BNL SRF-gun Program

Subtitle: unintended success with SRF photo-electron gun for Coherent electron Cooling

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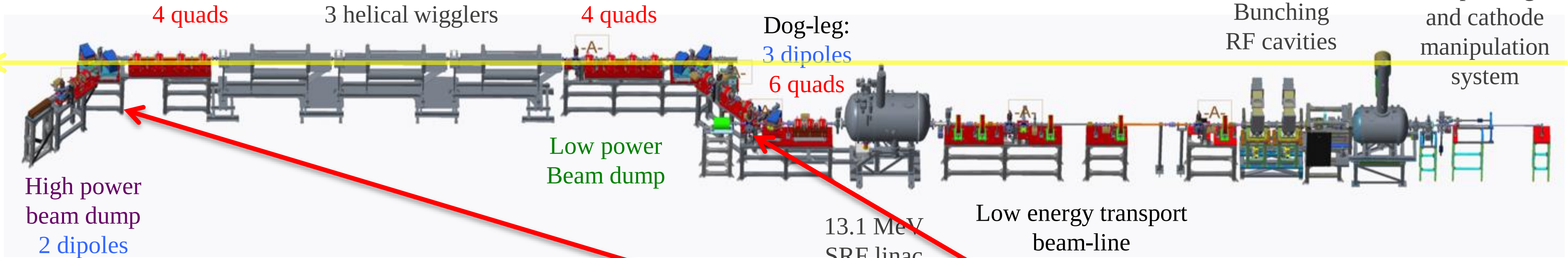
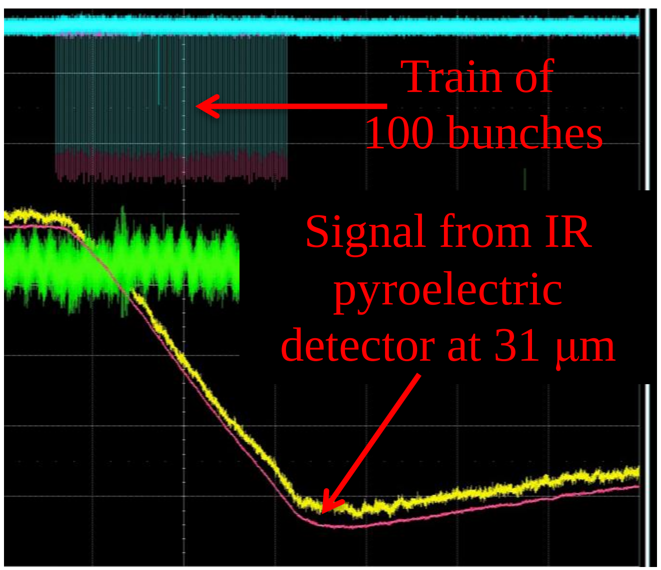
Main points

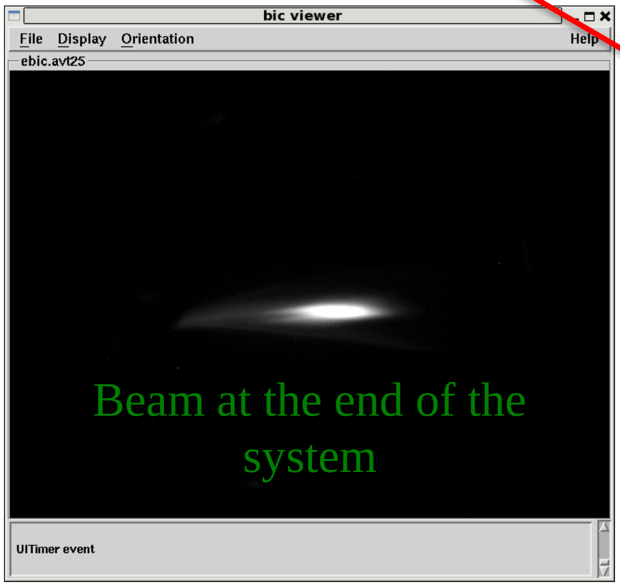
- 113 MHz CW SRF photo-electron gun was designed and built to provide a 1-2 nC bunches with modest normalized emittance ~ 5 mm mrad and rep-rate of 78 kHz... but it turned record after record.
  - *maximum charge per bunch was > 10.5 nC per bunch (saturated charge measuring system – will be updated)*
  - *normalized emittance of 0.32 mm mrad at 0.5 nC per bunch*
  - *2 months long lifetime of high QE lifetime for CsK2Sb photocathode*
- The gun routinely generated at 1.25 MeV (kinetic) CW electron beam (typically 1.5-1.6 nC per bunch), but was also tested at1.5 MeV CW operation, which is limited by LiHe system capacity
- The most important (unique) features of our SRF gun are:
  - *low RF frequency, providing for nearly on-crest acceleration of the electron beam from the emission to the exit: optimal photo-emission phase for 1.25 MeV beam is only -15.37 degrees*
  - *room temperature of the CsK2Sb photocathode system (gold-coated water cooled/warmed stainless steel stalk serving as a half-wave choke) inside 4K Nb cavity*
  - *adjustable depth of the cathode stalk position with respect to the cavity nose – allows to optimize RF focusing of the gun*
  - *UHV transport and storage system for three Mo pucks coated with CsK2Sb*
  - *a dedicated and well-tuned script to pass multipacting barriers*

