Status of Design Work towards an Electron Cooler for HESR

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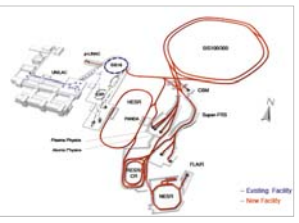
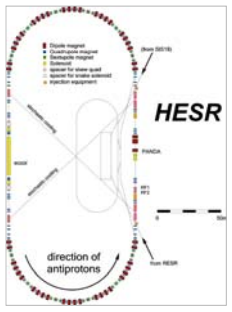
FAIR





Why electron cooling at HESR?

Cooling of antiprotons 0.8 GeV - 8 GeV to counteract the internal target

- Users want resolution near what corresponds to $\Delta p/p = 10^{-5}$. Not possible with stochastic cooling alone
- Easy cooling of bunched beam
- Cooling rate is independent of antiproton intensity. No degradation of cooling at higher intensity
- Possibility for absolute calibration of antiproton energy (by means of H^--beam and $^7Li(p,n)$-reaction: $E_{threshold} = 1880.3558 \pm 0.0812$ kV)
- Possibility for cooling below 3 GeV. Difficult with stochastic cooling in HESR due to band overlap

HESR Electron Cooler

- Energy range 0.45 - 4.5 MeV
- Design based on Pelletron, upgradeable to 8 MeV
- Maximum current 1 A
- Magnetic field in interaction section 0.2 T
- Magnetic field in tank column 0.07 T
- Magnetic field straightness 10^{-5} rad rms
- Interaction section length 24 m
- Normal conducting magnets based on separate “pancake” solenoids
- H^--beam line for precise voltage and stability control ~10^{-5}

Electron gun and collector

Electron gun

Cathode diameter	10 mm
Magnetic field	0.2 T

Collector

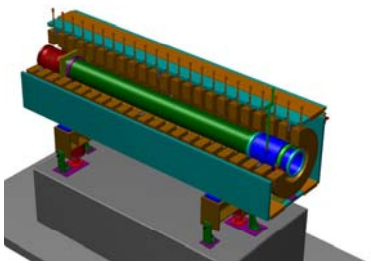
- Collection efficiency of 99.999% of recirculating electrons is needed
- Water cooled

- Electron optics simulations using UltraSAM
- Design in collaboration with Fermilab

Magnet system for longitudinal field

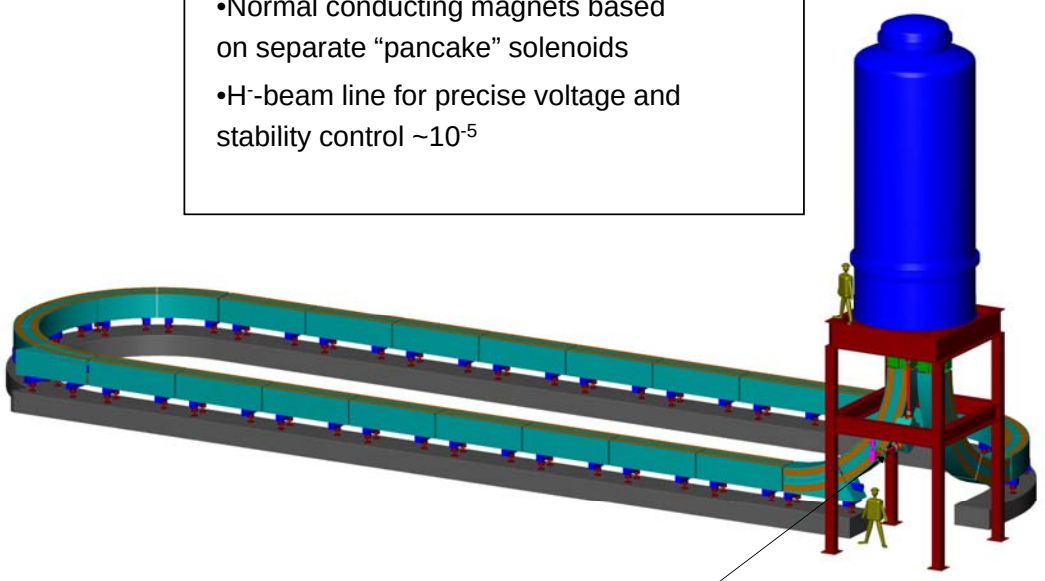
Interaction section:

- 23 individually adjustable pancake solenoids to give straightness of 10^{-5} rad rms
- 4 horizontal and vertical corrector solenoids

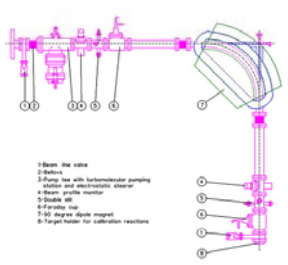


Pancake solenoids

Pancake Solenoid Parameters		
Inner radius	*R*	170 mm
Period	*L*	130 mm
Wire dimension	*δ*	13 mm
Width	*D*	80 mm
Height	*H*	145 mm
Number of turns	*N*	63
Conductor		
Copper cross section	A_{Cu}	116 mm²
Cooling water hole	*d*	∅ 6 mm
Length	*λ*	96.5 m
Weight	*M*	100 Kg
Power consumption		
Current	*J*	328 A
Power consumption	*P*	1.8 kW
Voltage	*U*	5.5 V
Operational costs:		
Temperature increase	*ΔT*	10 K
Water flow	*Φ*	2.6 dm³/min
Water pressure	*p*	5 bar

