Accelerator R&D towards eRHIC

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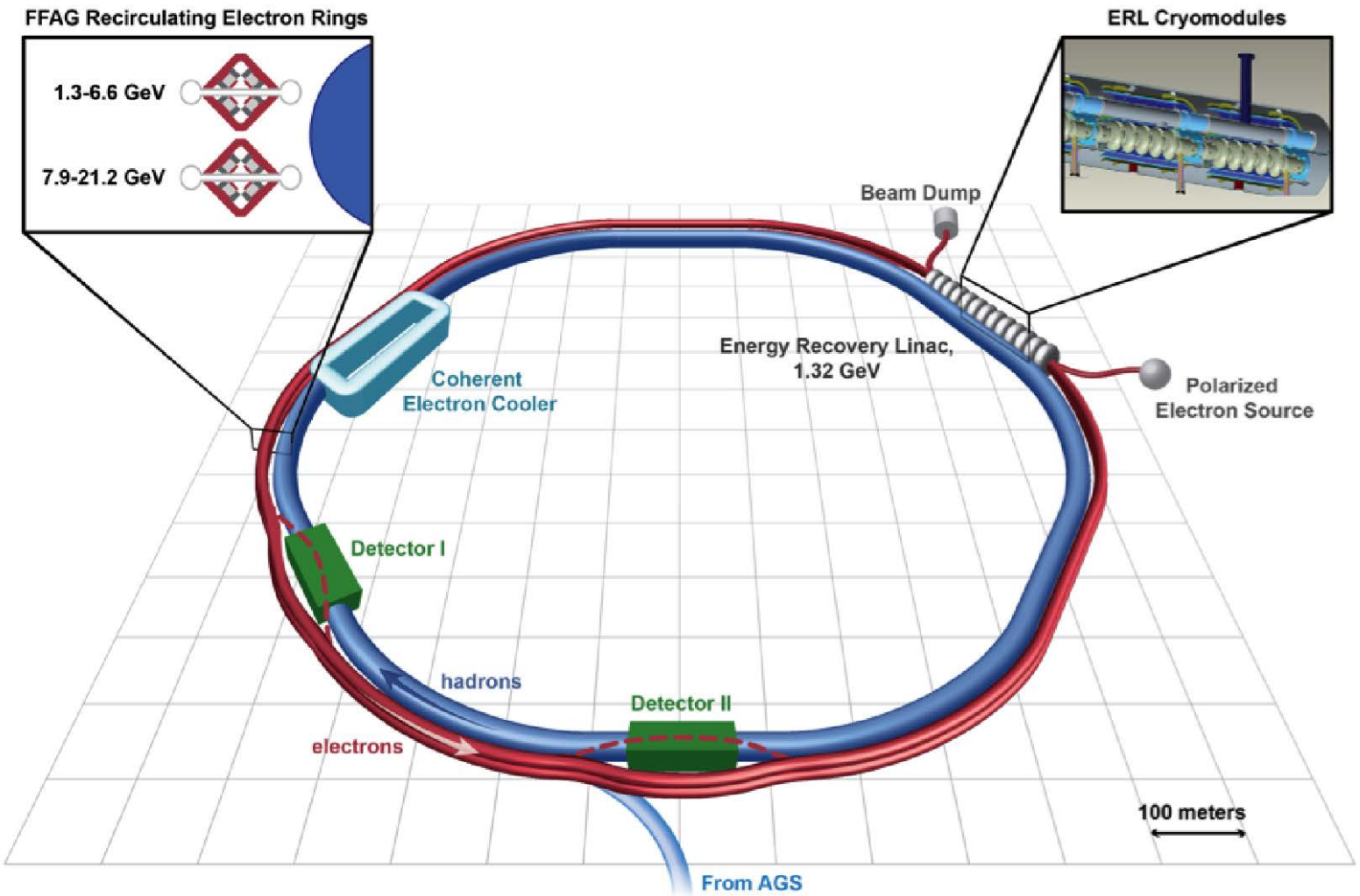
For the eRHIC Team

eRHIC, linac-ring EIC

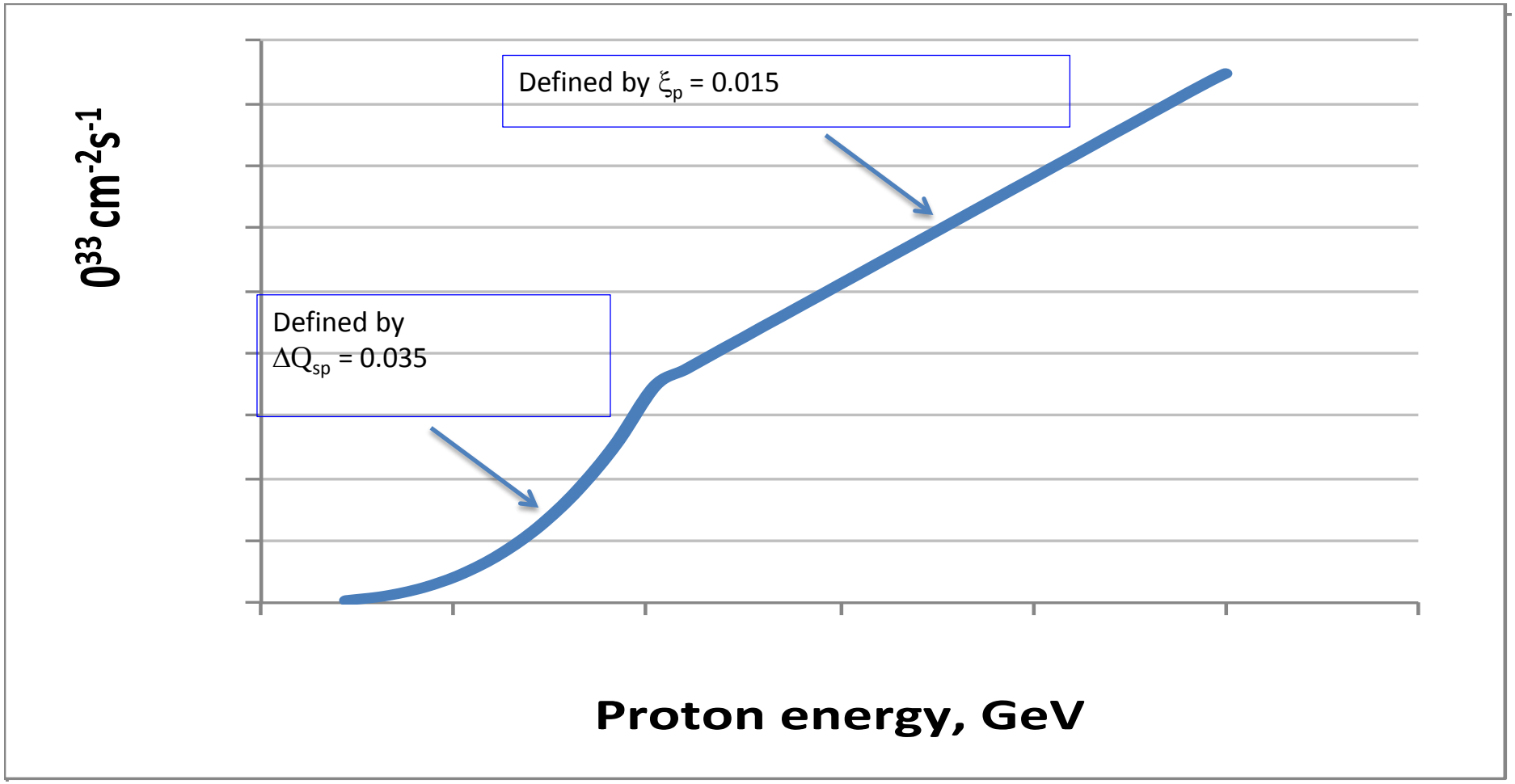
- Linac=ERL, or the luminosity is negligible
- The first proposed linac-ring collider
  - 250GeV (p) *15.9 (e) @1.5e33 cm-2 s-1
- Why linac-ring
  - Luminosity, remove the limitation of b-b parameter of e-beam
  - High spin polarization (e-beam)
  - Easy to upgrade
  - Easier synchronization with various ion energy.

