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Injector linac upgrade and new RF gun development for SuperKEKB

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KEK

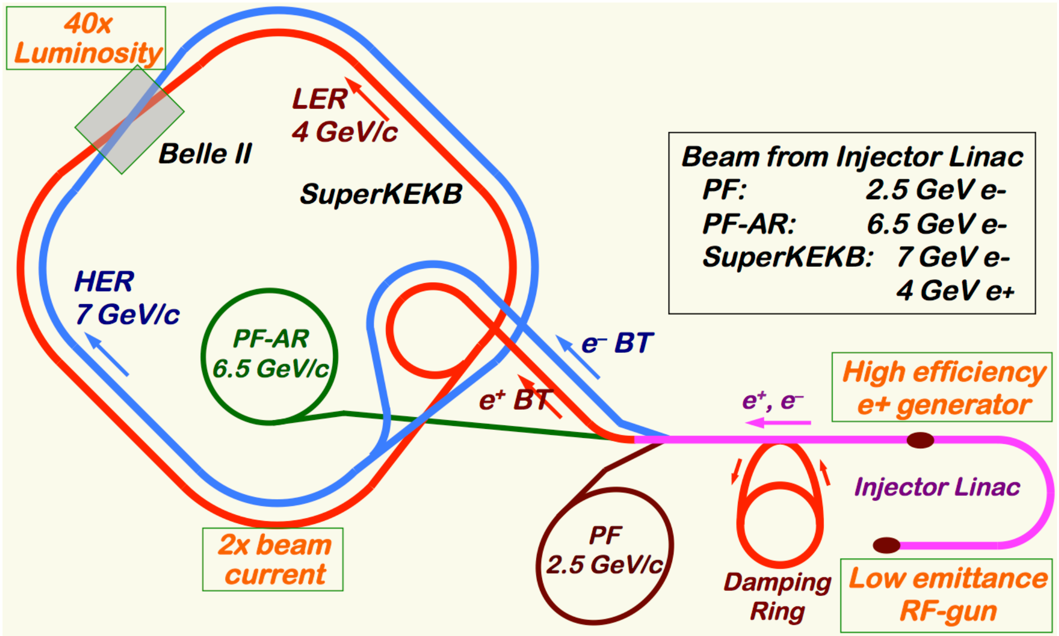
Contents

- Injector linac in KEK and upgrade for SuperKEKB
- RF gun development
- Phase1 commissioning in RF gun
- Conclusion

Mission of electron/positron Injector in SuperKEKB

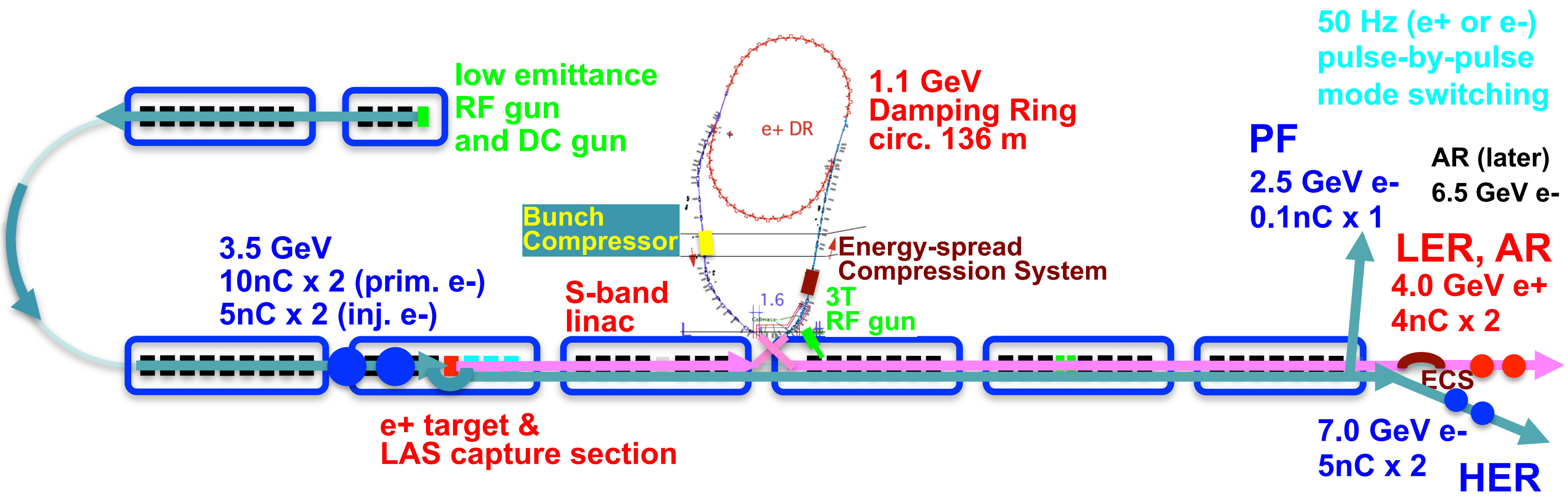
- 40-times higher Luminosity
  - 20-times higher collision rate with nano-beam scheme
    - → Low-emittance even at first turn → Low-emittance beam from Linac
    - → Shorter storage lifetime
  - Twice larger storage beam → Higher beam current from Linac

- Linac challenges
  - Low emittance e-
    - with high-charge RF-gun
  - Low emittance e+
    - with damping ring
  - Higher e+ beam current
    - with new capture section
  - Emittance preservation
    - with precise beam control
  - 4+1 ring simultaneous injection



