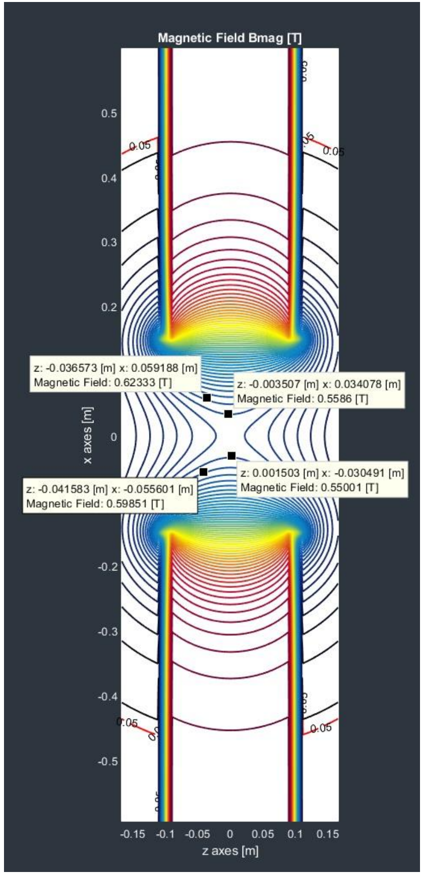
Hollow Electron Lens parameters

- HEL optics for protons: 280 m beta, emittance 3.5 μradm
- HEL electron beam from 3 to 6 proton σ
- Proton at 450GeV:
  - proton $\sigma = \sqrt{\varepsilon\beta/\gamma}$ = 1.43mm
  - e-beam size in main solenoid ∅ 8.6 to 17.2 mm
- Proton at 7TeV:
  - proton σ = 0.36mm
  - e-beam size in main solenoid ∅ 2.2 to 4.4 mm

Operations at 450GeV protons

Cathode
∅ 8 to 16 mm





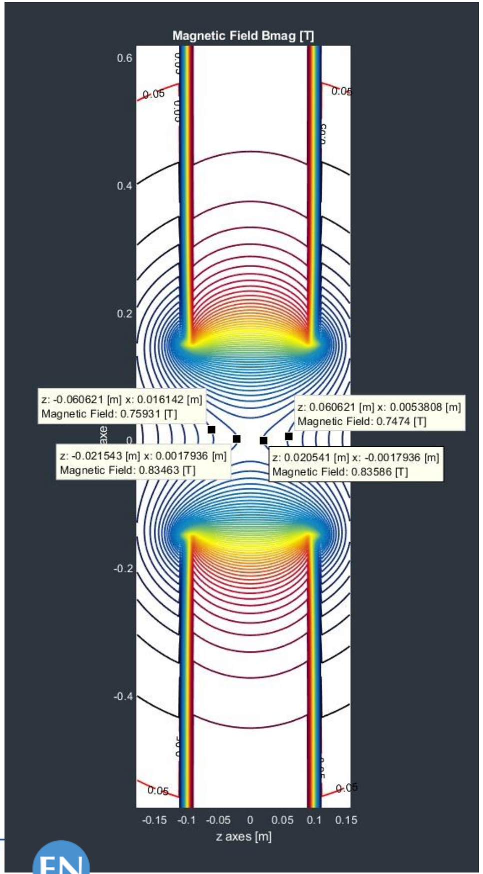
3.45 T in Gun solenoid
3 T in Main Solenoids