I. Ben-Zvi, J. Kewisch, J. Murphy and S. Peggs, Accelerator Physics Issues in eRHIC, NIM A463, 94 (2001), C-A/AP/14 (2000).

eRHIC Layout



Luminosity


Defined by ξ_p = 0.015
Defined by
ΔQ_{sp} = 0.035
0^{33} cm^{-2}s^{-1}
Proton energy, GeV

Beam Synchronization, Detail

- Ion at sub-TeV energies is not ultra-relativistic, Change in energy → velocity → frequency
- Linac-ring scheme enable a trick to adjust the frequency of RF to sychronize electron and ion at discrete ion energies
- Reduces the need of path lengthening.
- Ring-ring scheme can not take the trick.

eRHIC R&D efforts

- IR design, crab cavity and dynamic aperture
- Beam cooling – major R&D efforts, high priority R&D
- Polarization and Polarimetry (including electron polarimetry)
- Polarized ^{3}He production and acceleration

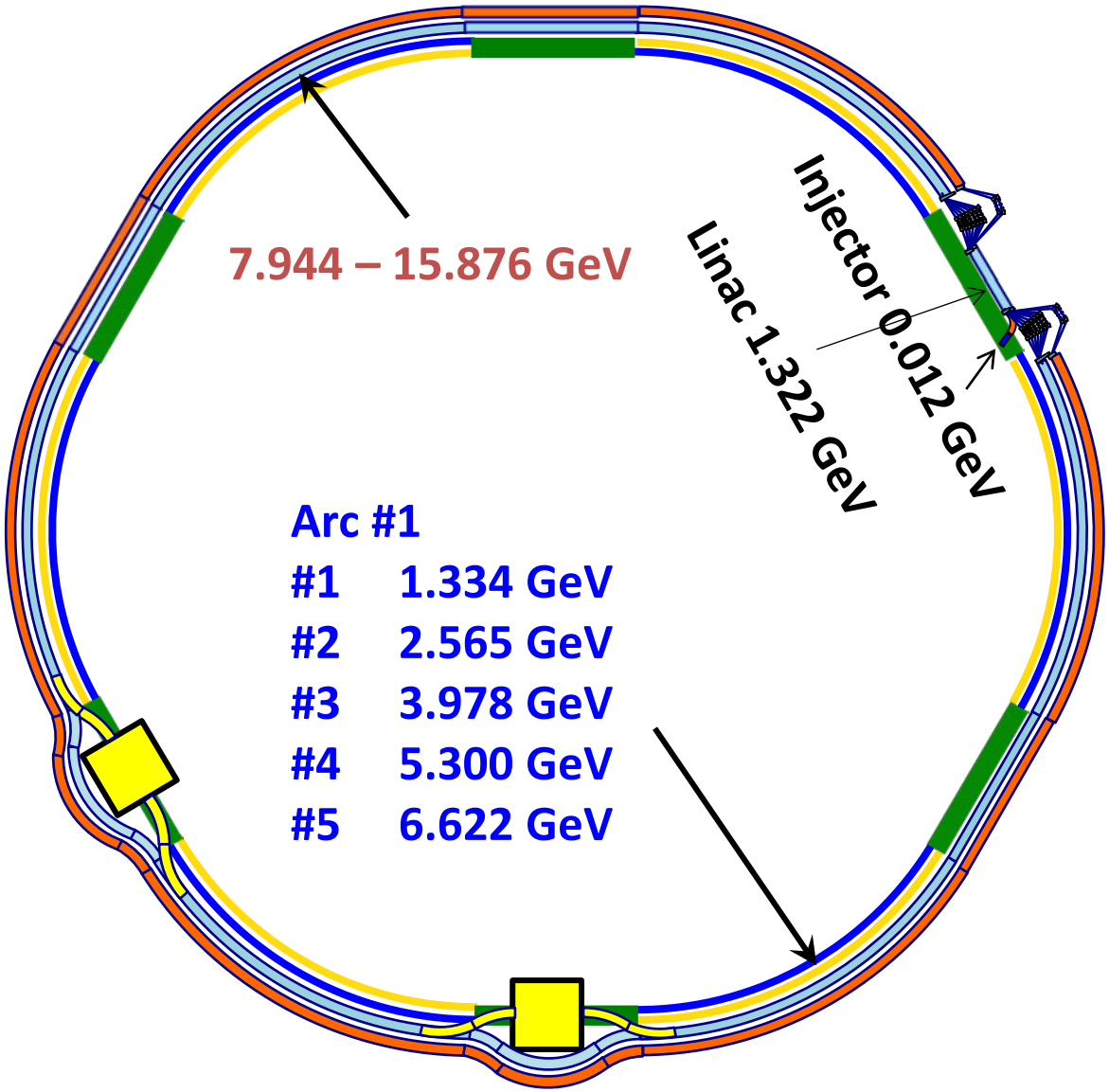
- Polarized electron source
- Superconducting RF system
- Multipass ERL and related beam dynamics
- FFAG energy recovery pass
- Linac-ring beam-beam interaction
- .....