Required injector beam parameters for SuperKEKB

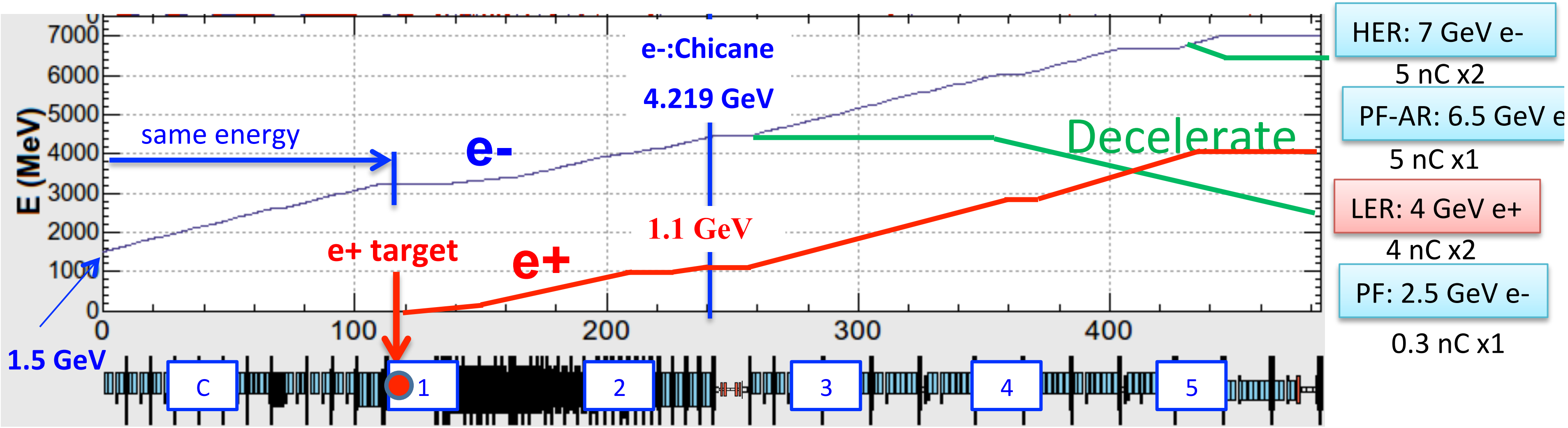
	KEKB obtained (e+ / e-)	SuperKEKB required (e+ / e-)
Energy	3.5 GeV / 8.0 GeV	4.0 GeV / 7.0 GeV
Charge	e- → e+ / e- 10 → 1.0 nC / 1.0 nC	e- → e+ / e- 10 → 4.0 nC / 5.0 nC
Emittance [mm-mrad]	2100 / 300	20 / 20



4 ring injection and Virtual Accelerator(VA)

We have to inject to different 4 rings with one beam line, simultaneous injection.

	Particle	Energy [GeV]	Charge [nC]
SuperKEKB HER	Electron	7	5 x2
SuperKEKB LER	Positron	4	4 x2
PF	Electron	2.5	0.3 x1
PF-AR	Electron	6.5	5 x1

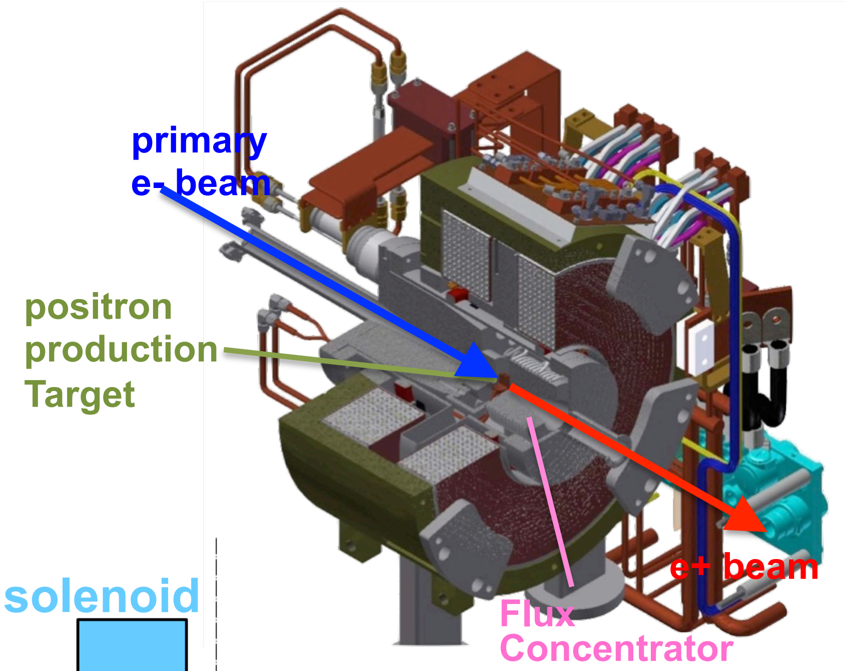


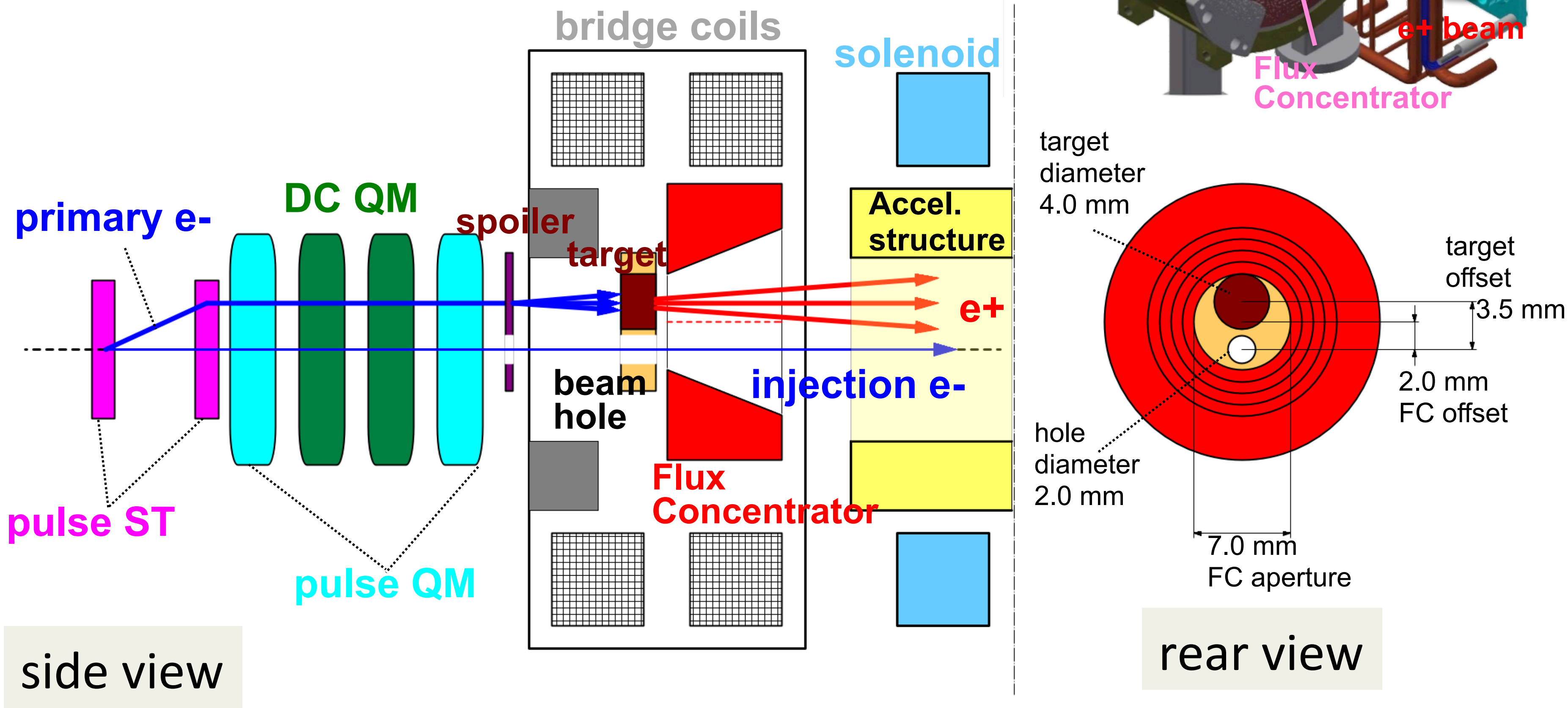
50 Hz pulse-to-pulse control system is required.

