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The ELENA Electron Cooler; Parameter Choice and Expected Performance

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ABSTRACT

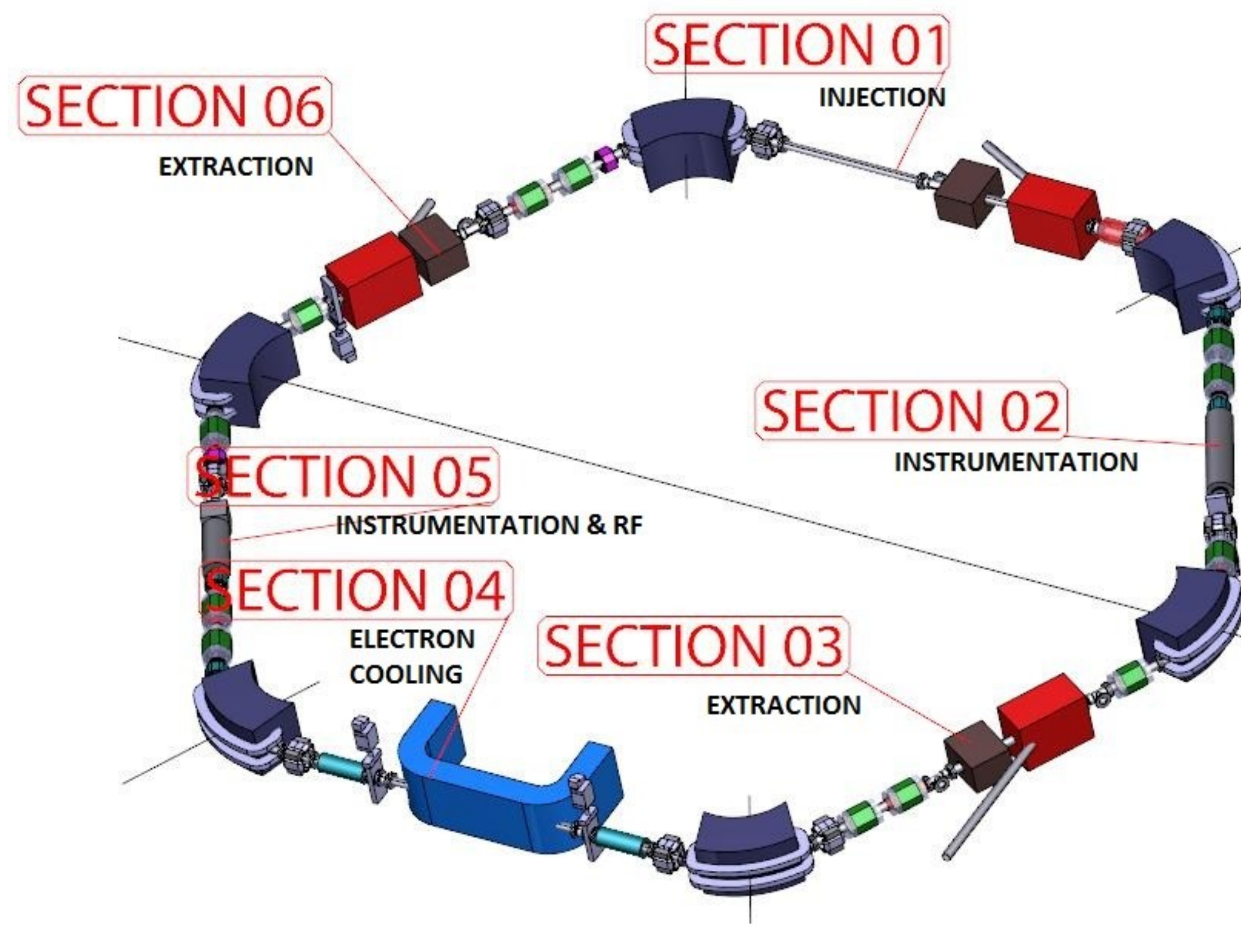
Electron cooling will be central to the success of the ELENA project which aims to increase by a factor of up to 100 the number of antiprotons available for the trap experiments. Because of the tight space constraints, the design of the device will be based on the compact electron cooler in operation on the S-LSR ring in Kyoto.