NS-FFAG Layout of the eRHIC

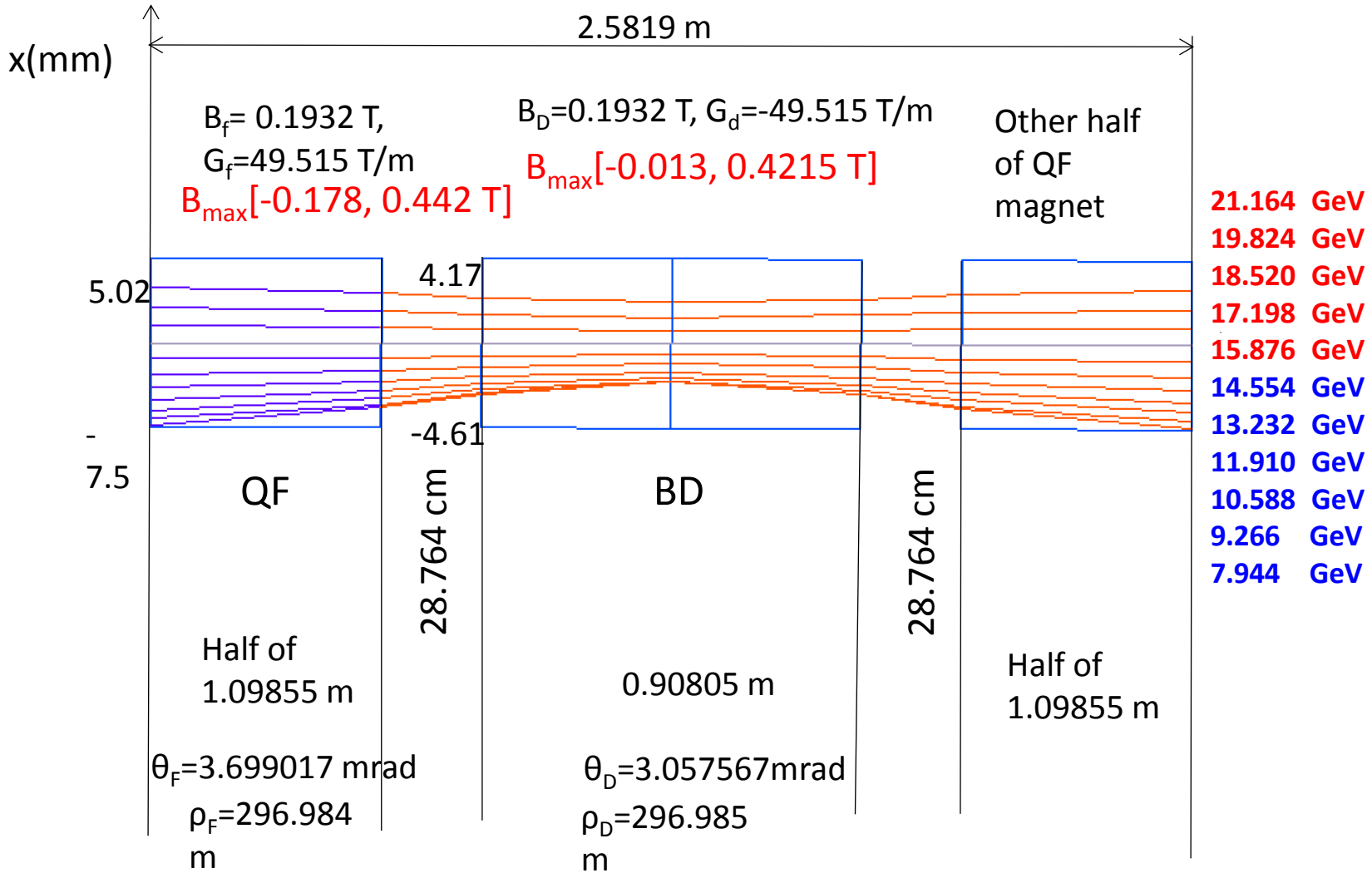
* 21GeV Design, Jan'14

Arc #2

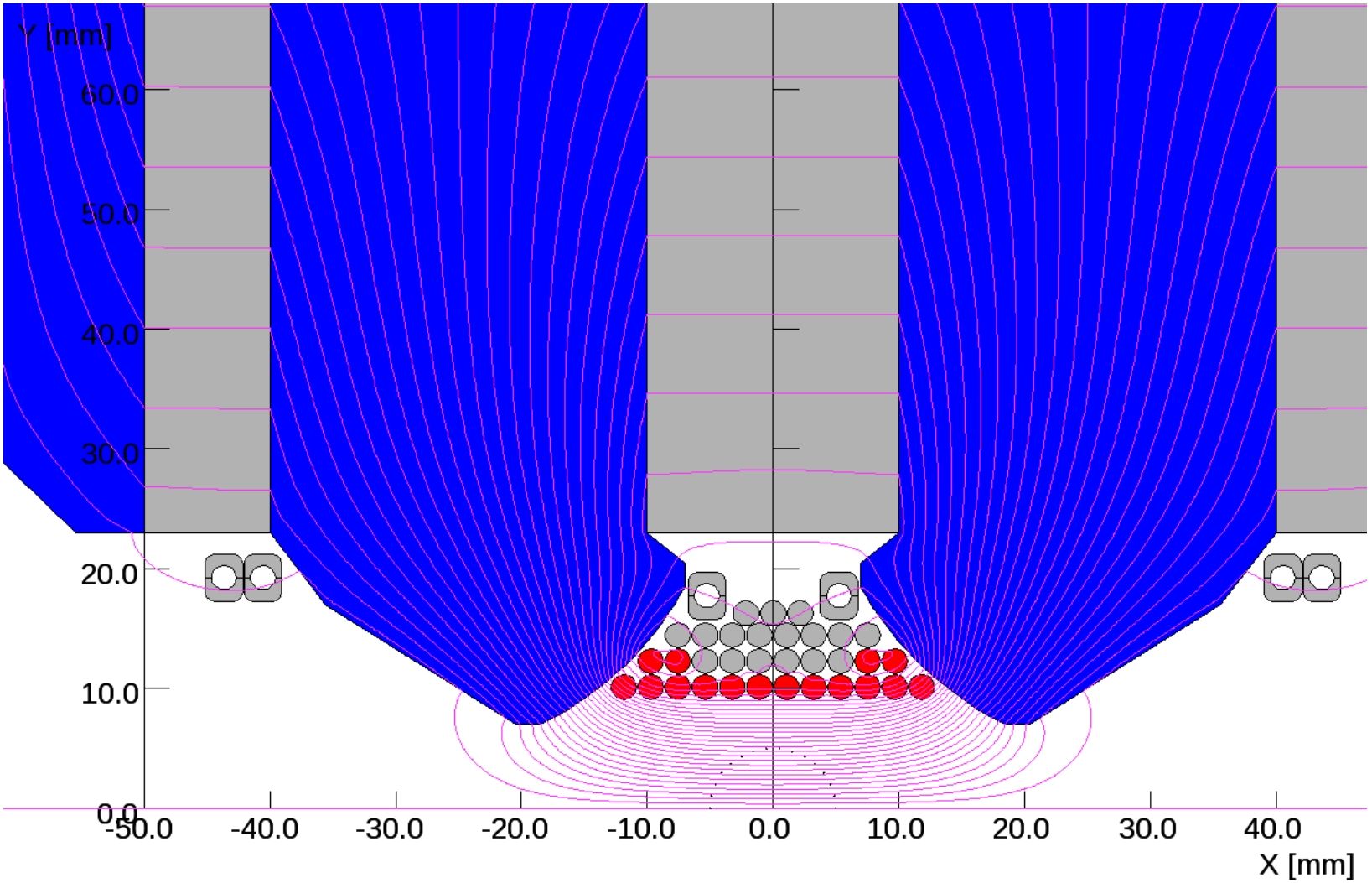
#1	7.944 GeV
#2	9.266 GeV
#3	10.588 GeV
#4	11.910 GeV
#5	13.232 GeV
#6	14.554 GeV
#7	15.876 GeV
#8	17.198 GeV
#9	18.520 GeV
#10	19.842 GeV
#11	21.164 GeV