Developing pulse magnets and pulse to pulse LLRF control system.

Flux concentrator (FC)

The positron bunch intensity is boosted from 1 nC to 4 nC by efficient FC capture.
This FC based on the SLAC-IHEP model design.
Primary beam: 3.3 GeV 10 nC e-.
Emittance will be reduce by using the new damping ring.

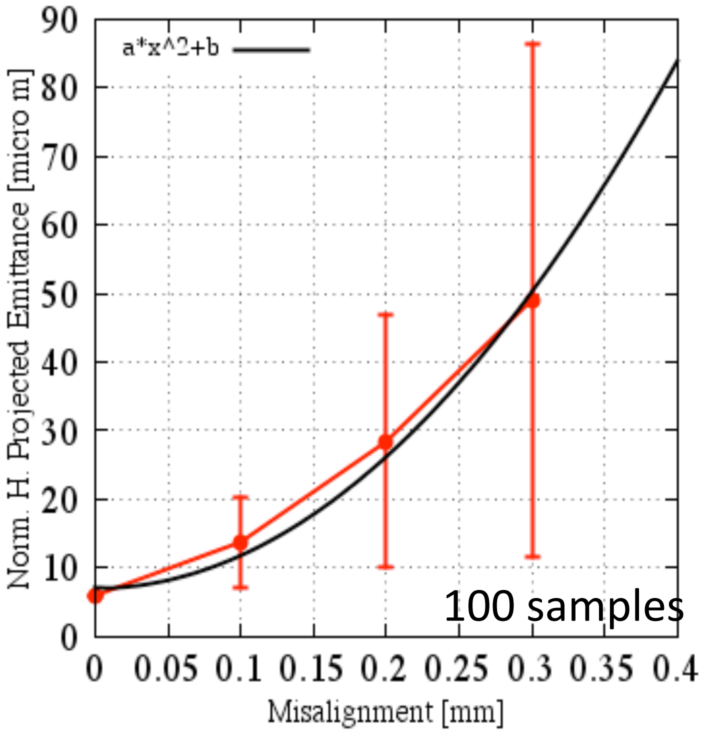




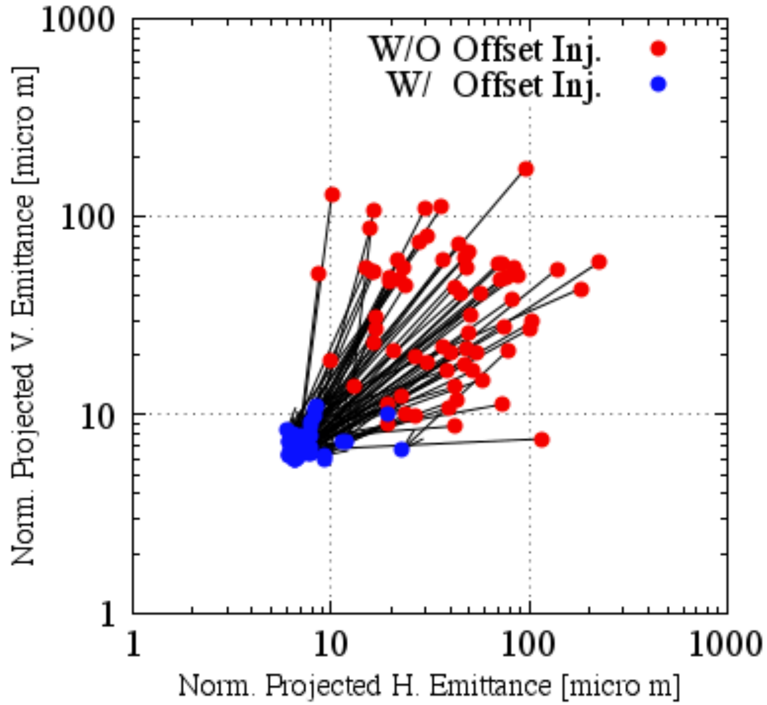
Emittance Preservation

- Linac is 600 m. Misalignment can not avoid
- Transverse kick due to wakefield increases slice emittance
- Offset injection may solve the issue
- Orbit have to be maintained precisely
- Misalignment should be <0.1mm locally, <0.3mm globally