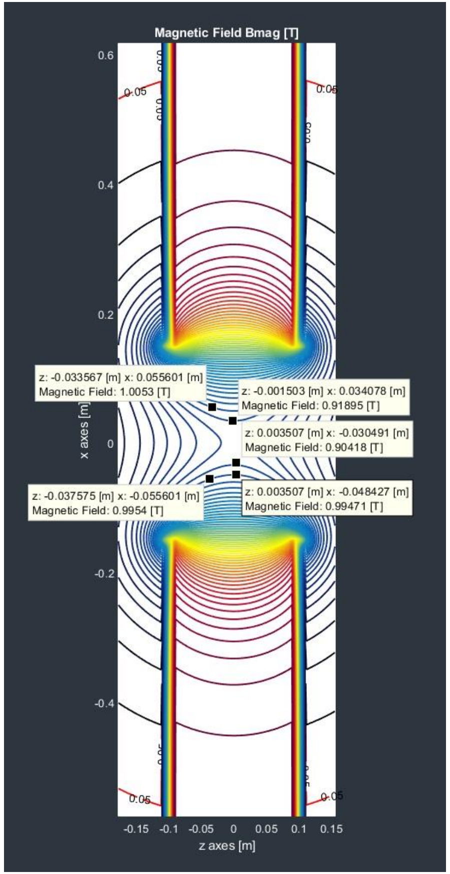
0.5 T in the middle of the gap

e-beam at BGC =
∅ 21 mm to **42 mm**

Operations at 7TeV protons

Cathode
∅ 8 to 16 mm





0.37 T in Gun solenoid
5 T in Main Solenoids

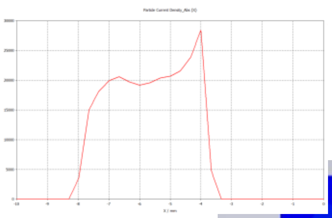
↓

0.85 T in the middle of the gap

↓

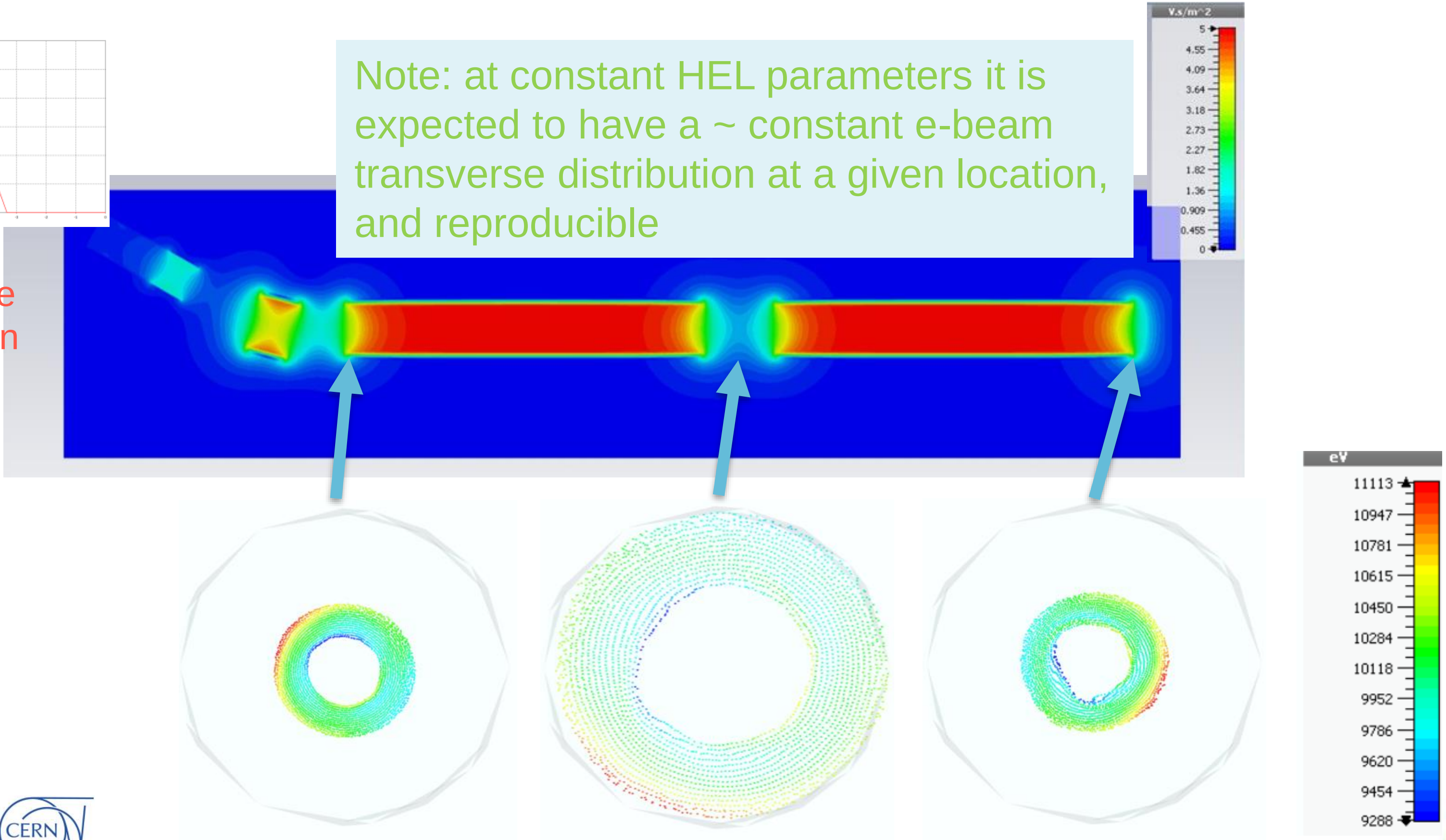
e-beam at BGC =
∅ 5.3 mm to **10.6 mm**

Electron beam through e-lens



Electron transverse distribution at gun

Note: at constant HEL parameters it is expected to have a ~ constant e-beam transverse distribution at a given location, and reproducible