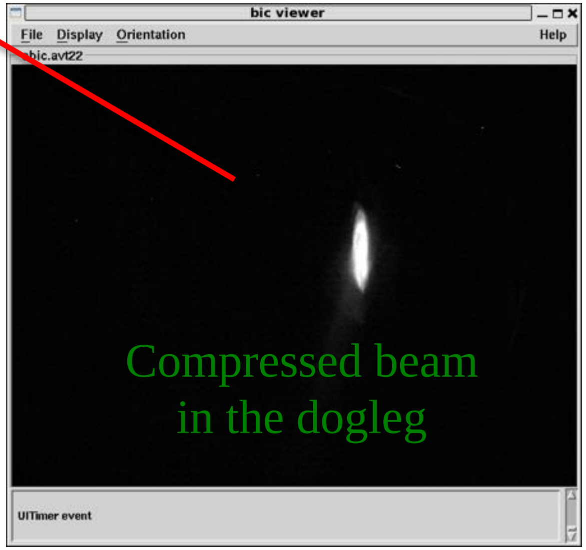
The CeC system commissioning

Common section with RHIC

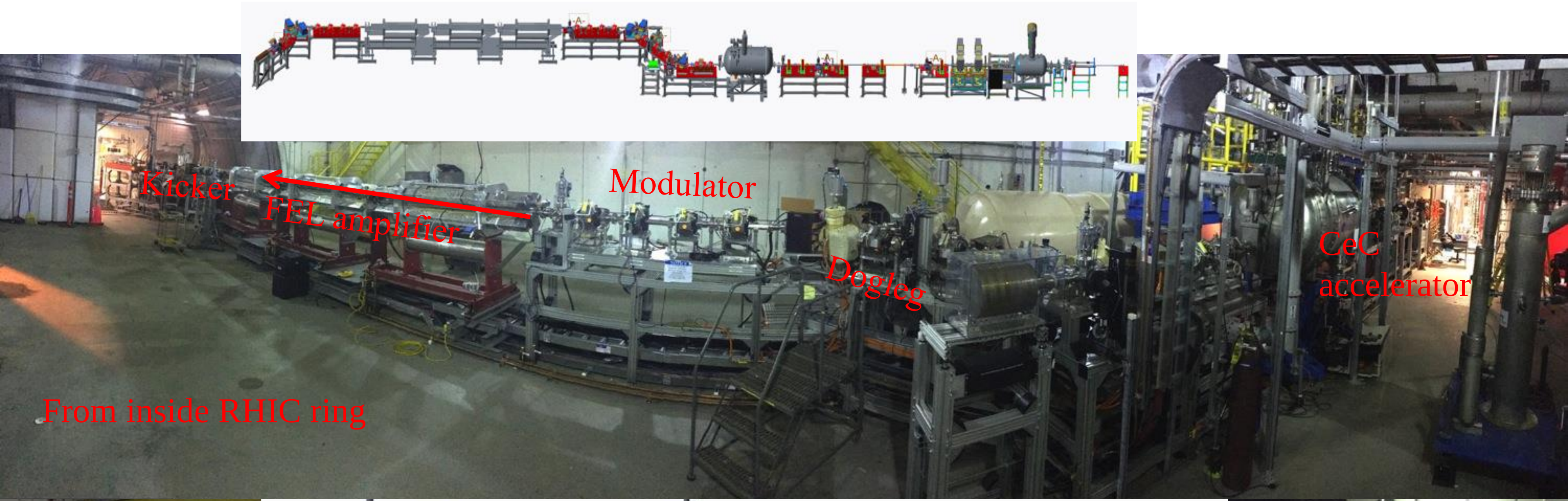


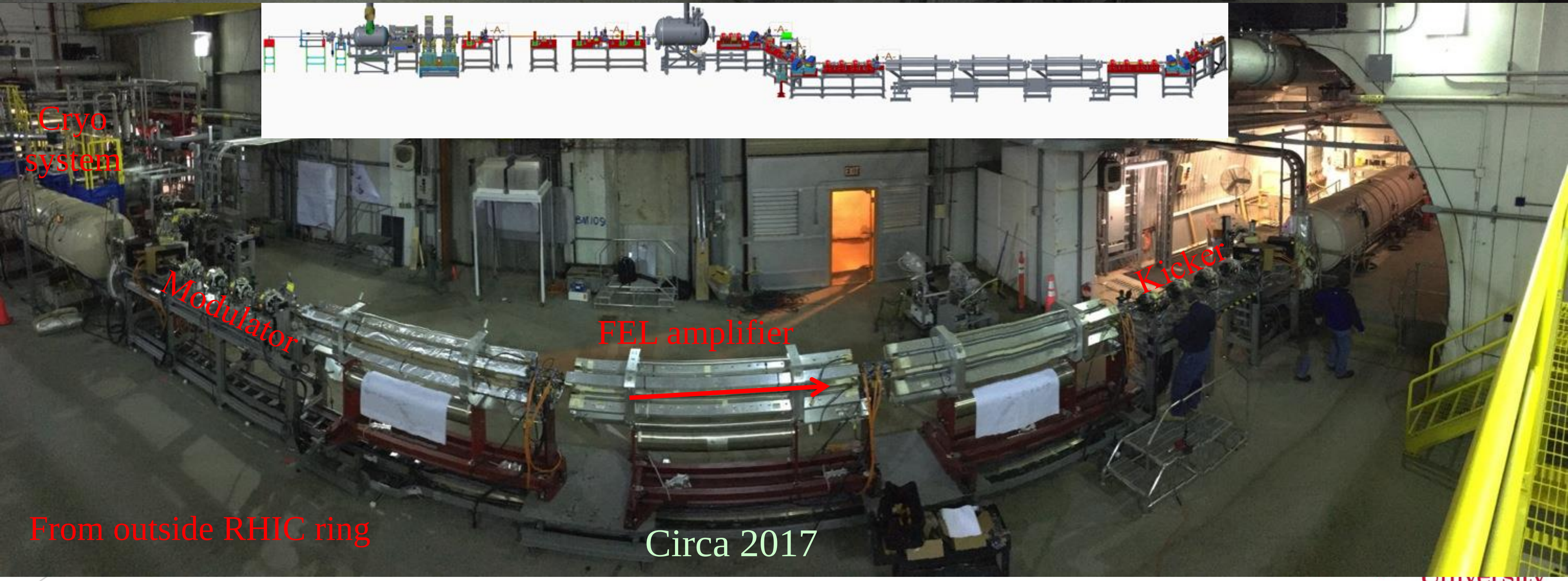




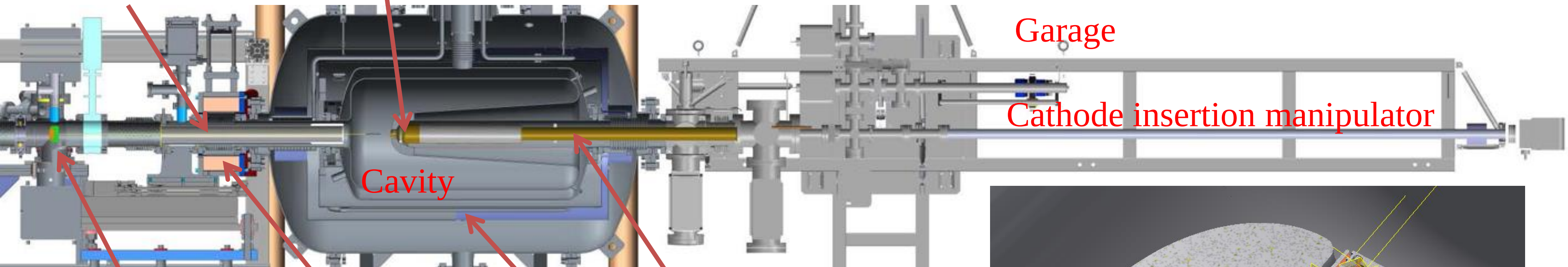


CeC system's panoramic views

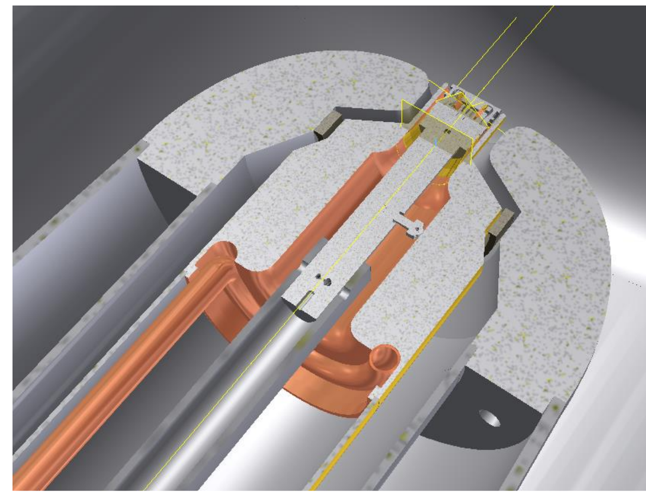




CeC SRF Gun



- Quarter-wave cavity
- Low 113 MHz operating frequency
- Maximum CW voltage – 1.5 MV
- Field gradient 14.1 MV/m at 1.25 MV
- 4 K operating temperature
- Manual coarse tuner
- Fine tuning performed by fundamental power coupler (FPC)
- 4 kW CW solid state power amplifier
- CsK_2Sb Cathode is at room temperature
- Adjustable cathode stalk with an impedance transformer serving as ½ RF choke, used for cavity field pick-up antenna
- Three cathodes are stored in “a garage” for quick change-out



Photocathode end assembly

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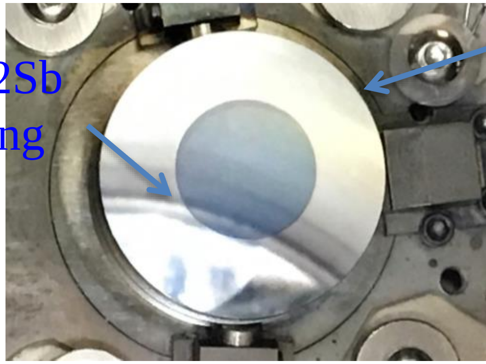
Samples of SRF photo-electron gun performance