Mis-alignment leads to Emittance blow-up



Orbit manipulation compensates it

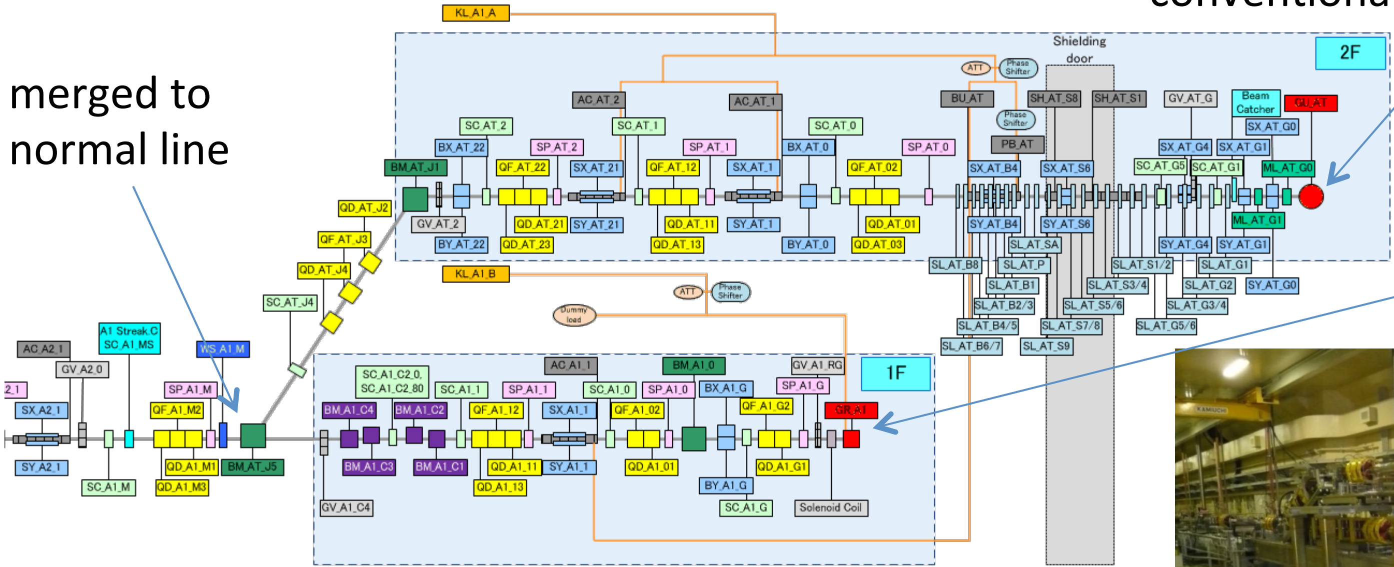


Sugimoto et al.