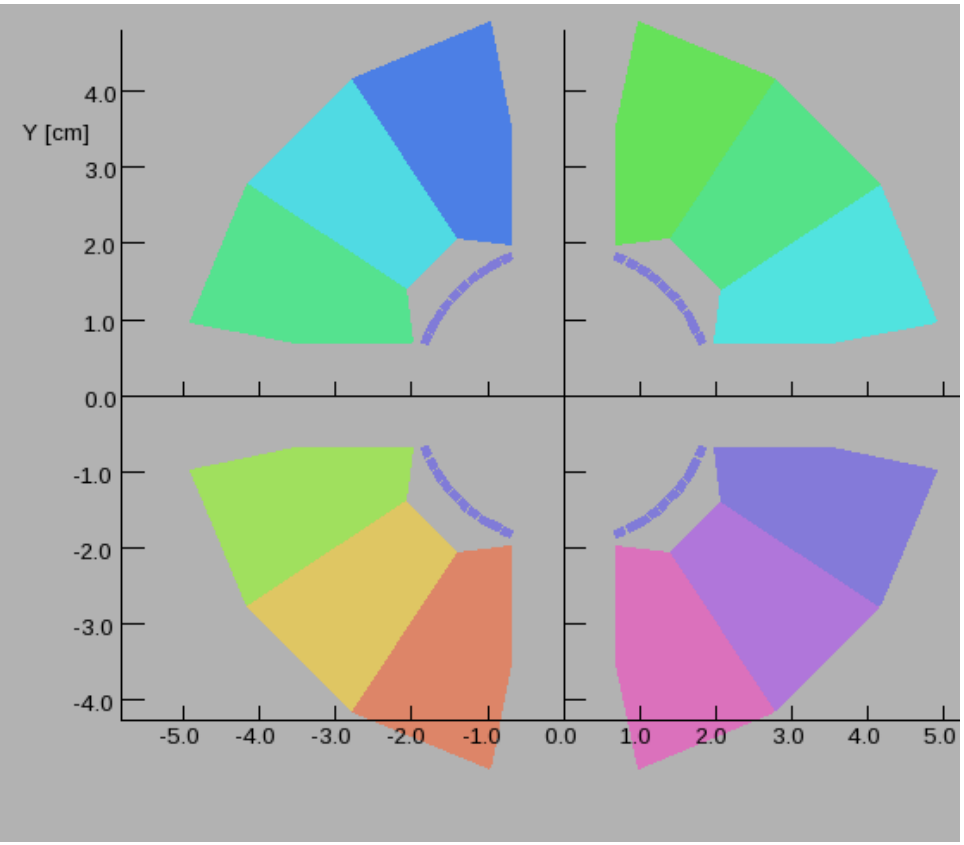
Trajectory in FFAG

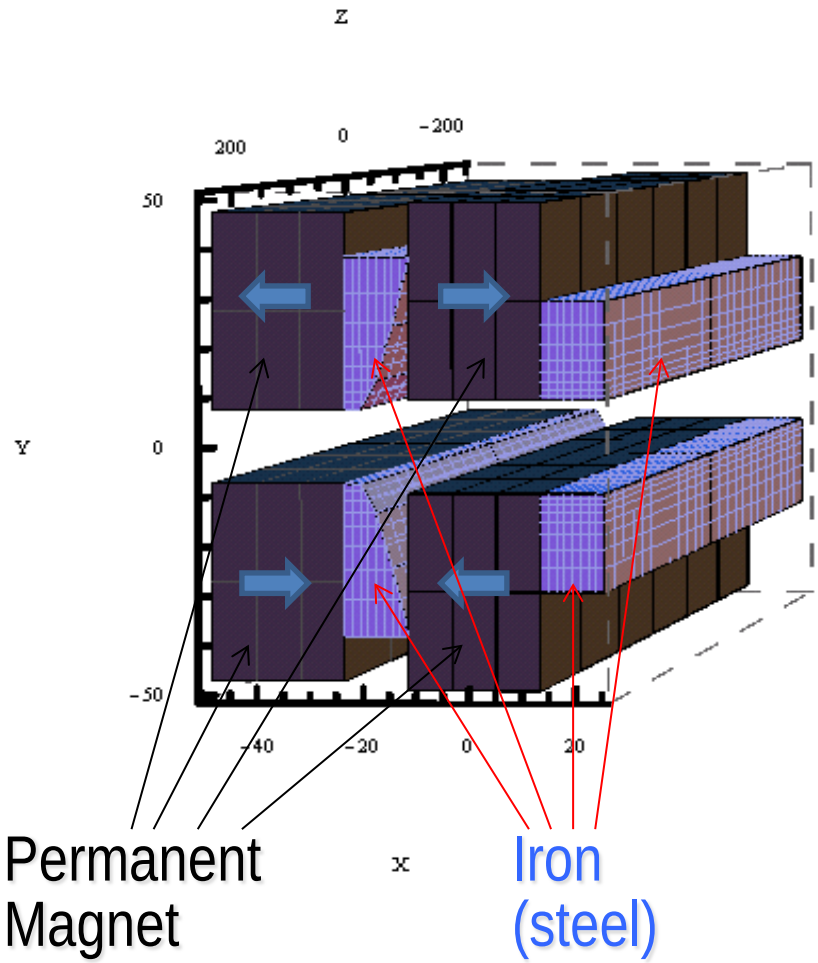


Magnet for FFAG arcs



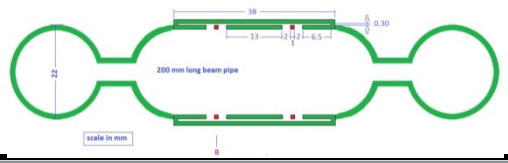
Two alternative magnets

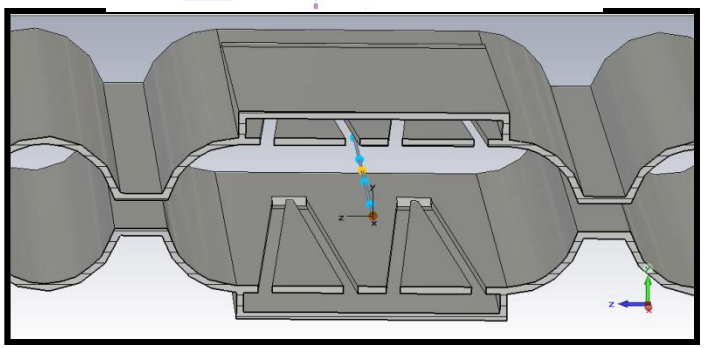


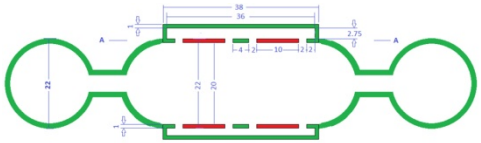


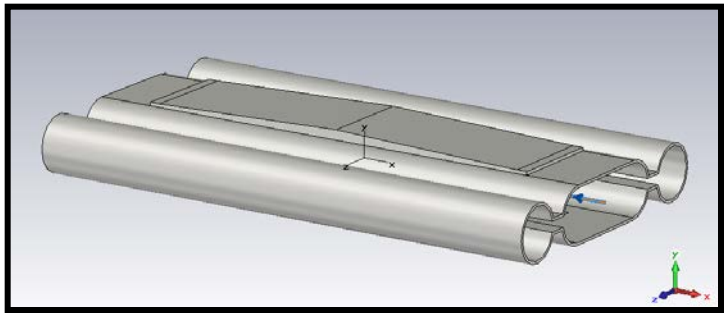
Bunch-by-Bunch BPM

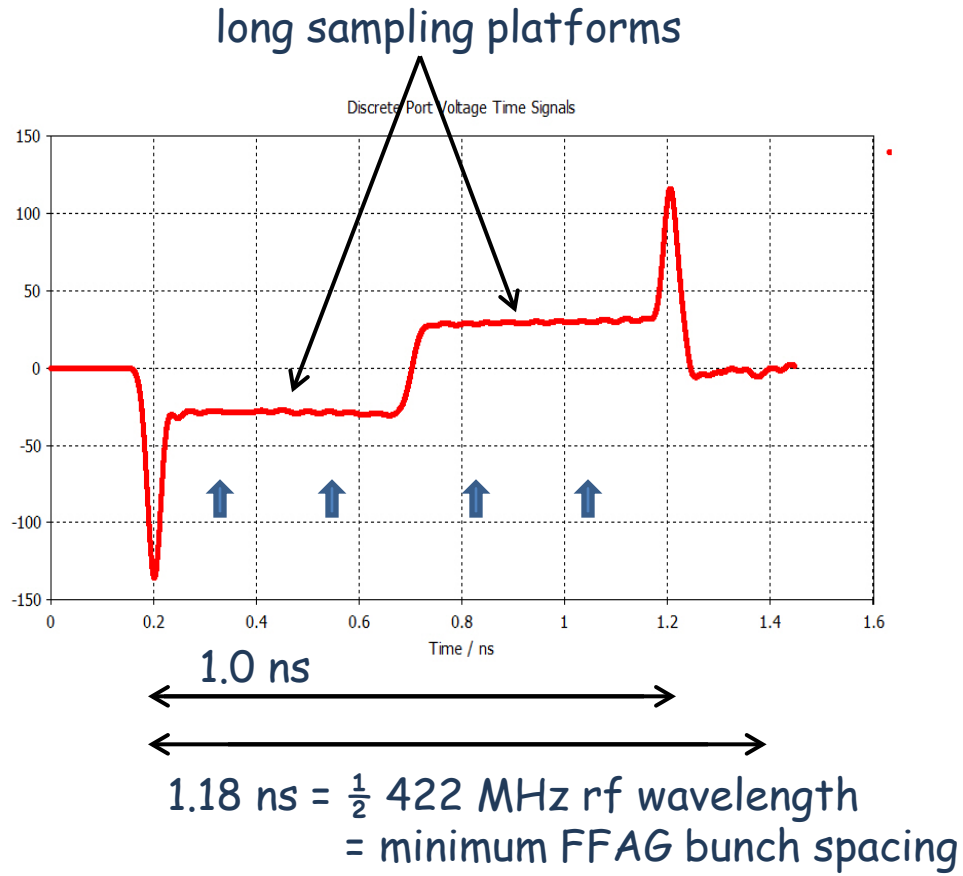
With fewer BPMs than magnets, the space between some FFAG magnets could be used entirely by a BPM; this design produces "stretched" output pulses (from 13 ps rms bunches) intrinsically in the BPM in-vacuum hardware









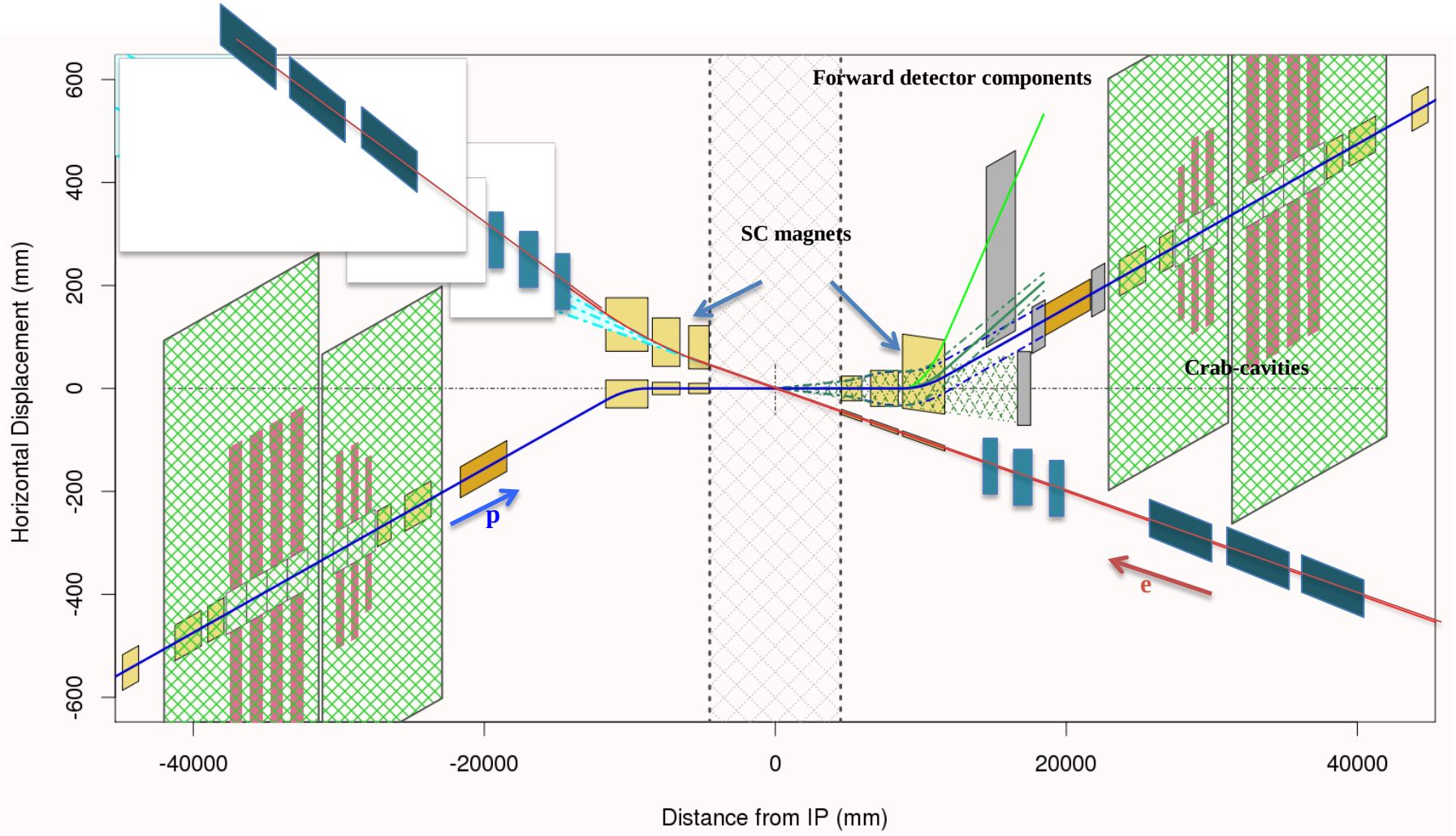


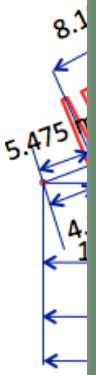
signal processing: use pair of 2 GSPS ADCs triggered ~ 200 ps apart