In the deposition chamber

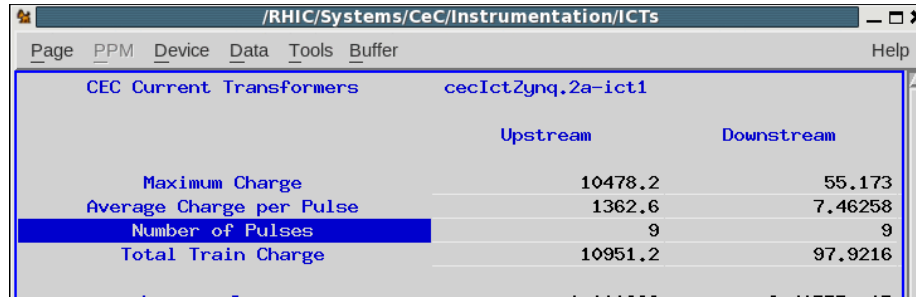
CsK2Sb coating

Mo puck



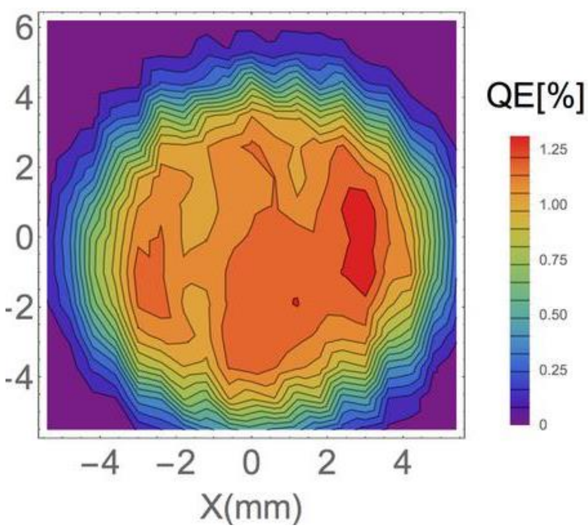
Test of high charge operation

ICT is saturated, Q> 10.5 nC

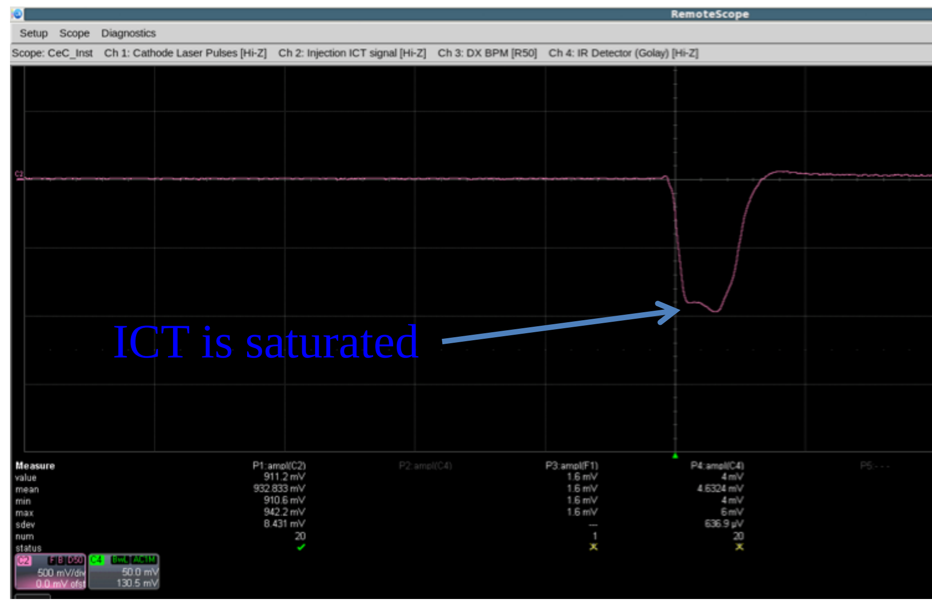


CEC Current Transformers	cecIctZynq.2a-ict1	
	Upstream	Downstream
Maximum Charge	10478.2	55.173
Average Charge per Pulse	1362.6	7.46258
Number of Pulses	9	9
Total Train Charge	10951.2	97.9216