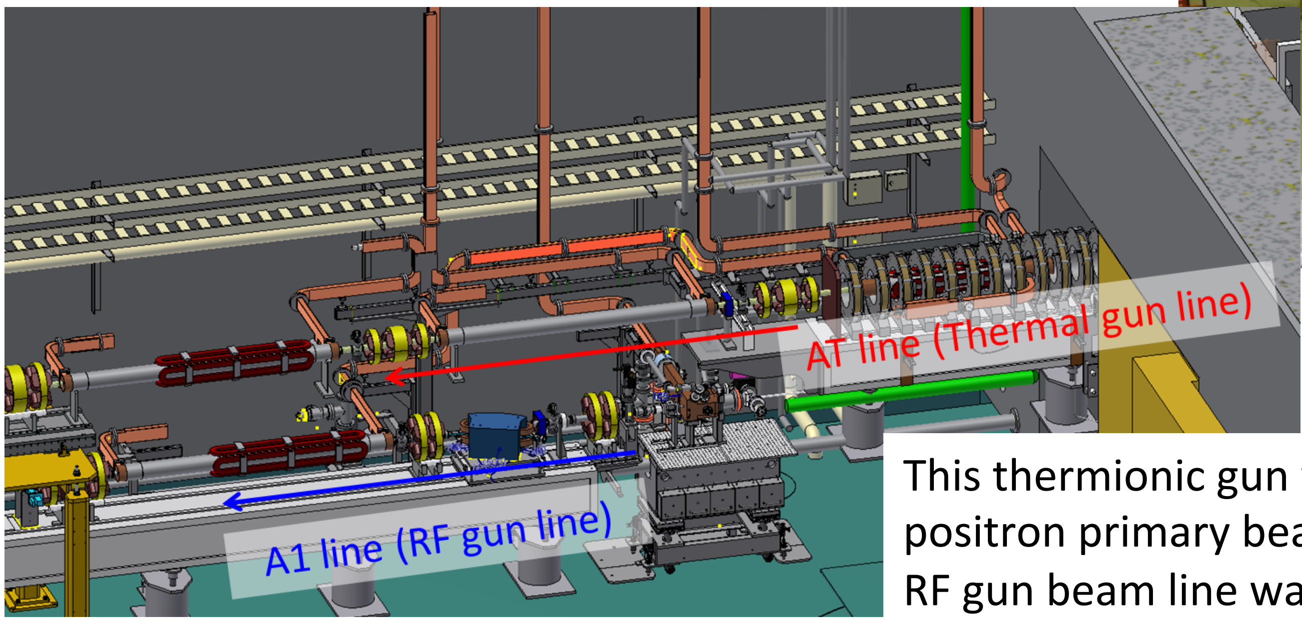
Double electron gun system

conventional thermionic DC gun

merged to normal line



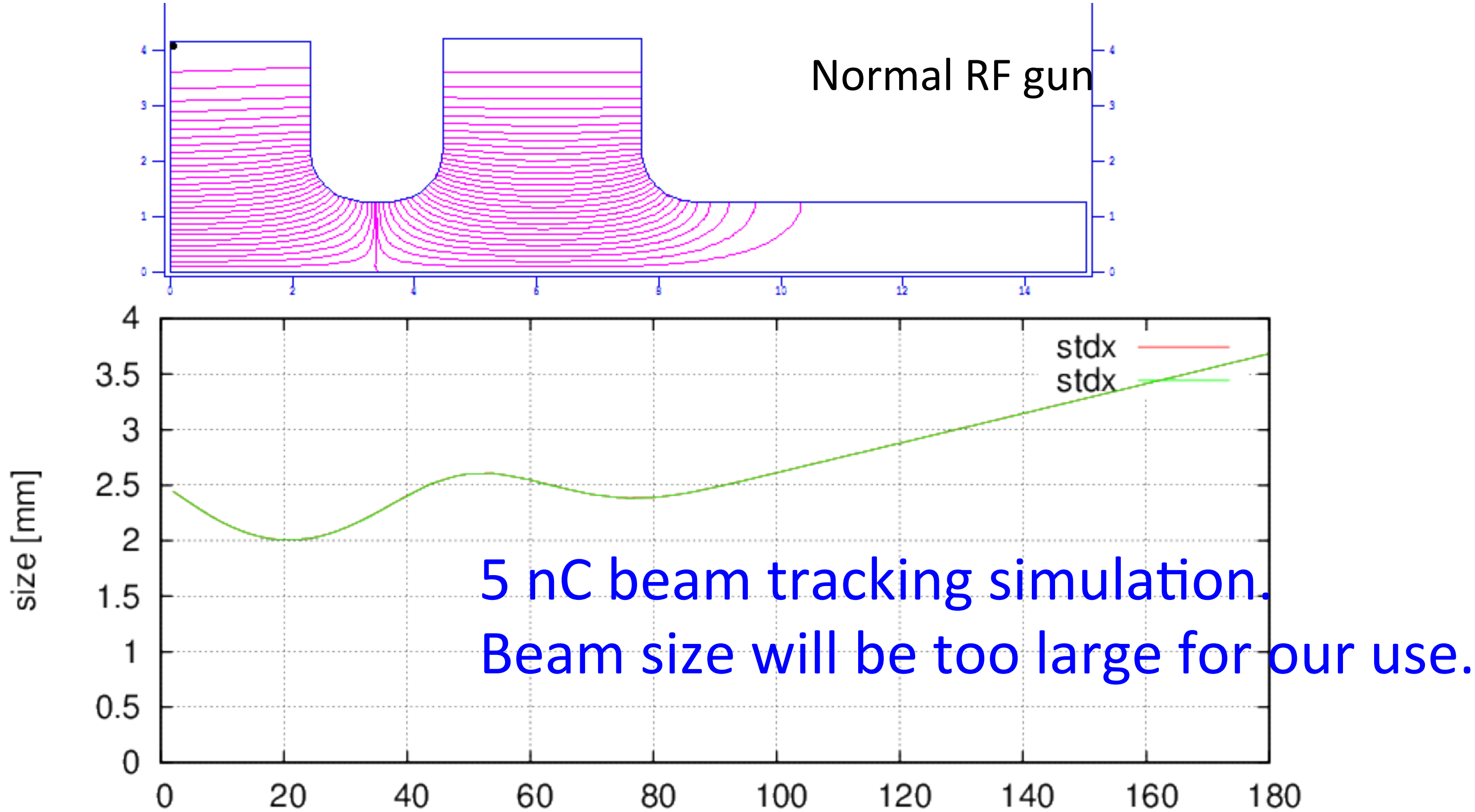
New RF gun



This thermionic gun was used for Phase1 positron primary beam and normal operation.
RF gun beam line was used for study in Phase1.

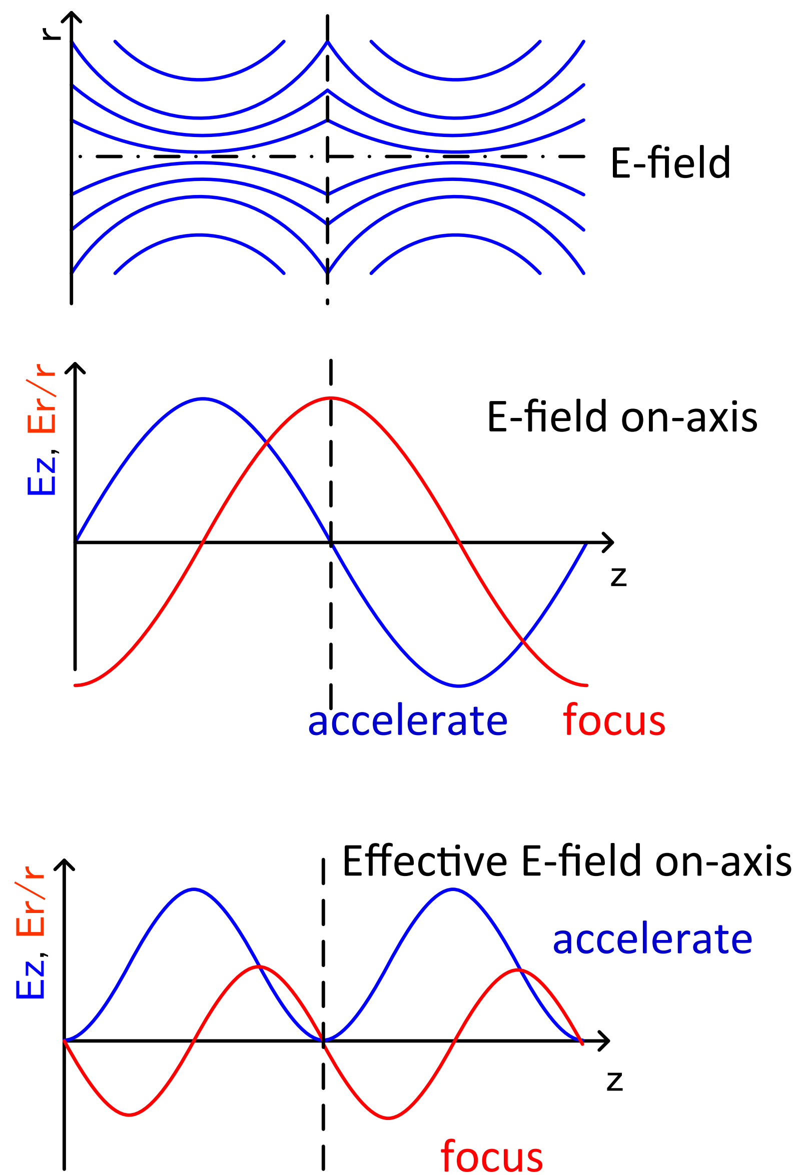
RF gun development

Why we need advanced RF gun?