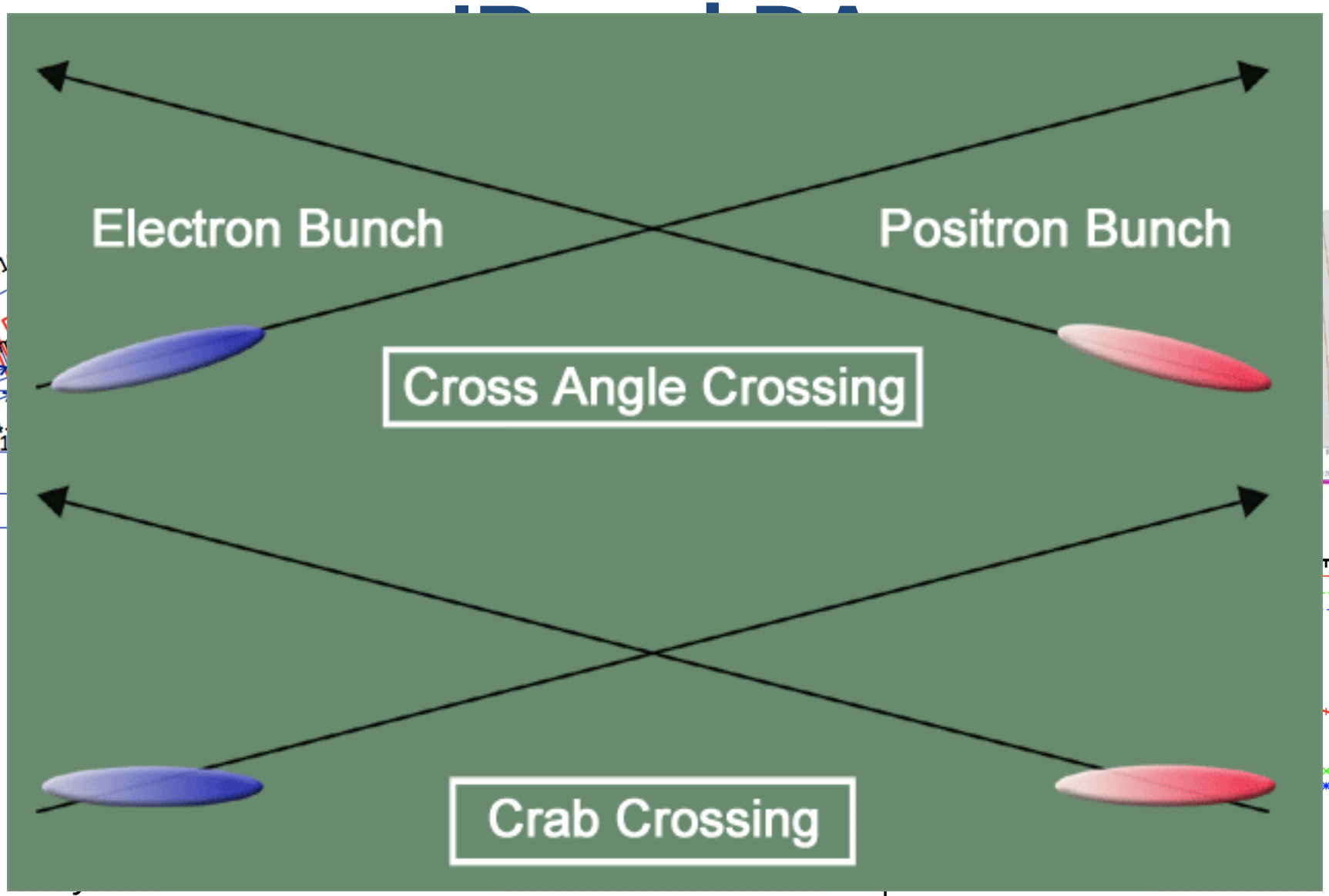
Multi-pass FFAG Prototype

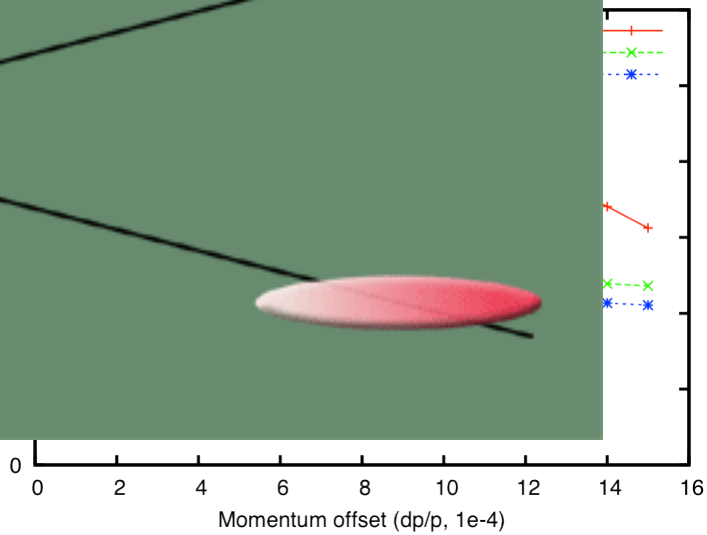
- There is on-going plan to build a multi-pass FFAG Energy Recovery Linac prototype to prove the principle and the method of detecting and correcting the beam.
  - Energy of linac ~100MeV
  - # of passes: ~4

IR design


Forward detector components
SC magnets
Crab-cavities
p
e
Horizontal Displacement (mm)
600
400
200
0
-200
-400
-600
-40000
-20000
0
20000
40000
Distance from IP (mm)







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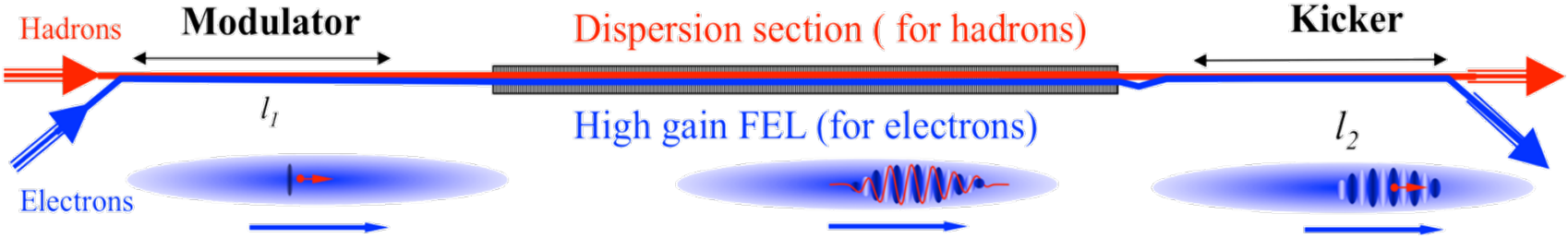
upstream of IP