The biggest challenge will be to generate a cold and stable electron beam at an energy of just 55 eV in order to cool the 100 keV antiprotons. The use of photocathodes is excluded because their relatively short lifetime would require too many vacuum interventions during operation. We present the design parameters of our cooler as well as the results of the cooling performance simulations made with BetaCool and on-going work into "cold" cathodes.

Main Parameters of the Electron Cooler

Momentum (MeV/c)	35	13.7
β	0.037	0.015
Electron beam energy (eV)	355	55
Electron current (mA)	5	2
Electron beam density (m^{-3})	1.38 x 10^{12}	1.41 x 10^{12}
Bgun (G)	1000	
Bdrift (G)	100	
Expansion factor (desired)	10	
Cathode radius (mm)	8	
Electron beam radius (mm)	25	
Length of cooling section (m)	1	
Total cooler length (m)	1.93	
Twiss parameters (m)	β_h=2.103, β_v=2.186, D=1.498	

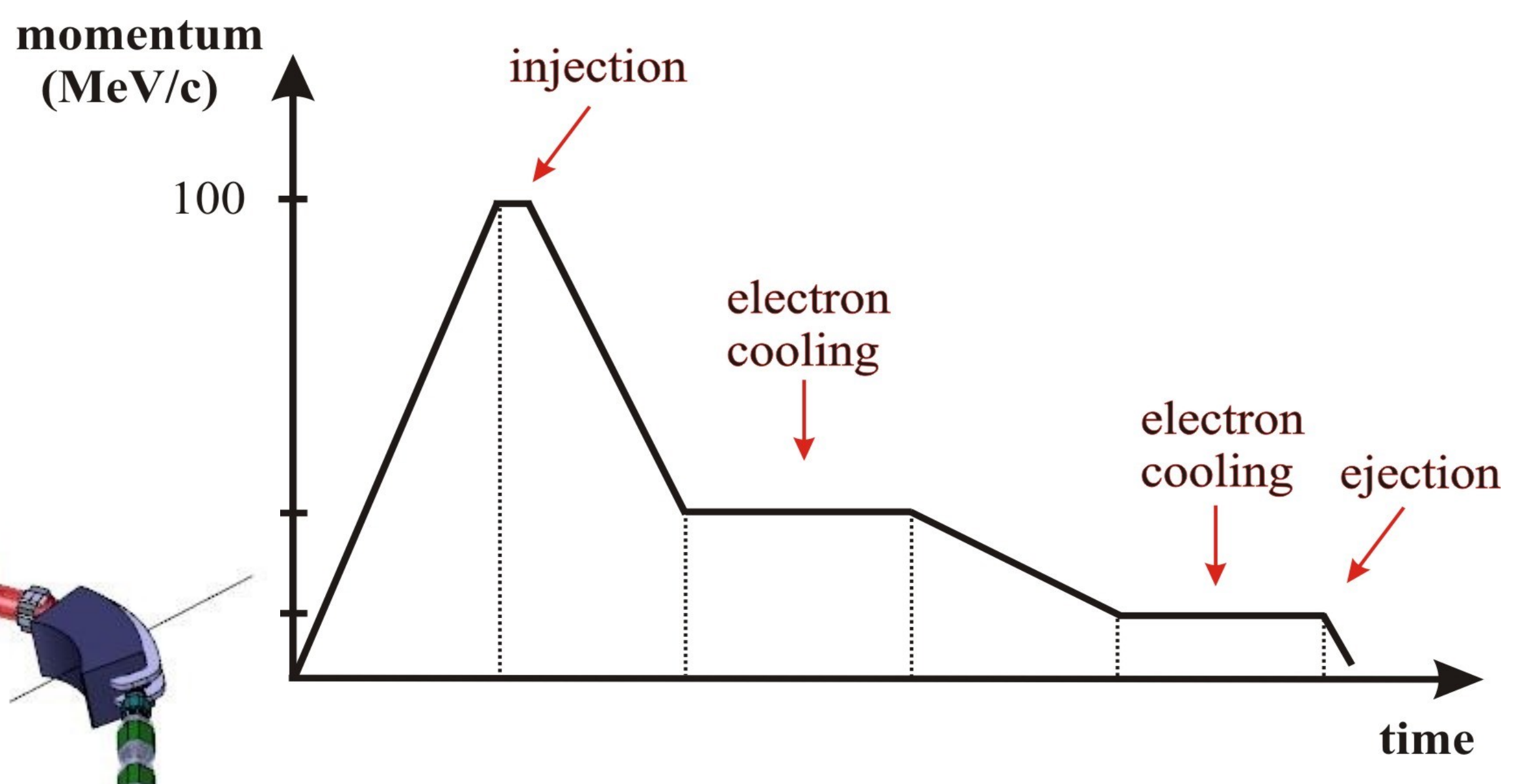
Cooling will be needed at two momenta during the ELENA deceleration cycle. At the intermediate momentum of 35 MeV/c the antiproton beam will need to be cooled in order to guarantee that it can be decelerated further to 13.7 MeV/c without any excessive blowup of the beam dimensions which could lead to beam loss. At the lower momentum the cooling will ensure that the phase-space characteristics of the extracted antiproton beam fit the requirements of the experiments.