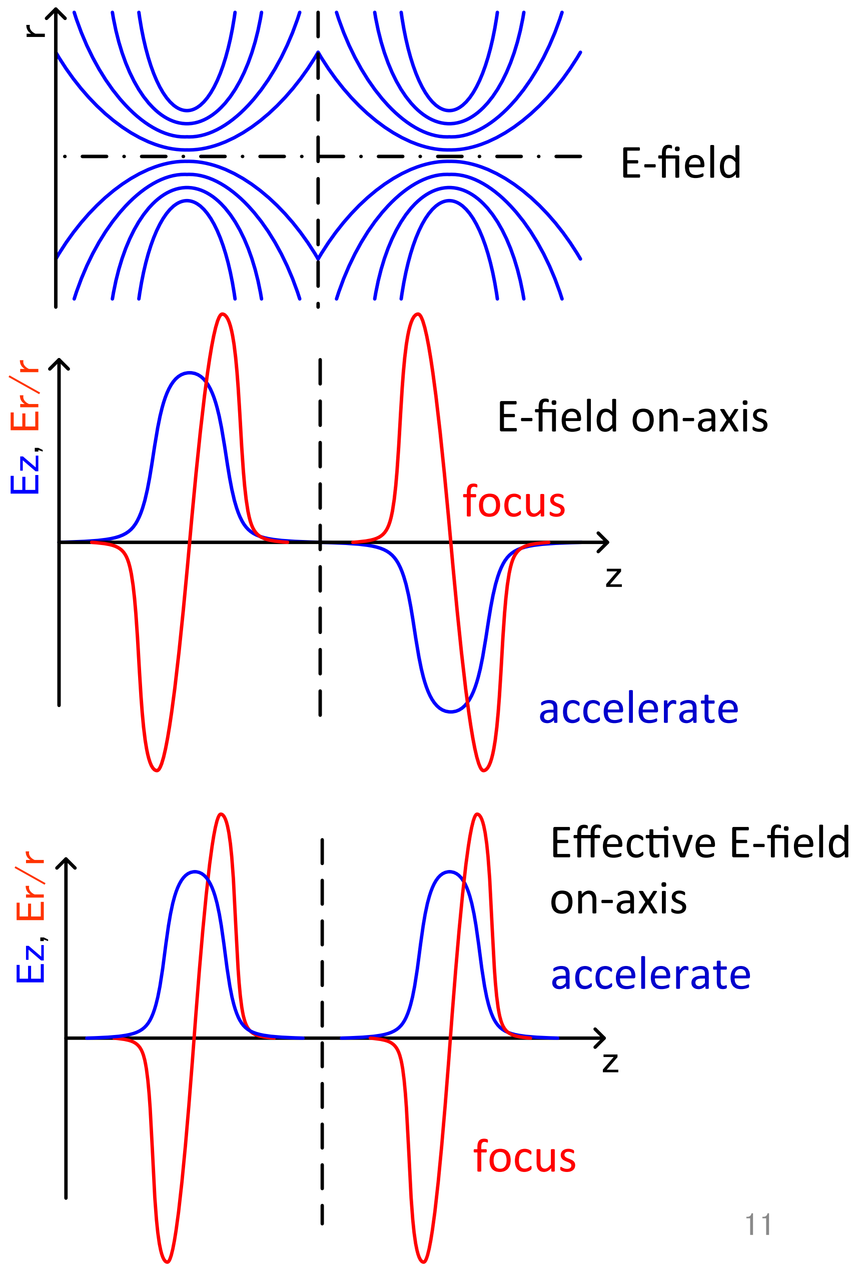


Normal RF gun does not have focusing E-field.
5 nC beam charge has much higher space charge.
We need advanced RF gun.