Typical QE from 1% to 4%



QE map inside the gun



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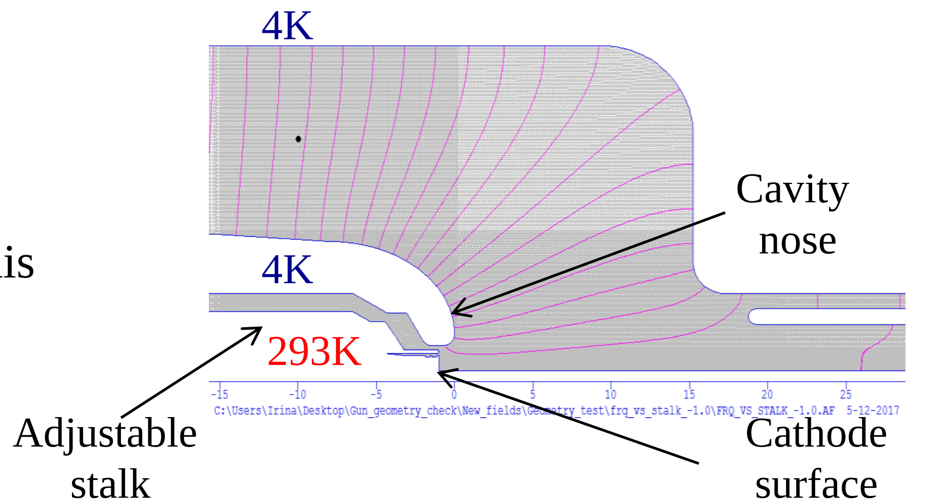
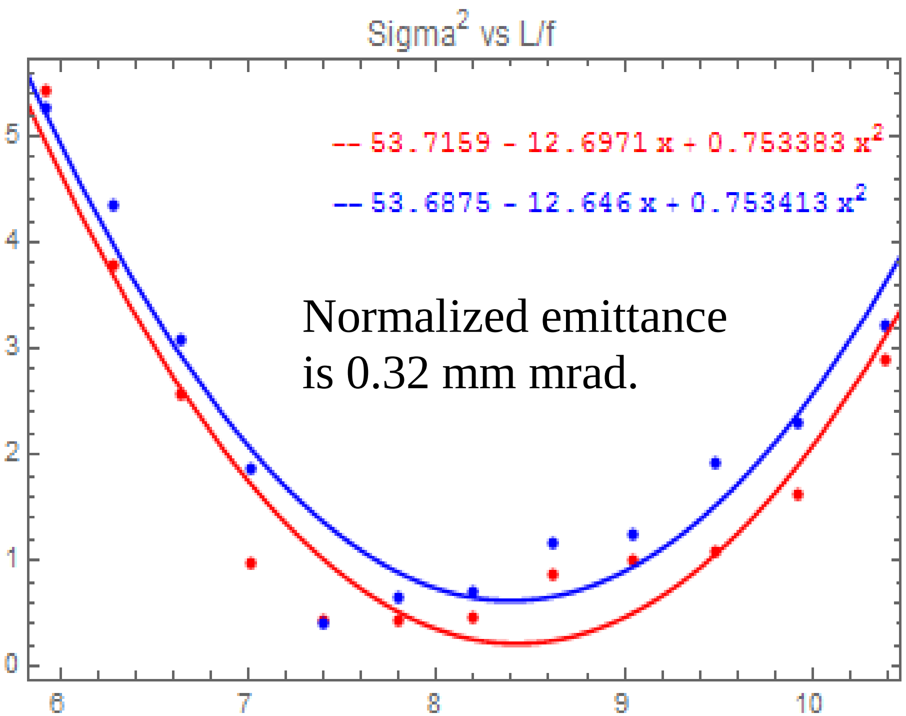
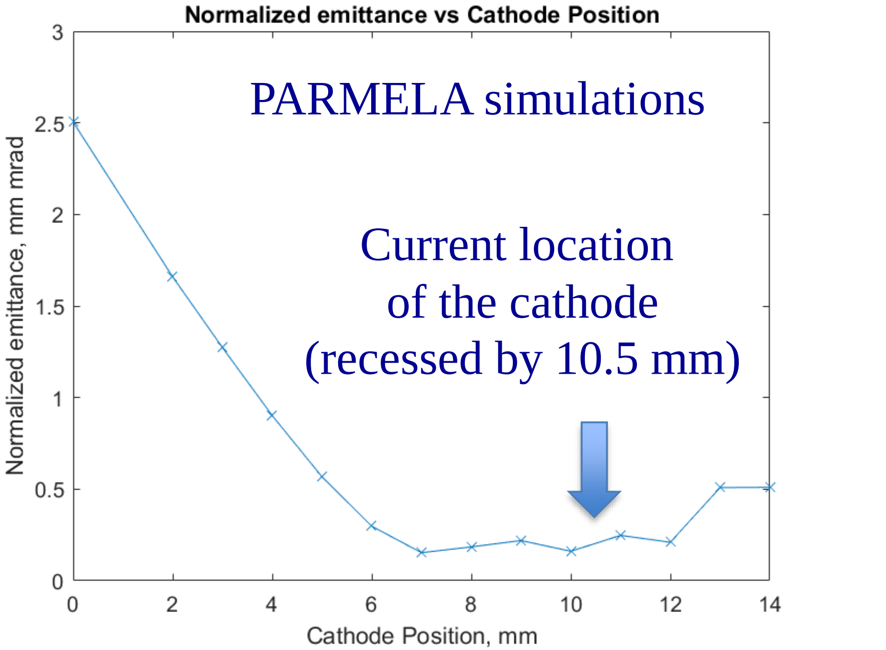
Most unexpected: record low transverse emittance

The beam size was measured on the first profile monitor (3.5 m from the gun) using scan of the gun solenoid current. Beam kinetic energy for this scan was 1.04 MeV, beam charge was 0.5 nC.