ELENA Layout

Schedule:
2013 Negotiations with Toshiba, update design
2014-07/2015 Contruction, tests and delivery to CERN
2015 Vacuum preparation, magnetic field correction
2016 Installation on ELENA, first cooling with p/H⁻

The S-LSR cooler at Kyoto Uni.



The ELENA Magnetic Cycle

The cooler will be installed in long straight section 4 of the machine and will take up almost half the available space. It will be based on the compact electron cooler built by Toshiba Corp for the S-LSR ring in Kyoto. The rest of the section will accommodate the orbit correctors and the compensation solenoids of the cooler..

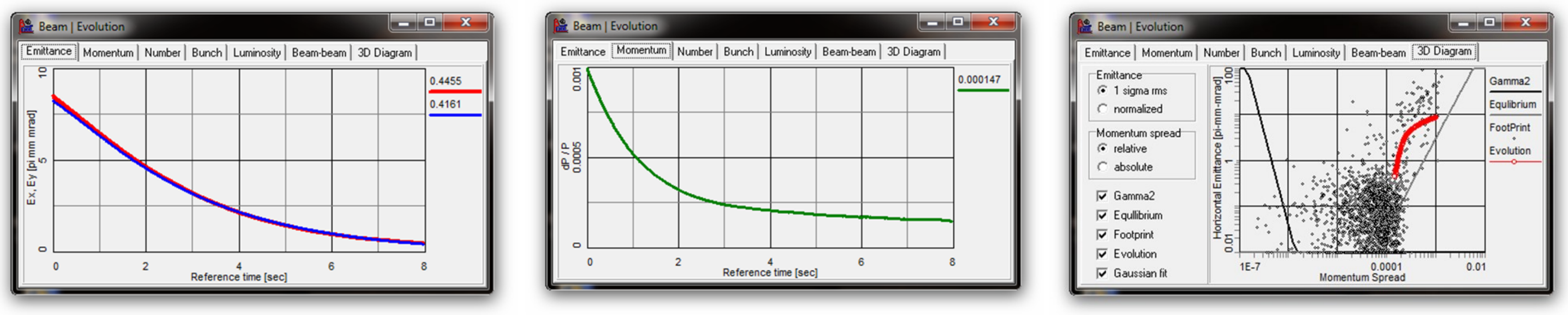
Differences w.r.t. the S-LSR cooler

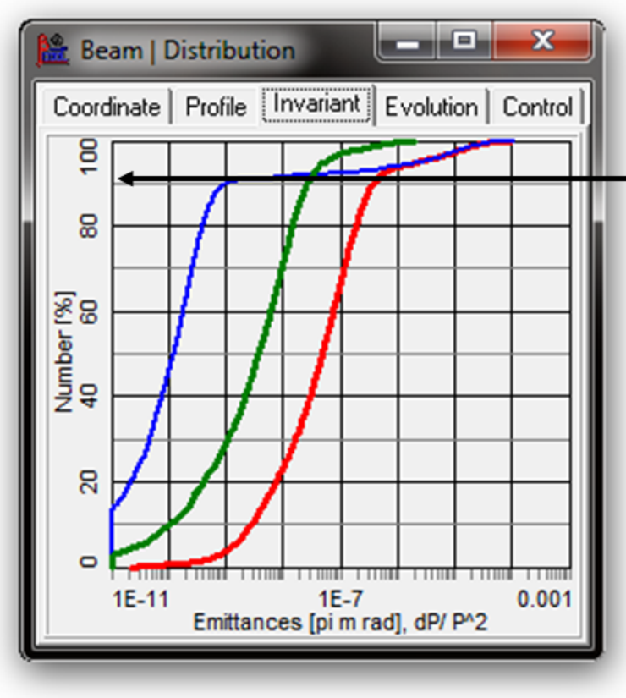
XHV compatibility, NEG coating
Device will be installed horizontally
Lower electron energy, < 355 eV
Lower B field (100G) in cooling region
Expansion factor of 10

Preliminary results of cooling simulations with BetaCool

Cooling @ 35 MeV/c

- Initial beam parameters: $e_{h,v}$ = 50 p mm mrad, DP/P = ±2 x 10^{-3}
- Look at emittances (95% of the distribution) after 8 seconds of cooling
- Check influence of electron beam transverse temperature