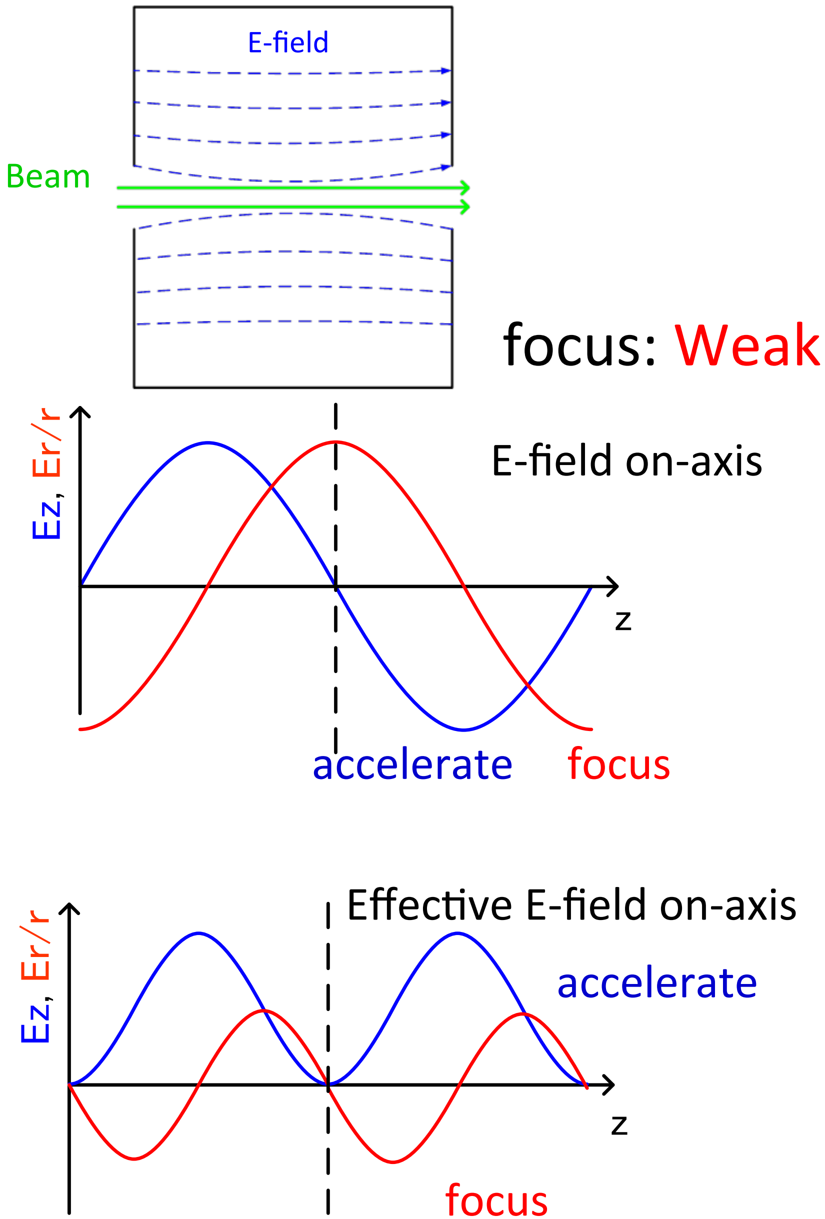
normal cavity



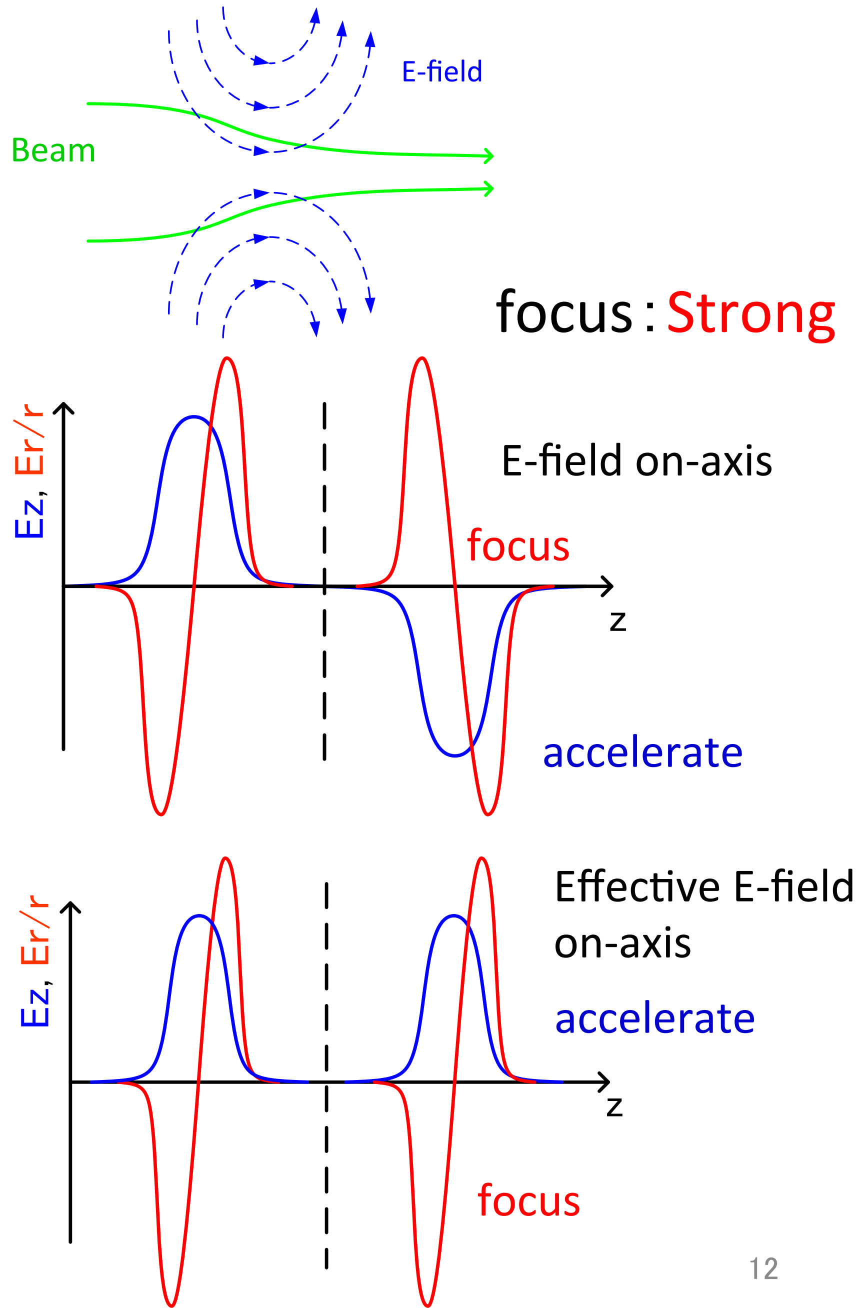
developed cavity



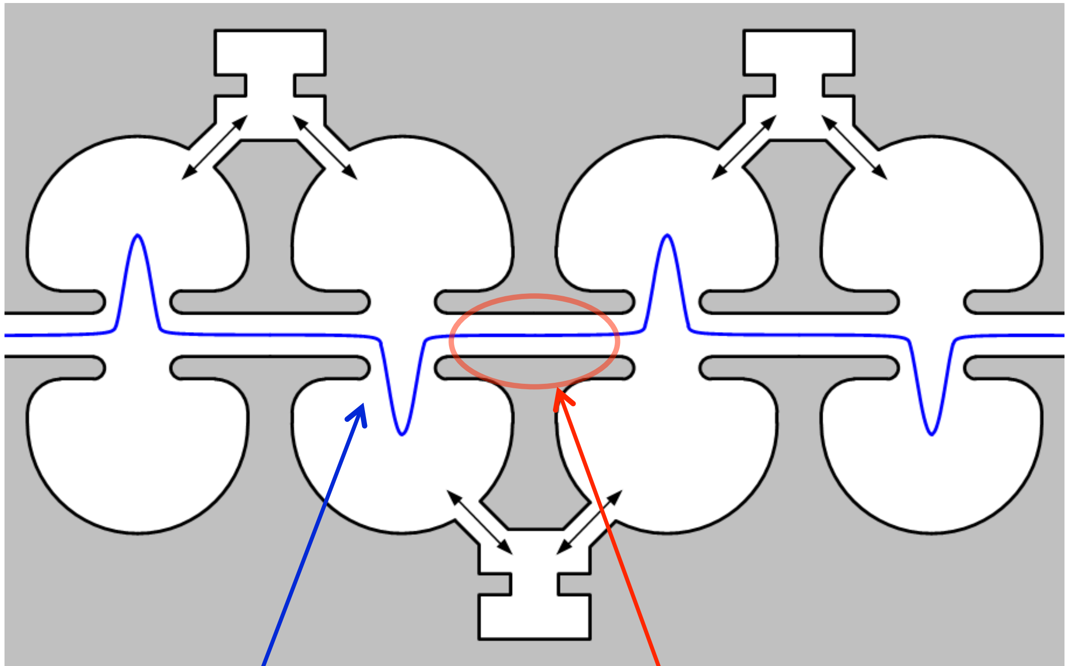
normal cavity

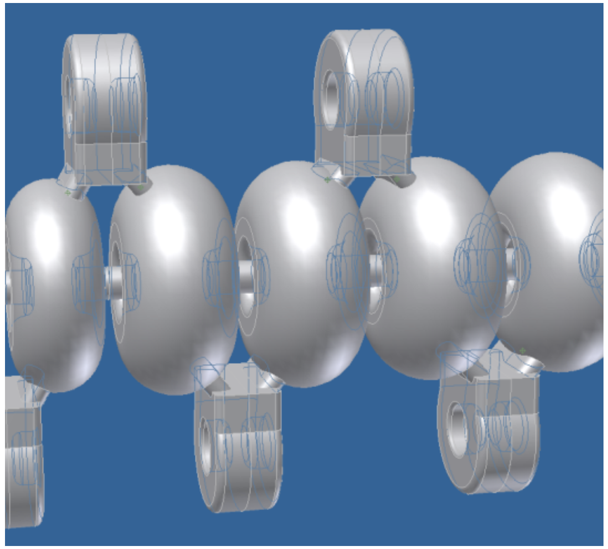


developed cavity



Annular coupling cavities makes narrow accelerating gap





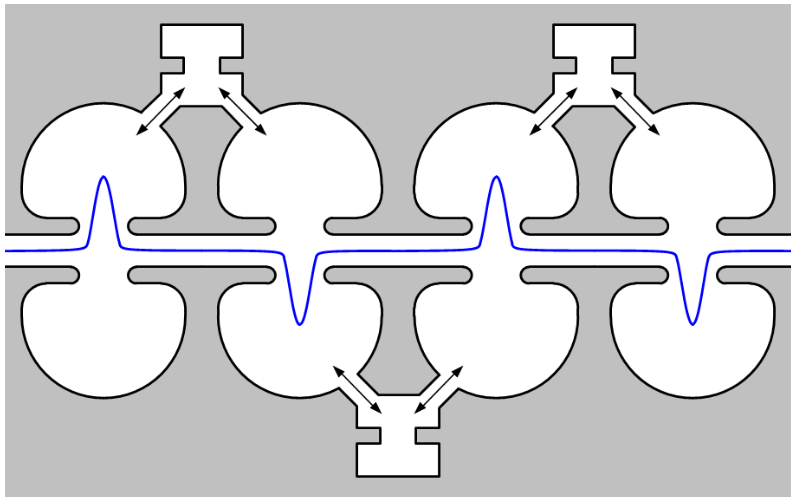
Close nose make narrow acceleration field