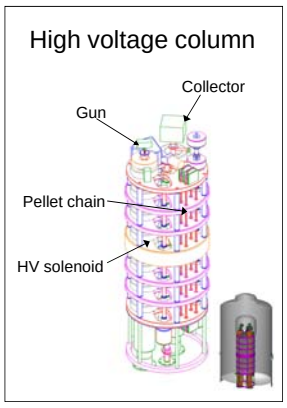


H^--beam line



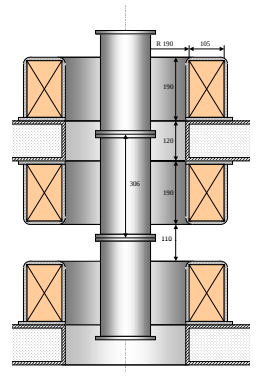
Magnetic spectrometer for precise voltage and stability control. Experimental requirements of ~10^{-5}

High voltage column

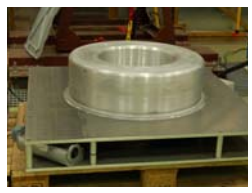


High Voltage Solenoid

- 24 Solenoids in accelerating column
- SF6 cooled



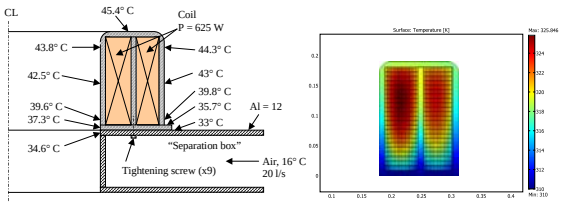
Prototype



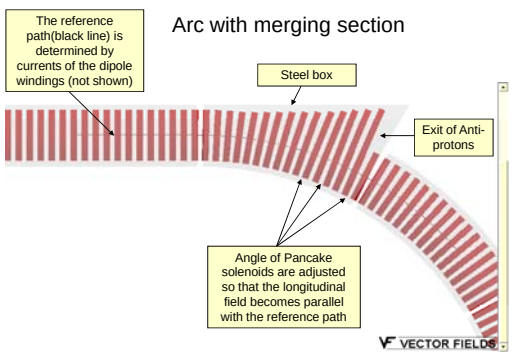
B = 0.07 T
NI = 17 kAt
P = 625 W
Coil distance c-c = 305 mm

Measurements
Steady state temperatures

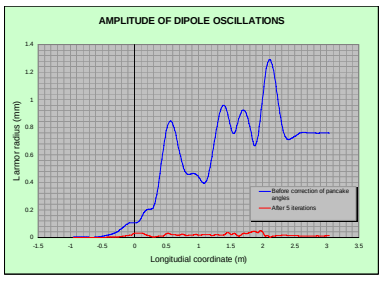
Simulations with COMSOL Multiphysics



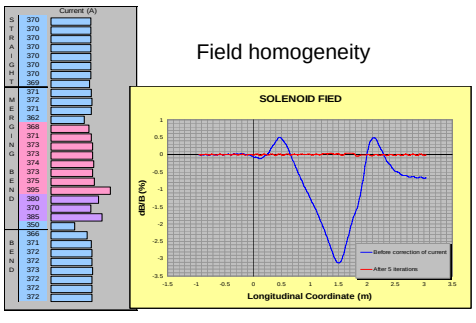
Field matching in arcs and intersections with TOSCA



Beam matching in arc



Field homogeneity



- The vertical corrector current is determined so that the radial offset of the reference path is a constant after approximately 45 degrees in the bend.
- The angles of the pan-cakes are adjusted to match the reference path.
- The current of the pancakes are adjusted to that the magnetic field along the reference path will be a constant
- The field matching takes about 5 iterations in TOSCA

Magnetic field measurements

- Straightness of magnetic field on interaction straight needs to be measured and corrected to10^{-5} rad rms to achieve good cooling

Prototypes

Compass-needle based sensor manufactured by BINP

Sensor and holder

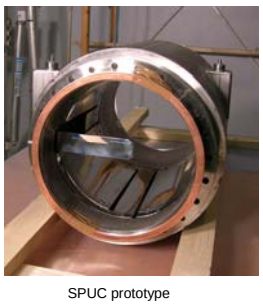
Carriage for magnetic field measurements

Carriage inside vacuum tube

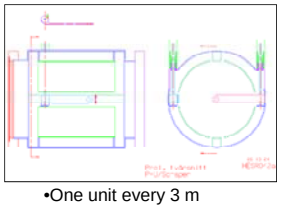
Electron Beam Diagnostics

- Pick-up electrodes: To measure positions of antiproton and electron beams with resolution of 10 µm.
  => Beam alignment
- Scrapers: To measure envelope oscillations of the electron beam
  => Ensure quality of electron beam
- Beam loss monitors
- OTR, Beam profile monitors

SPUC: Scraper and Pick-Up Combined



SPUC prototype



- One unit every 3 m
- Scraper with 2 mm orifice possible to fold in