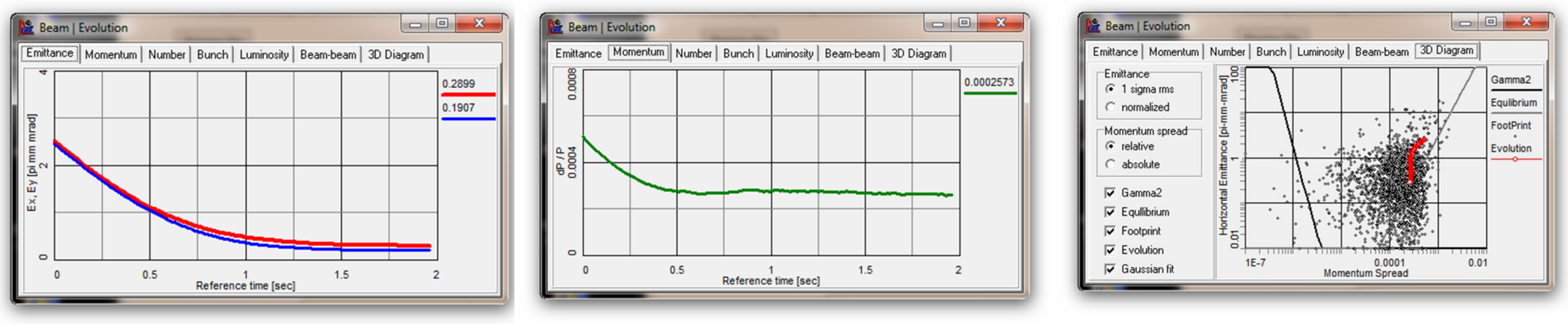


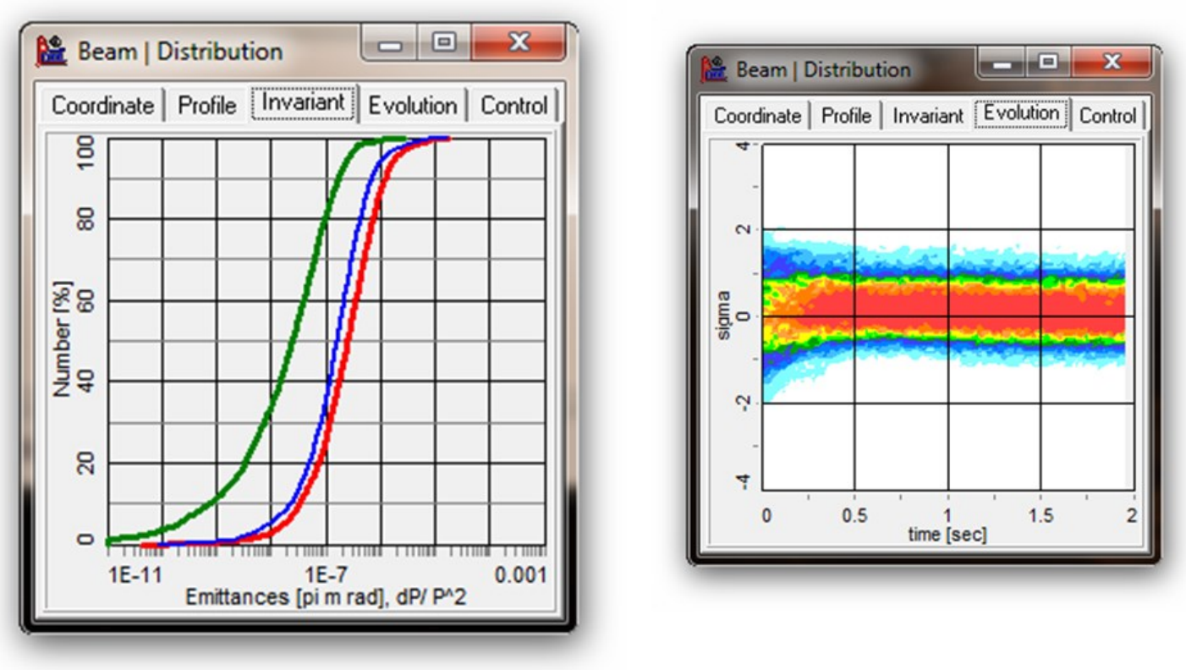
90%

Ie (mA)	kT (eV)	ε_h (π mm mrad)	ε_v (π mm mrad)	ΔP/P (10^{-3})
5	0.1	9.8 (2.7)	9.7 (3)	±0.36
5	0.03	4.5 (0.4)	5.3 (0.2)	±0.25
5	0.01	2.4 (0.3)	2.6 (0.01)	±0.23
10	0.01	5.9 (0.3)	6.8 (0.01)	±0.33

Cooling at 13.7 MeV/c

- Initial beam parameters: $e_{h,v}$ = 15 p mm mrad, DP/P = ±1 x 10^{-3}
- Look at emittances (95% of the distribution) after 2 seconds of cooling