A. Barnyakov, D. Nikiforov, M. Arsentyava, A. Levichev, BINP

BGC @ HEL

Cathode emission

- 8 –16 mm,
- Scandium doped Tungsten, at ~ 1000 K working T
- emission ε=0.4

- Total power emitted $P = \varepsilon \cdot \sigma_{SB} \cdot Area \cdot T^4$ ~ 9 W
- $\lambda_{max} = \frac{b}{T}$ ~ 2.28 µm
- $u(\lambda_{yellow}, T)d\lambda = \varepsilon \cdot \frac{2hc^2}{\lambda^5} \cdot \frac{1}{e^{hc/k_B T\lambda} - 1}$ ~ 4.4 µW

  - σ_{SB}= Stephan-Boltzmann constant = 5.67E-8 W m^{-2} K^{-4}
  - b=Wien's factor = 2.9E-3 m K
  - λ_{yellow}= 585 nm

BGC @ HEL

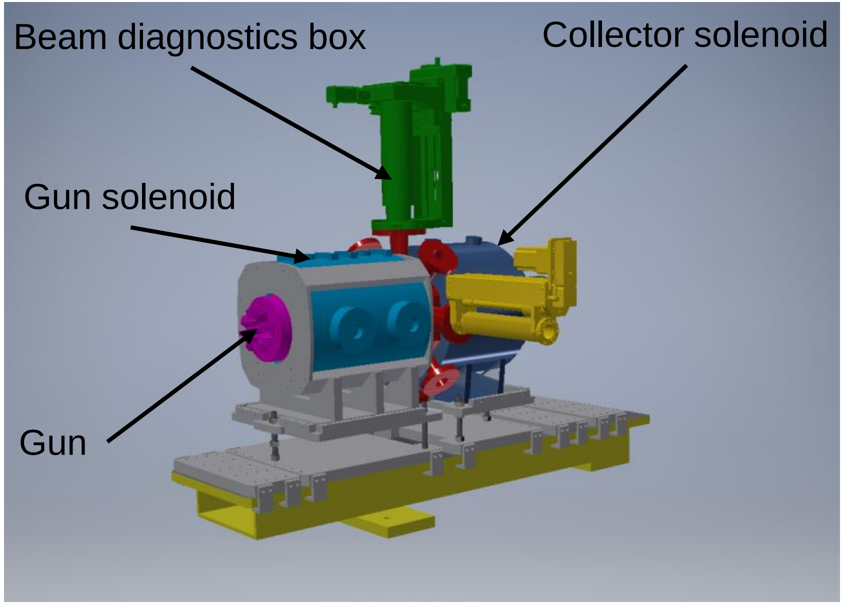
Ionization of Ne gas by protons and electrons impact

$$\sigma_{ion} n_{gas} I_{beam} L$$

- Assuming
  - 1e-6 mbar gas sheath of Neon, 2mm thick.
  - 5A electrons at ~ 10 keV ► $\sigma_{ionization}$ ~ 1E-24 m^2 ► 2E7 ionization/s
  - 2A protons at 7TeV ► $\sigma_{ionization}$ ~ 3E-26 m^2 ► 1.5E9 ionization/s
- Electrons and ions from ionization will likely have too low an energy to be extracted at collectors

The need of clearing electrodes will be studied at the electron lens test stand at CERN

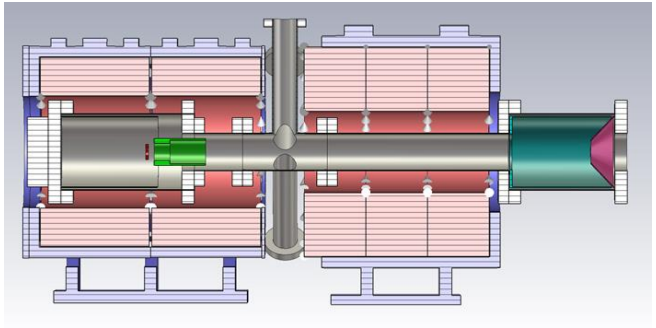
Electron lens test stand at CERN: stage 1



Purpose of first stage:

- Preparation:
  - Commissioning hardware (magnets, vacuum, HV system, control, etc.)
  - Safety and technical aspects of operation
  - Commissioning diagnostic procedures (current, profile, position)
- Measurements:
  - Electron gun tests: characterization (profile measurements)
  - Electron gun: anode modular
  - Initial tests with BGC

Covered by HL-LHC



Summary

- Design of HEL close to final
- HEL will be operated during whole proton fill cycle
- e-beam at BGC
  - ∅ 21 mm to **42 mm** at beginning of cycle
  - ∅ 5.3 mm to **10.6 mm** at collision energy
  - Shape should stay constant for same HEL paramenters
- Light from hot cathode ~ 9 W, but only 4.4 μW in the yellow wavelength, can be studied at e-lens test stand
- Ionization of gas jet by protons and electrons in the order of pA and fraction of nA respectively, can be studied at e-lens test stand
- Effect of proton-Ne gas scattering and losses downstream the HEL is under study with the Collimation team

Thank you

Many thanks to S. Mazzoni and S. Sadovich for useful discussions