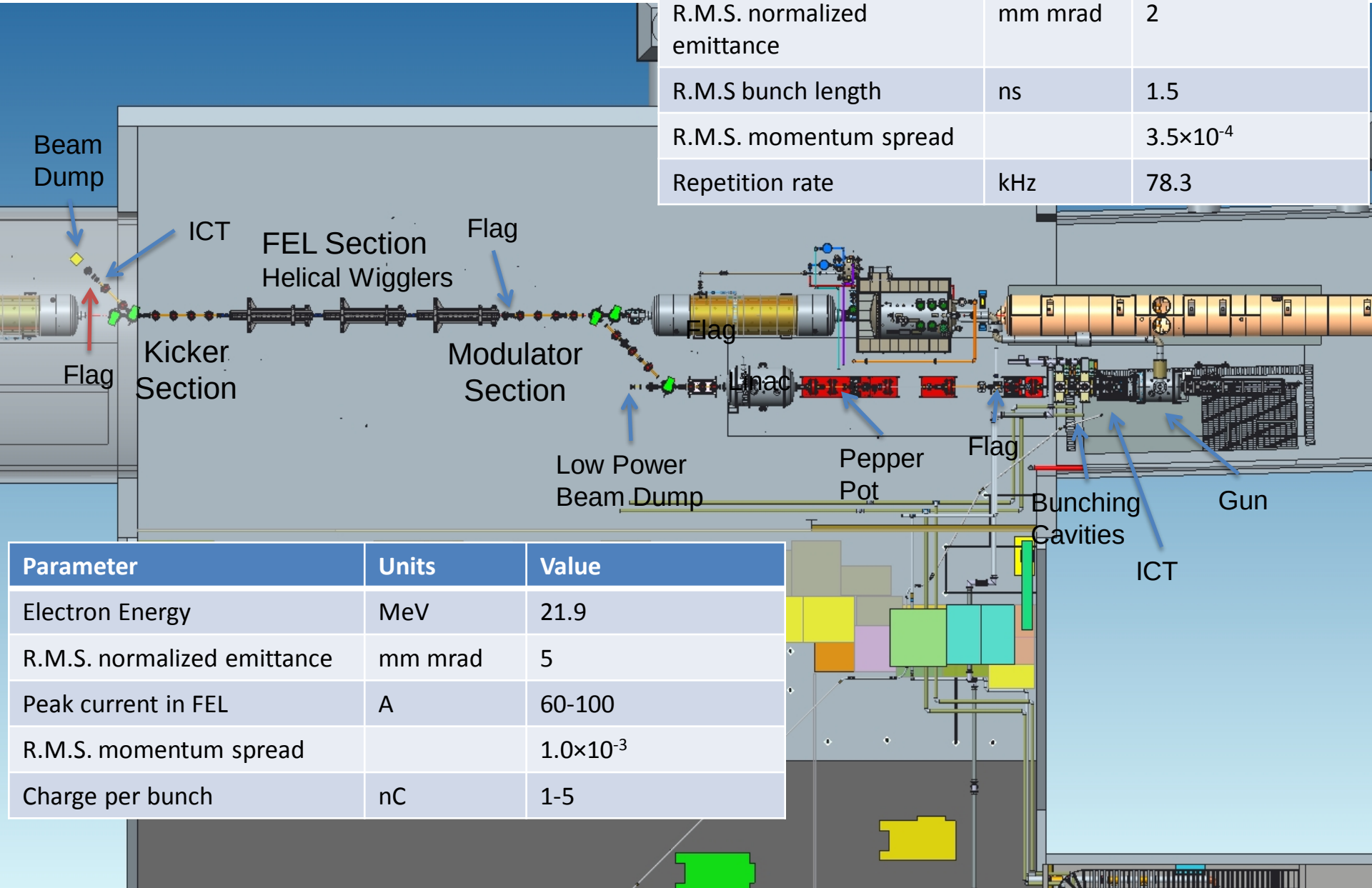
Beam cooling, CEC PoP



- Traditional stochastic cooling does not have enough bandwidth to cool intense proton beams (~ 3×10^{11}/nsec). Efficiency of traditional electron cooling falls as a high power of hadron's energy. Coherent Electron Cooling has a potential for high intensity beams including heavy ions.
- Research Goals:
  - Develop complete package of computer simulation tools for the coherent electron cooling
  - Demonstrate cooling of the ion beam
  - Validate developed model
  - Develop experimental experience with CeC system

CEC PoP, cont'd

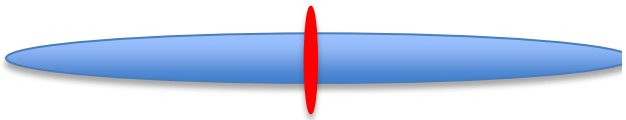
Parameter	Units	Value
Ion's Energy	GeV/u	40
R.M.S. normalized emittance	mm mrad	2
R.M.S bunch length	ns	1.5
R.M.S. momentum spread		3.5×10^{-4}
Repetition rate	kHz	78.3



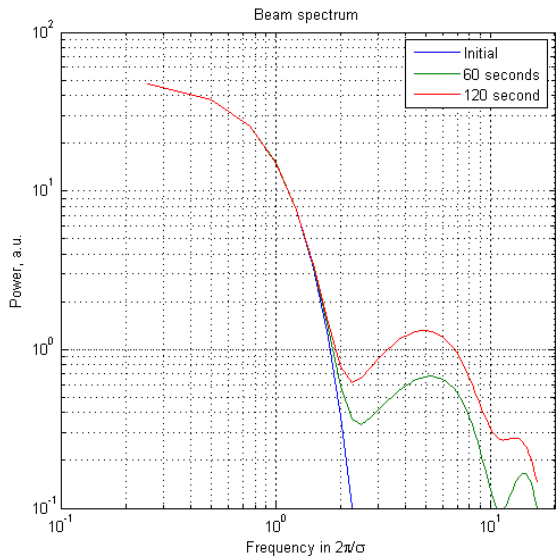
Parameter	Units	Value
Electron Energy	MeV	21.9
R.M.S. normalized emittance	mm mrad	5
Peak current in FEL	A	60-100
R.M.S. momentum spread		1.0×10^{-3}
Charge per bunch	nC	1-5

CEC PoP, anticipated results

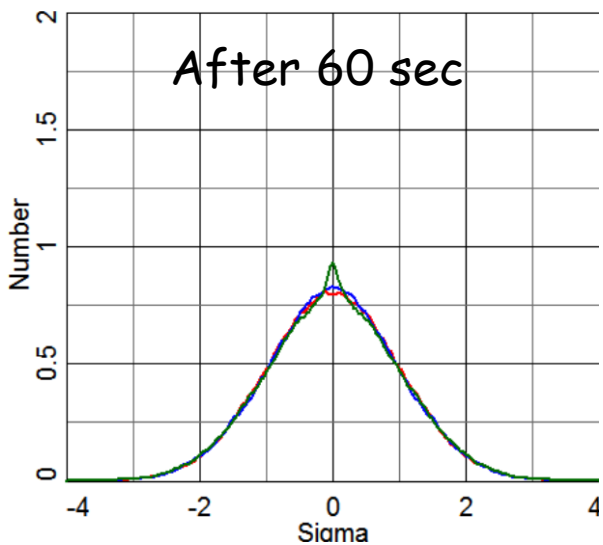
Electron bunch – 10 psec

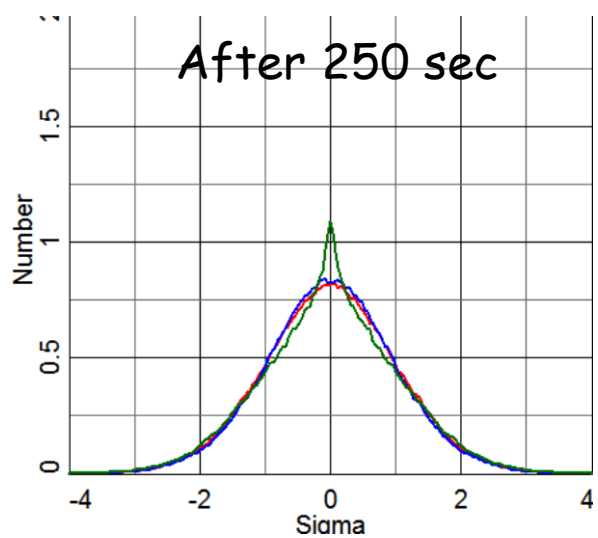


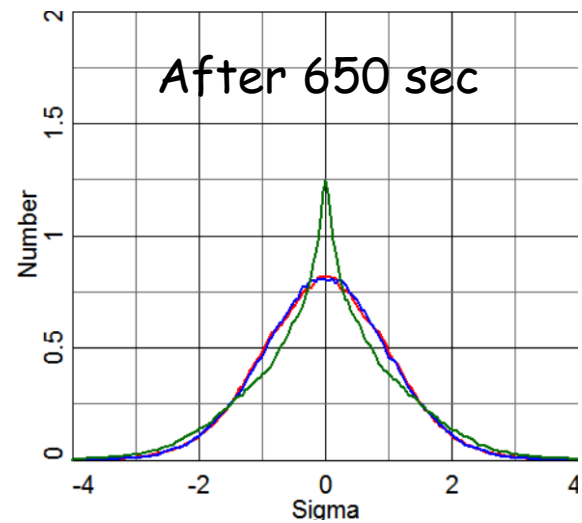
Ion bunch – 2 nsec



r.m.s. length of the cooled part 80-120 ps. The cooling effects can be observed with oscilloscope 2 GHz or more bandwidth or spectrum analyzer with similar upper frequency