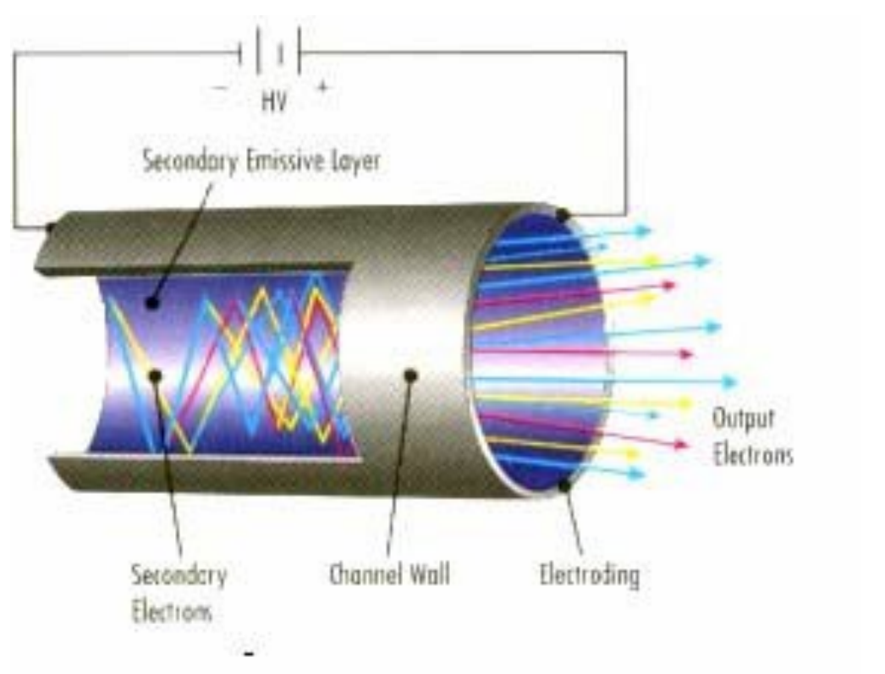


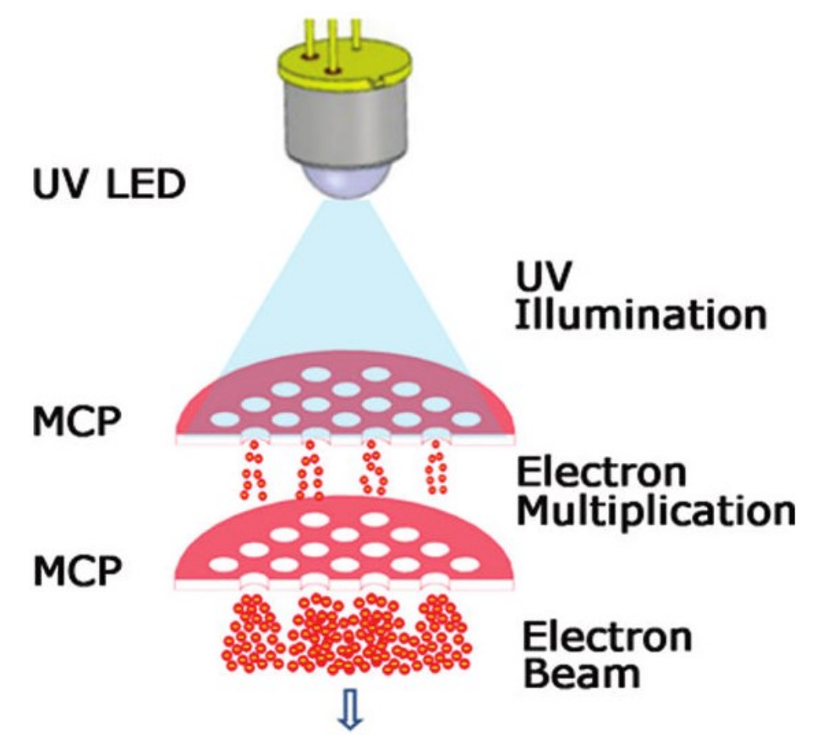
Ie (mA)	kT (eV)	ε_h (μm)	ε_v (μm)	ΔP/P (10^{-3})
1	0.03	2.4	1.5	±0.6
1	0.01	2.1	1.3	±0.5
2	0.01	1.9	1.1	±0.5