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Current status

- CeC experiments, during which beam emittance was not important, with hadron beam had been completed on June 18, 2018
- CeC accelerator will continue operate till mid-September
- During this period we plan to fully characterize quality of electron beam generated by our SRF gun
- CeC accelerator will be also used for studying novel plasma-cascade micro-bunching instability
- We proposed to continue the SRF gun program into the future and are exploring possible funding possibilities to conduct it

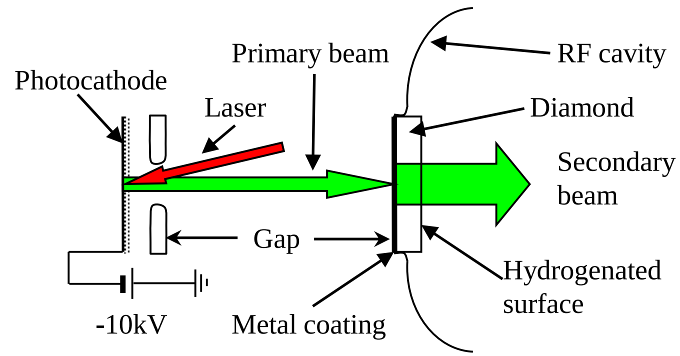
Proposed future research with CeC SRF gun

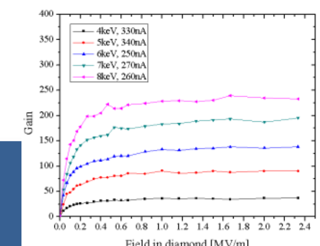
Take the advantage of 113 MHz SRF gun high gradient, CW operation and ultra high vacuum, it will be very unique test bed for the following cathodes researches.

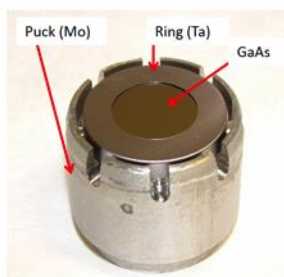
<u>High current, long lifetime, ultra code electron source:</u>

Diamond amplifier (needs CW RF field)

- Extremely small angular distribution
- Not sensitive to residual gas /quick recovery
- High average current in principle







<u>Polarized electron source:</u>

Strained GaAs (needs XHV)

- High polarization
- Extremely sensitive to residual gas

Topographic insulator (needs high gradient)

- High polarization
- Not wavelength dependence

<u>Ultra cold electron sources:</u>

Nano-crystalline diamond/Si (needs high gradient)

- Long lifetime
- Small thermal emittance

Large crystal K_2CsSb/heterjunction K(Na)CsSb

- Small mean transverse energy
- Small dark current

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Conclusions

- We built our SRF photo-electron gun for completely different purpose than typical guns pursuing generation of high brightness beams
- We expect this gun to do well, but experimental results exceeded our expectations:
  - the gun easily generated bunch charges in excess of 10 nC
  - it routinely generates CW 1.25 MeV e-beam with 1.5 nC/bunch and 78 kHz rep-rate
  - it generating beams with record high transverse brightness (0.32 mm mrad projected (!) normalized emittance for 0.5 nC bunch)
  - limited diagnostics (money!) does not allow to measure slice emittance, which is definitely lower than the projected
- Unique features of our SRF gun are responsible for this success:
  - *low RF frequency with on-crest acceleration of the electron beam from the emission to the gun exit*
  - *room temperature of the CsK2Sb photocathode system inside 4K Nb cavity*
  - *adjustable depth of the cathode stalk position*
  - *a dedicated and well-tuned script to pass multipacting barriers*
- Our SRF gun satisfies requirements as e-beam source for CW X-ray FELs