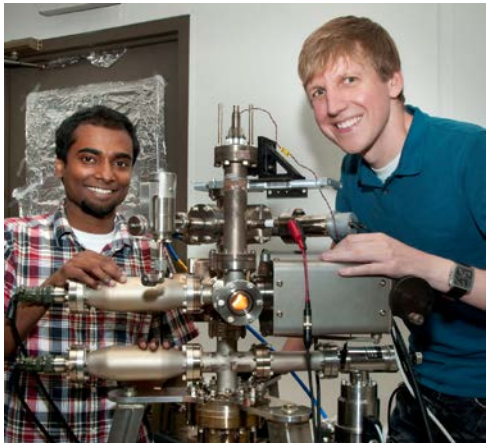
Modeling of cooling is performed with betacool by A. Fedotov

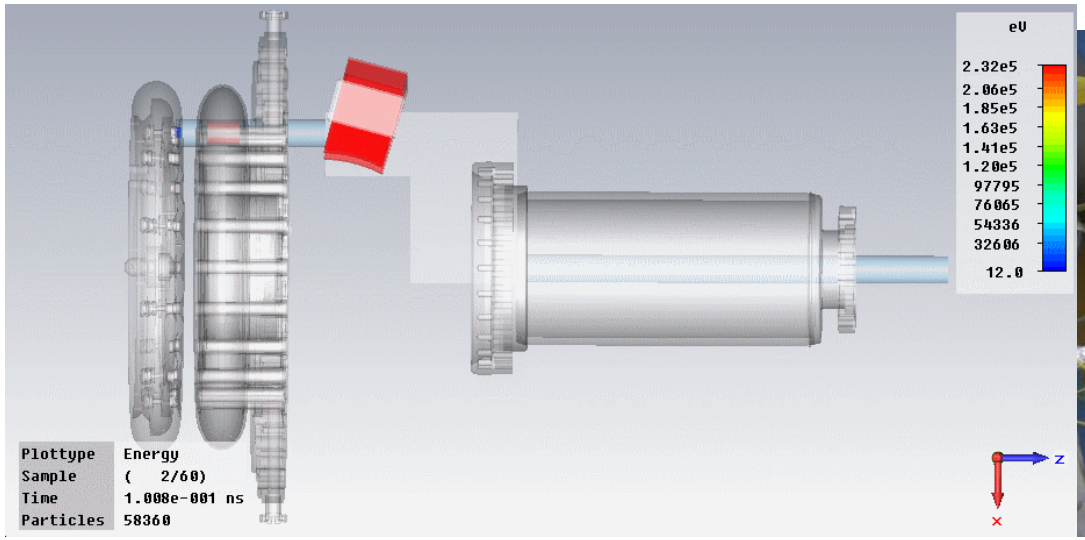
CEC timeline

- CEC PoP RHIC ramp is developed
- Injection system (112 MHz gun, 500 MHz buncher) were installed.
- Main cavity (704MHz) is fabricated.
- Commission injector system in July 2014
- Experiment starts 2015

Polarized e-source

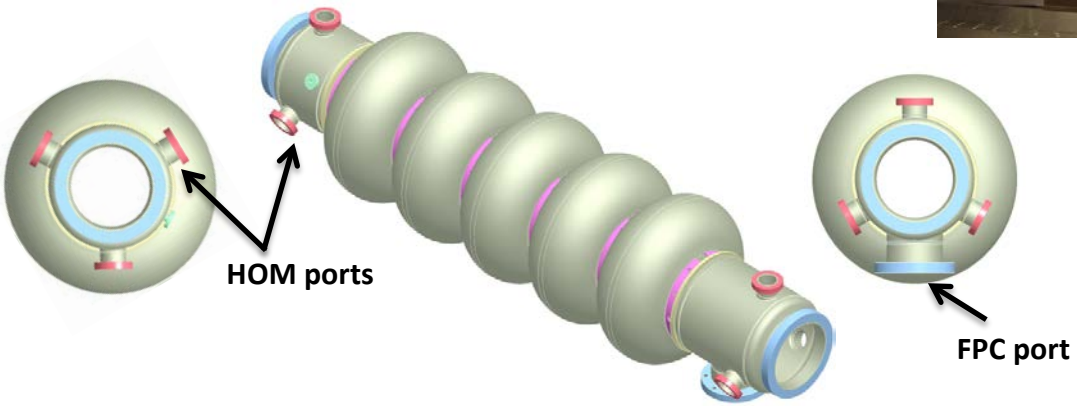
- We are aiming at a high-current (50 mA), high-polarization electron gun for eRHIC.
- The principle we are aiming to prove is funneling multiple independent beams from 20 cathodes.
- External review was carried out in 2012.
- Next week, first HV conditioning and possibly first beam!

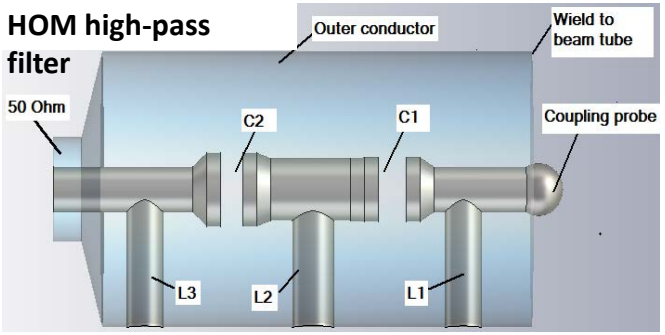




5-cell SRF cavity

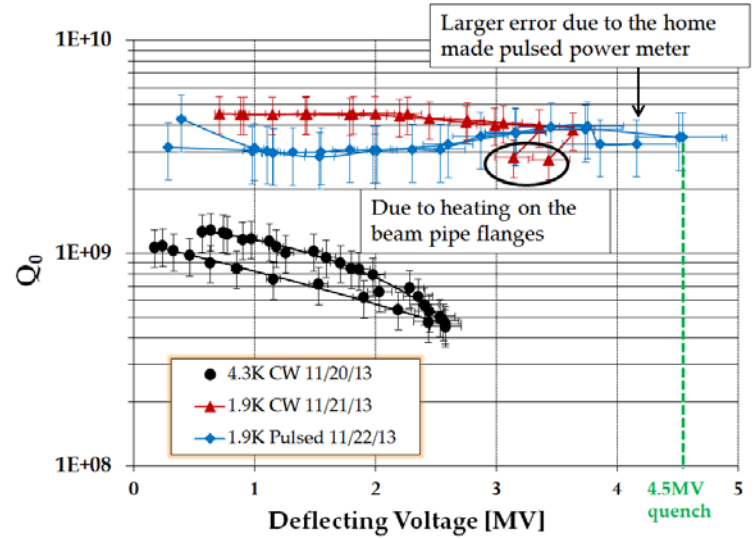
- eRHIC will utilize five-cell 422 MHz cavities, scaled versions of the BNL3 704 MHz cavity developed for high current linac applications.
- Stability considerations require cavities with highly damped HOMs.
- The HOM power is estimated at 12 kW per cavity at a beam current of 50 mA and 12 ERL passes.
- Apply funding to build prototype.