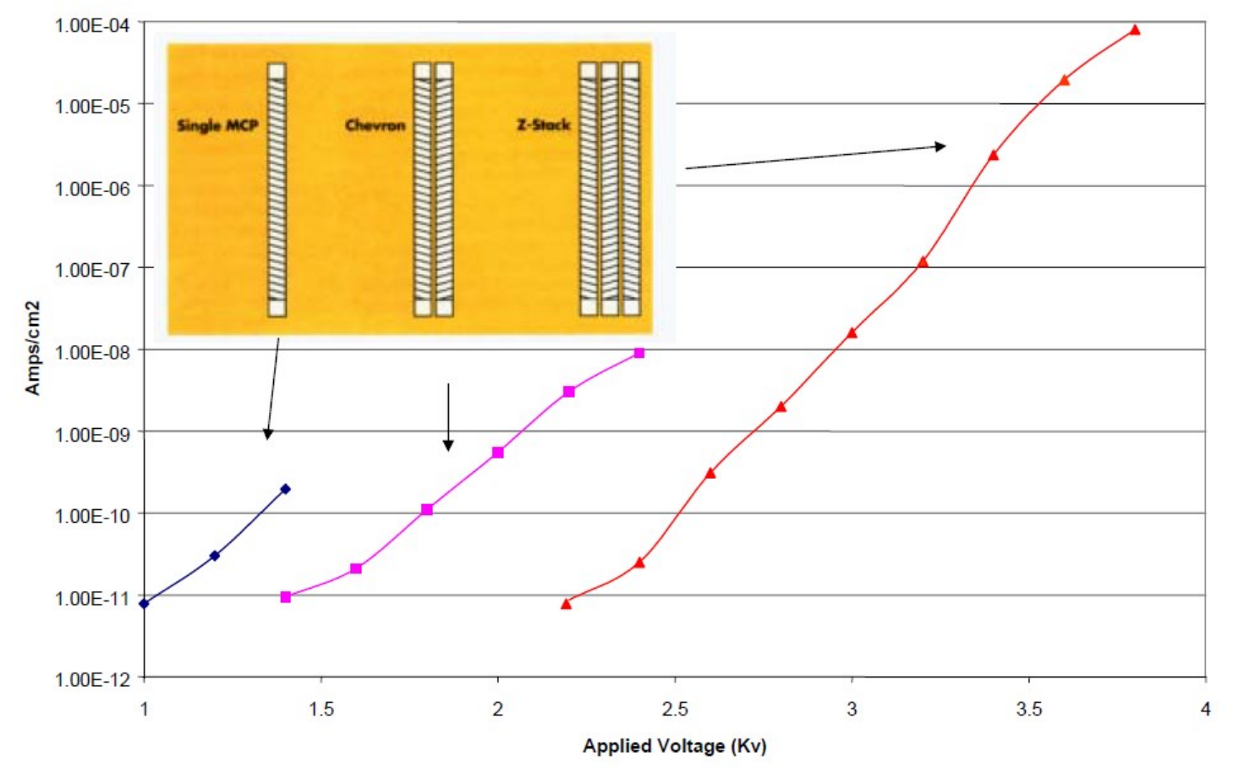
Cold electron sources

1. Photocathodes
2. Electron Generator Array (BURLE Electro-optics)
3. Electron multiplier (MCP) illuminated by e.g. photons (Hyun Sik Kim et al.)
4. Carbon nanotubes

Microchannel Plates operate on the principle of secondary electron emission. When a charged particle impinges on the input side of the channel with sufficient energy, a few secondary electrons are produced. The resultant electrons continue to cascade down the channel until a charge cloud exits the channel. By altering the microstructure within the channel, spontaneously emitted electrons can be produced, initiating the cascade of secondary electrons. By controlling the rate of spontaneous emission and the gain of the device, the emission current can be varied over a broad range.







Design of the ELENA electron cooler is well advanced
Preliminary studies with BetaCool to determine baseline
Negotiations with Toshiba Corp for the construction

Need to simulate adiabatic capture with electron cooling

Test stand to be built to invetigate the possibility of using a « cold » electron source