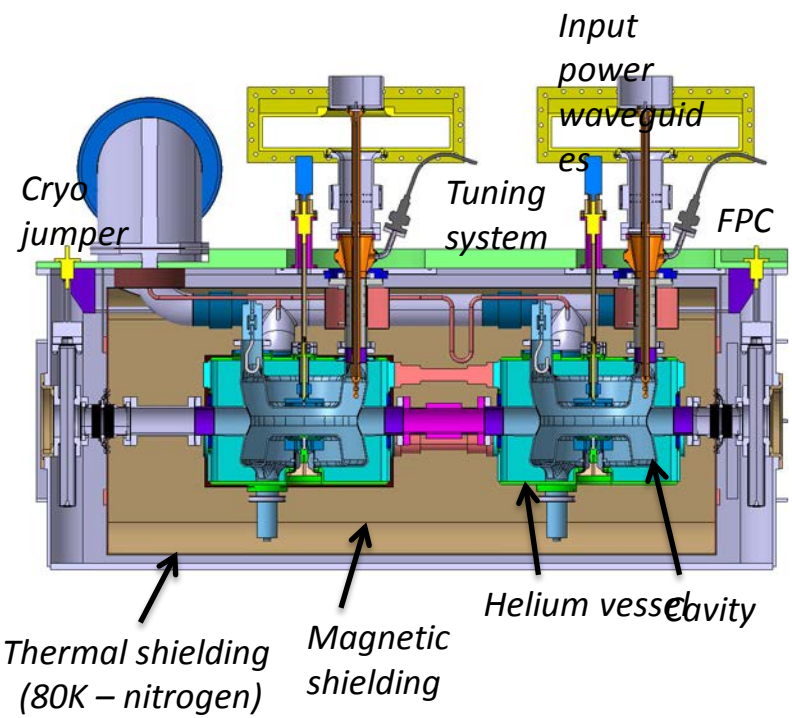


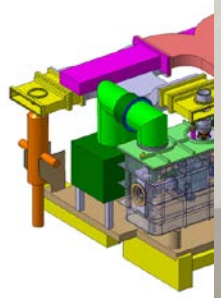


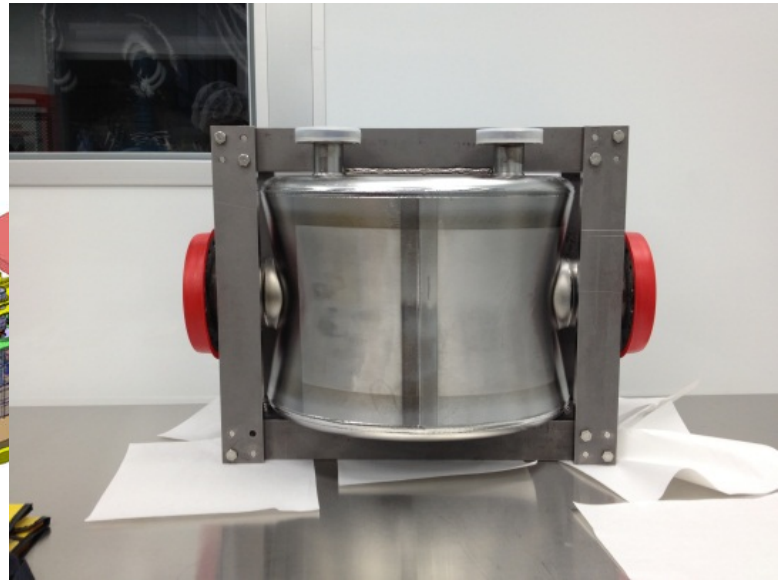
Crab Cavity

- Development of a highly compact Double Quarter Wave Crab Cavity at 400 MHz.
- Prototype to be tested in the CERN SPS in 2016- 2017.





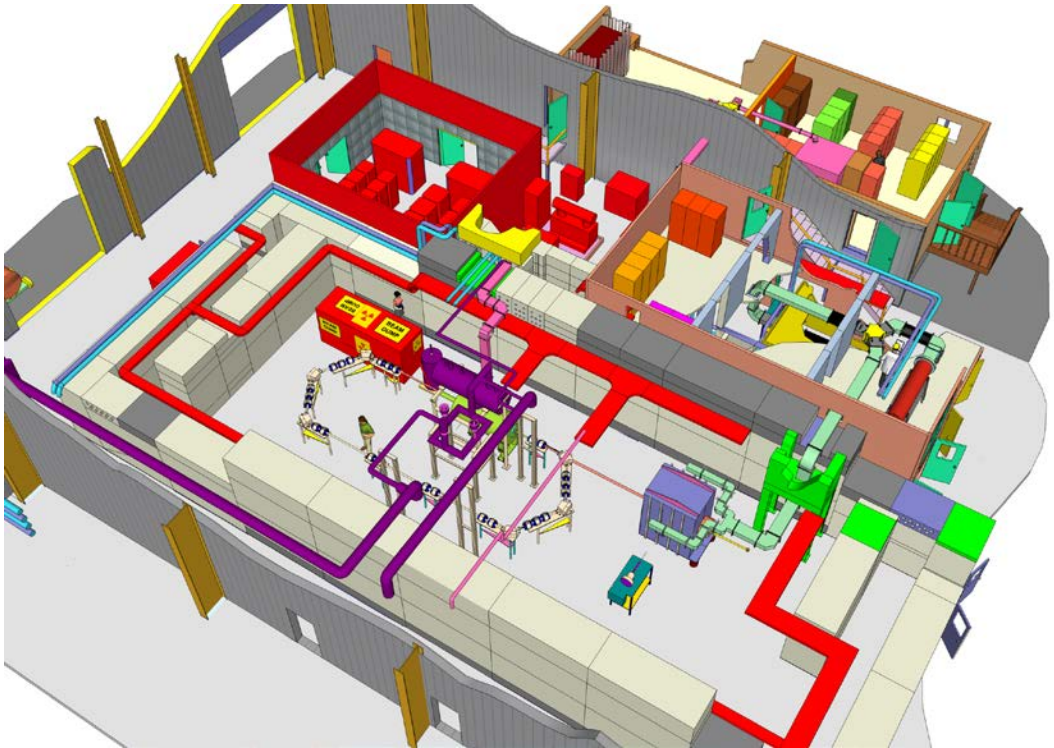




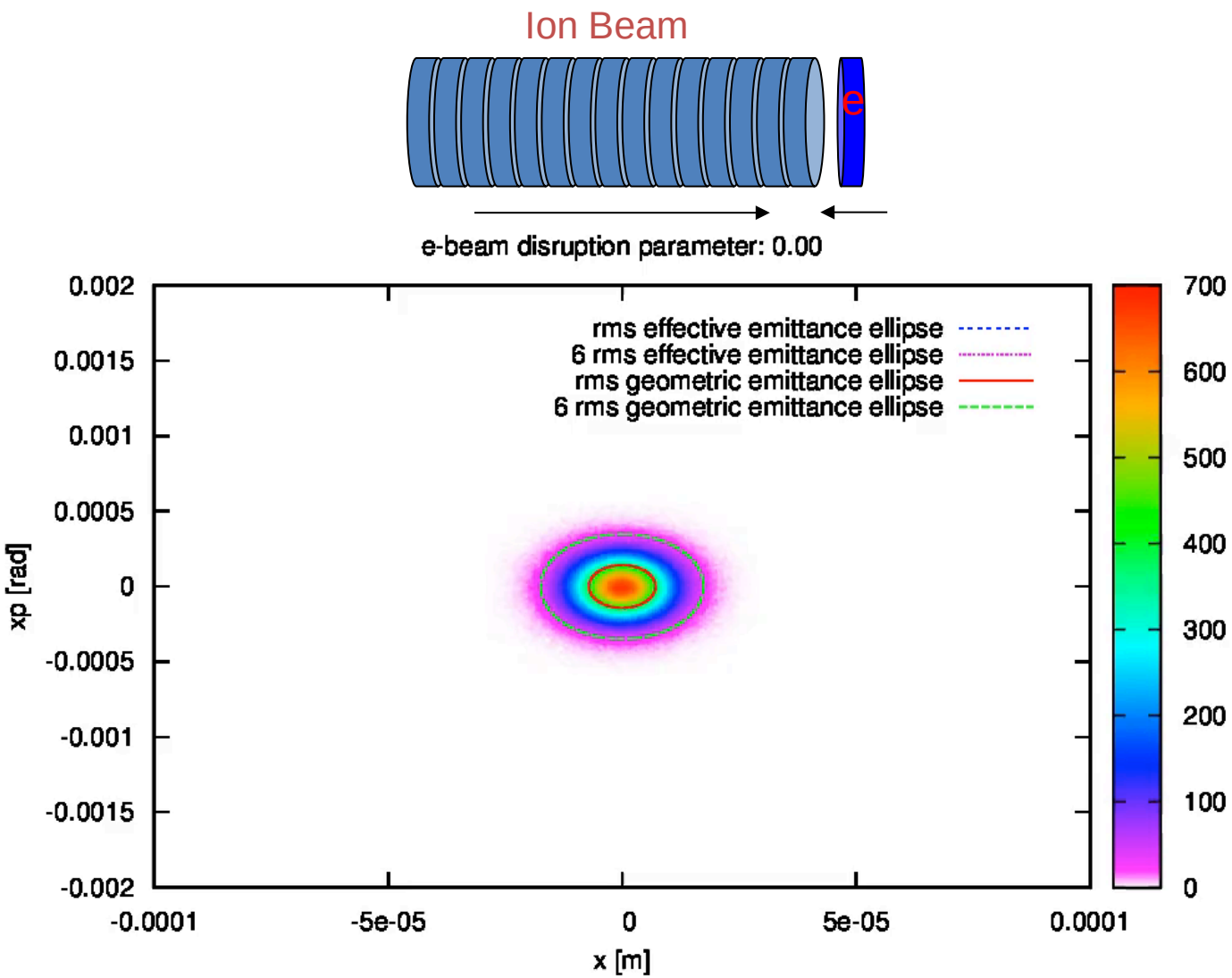
ERL test facility

- The BNL ERL objectives 20 MeV at >100 mA (500 mA capability).
- Experiment in progress, will see first photo-emission soon.
- Loop in Oct, 2014, project completes in 2016.

All hardware in house, most installed



Electron beam disruption



Summary

- There are many on-going simulation and experiment aiming on the challenge port of eRHIC.
- The design now is based on extensive simulations.
- R&D experiments are on-going, need few years to finish.

THANK YOU FOR YOUR ATTENTION!