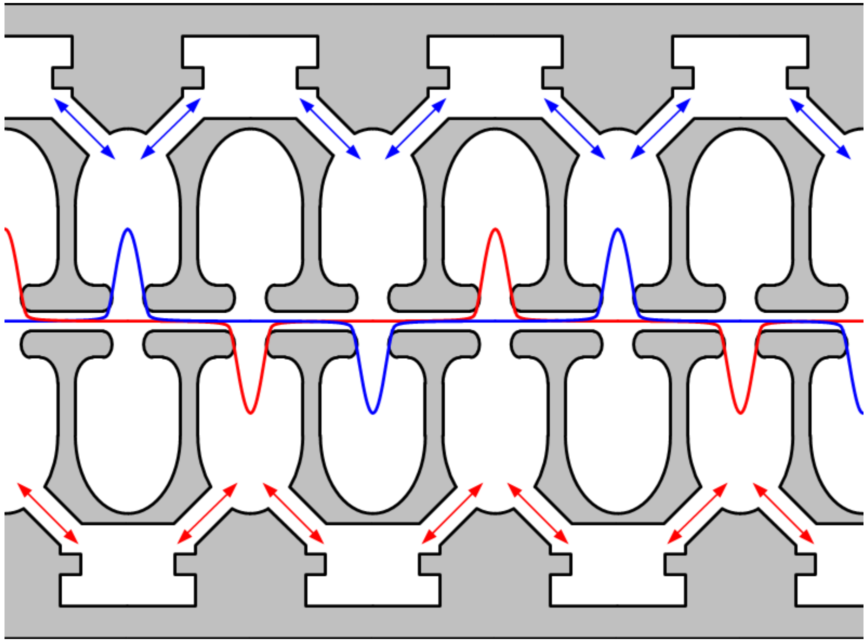
Long drift space causes the beam defocus

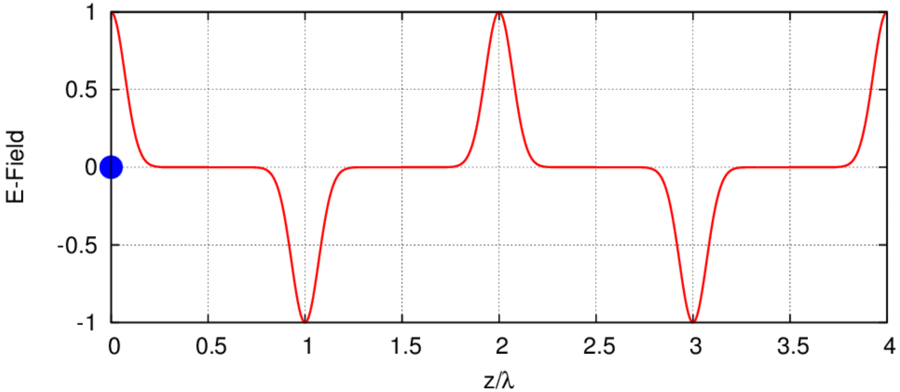
The close nose makes focus field. Side coupled cavity can be made the close nose. But, long drift space is problem. One solution is to use tow standing wave cavity.

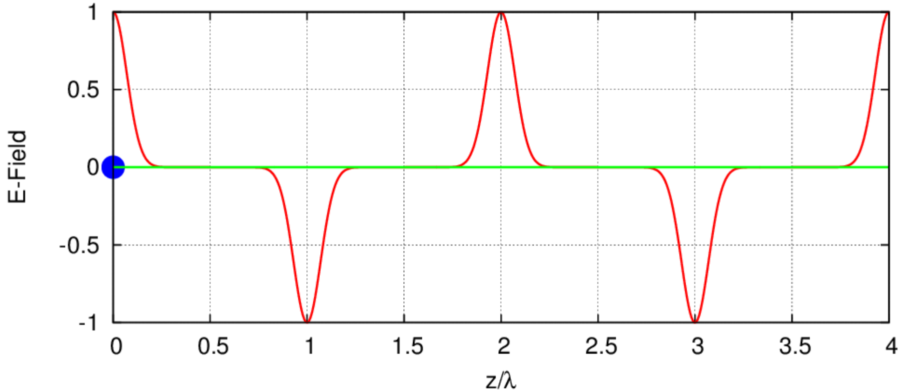
Quasi traveling wave side coupled cavities

Normal side coupled cavities



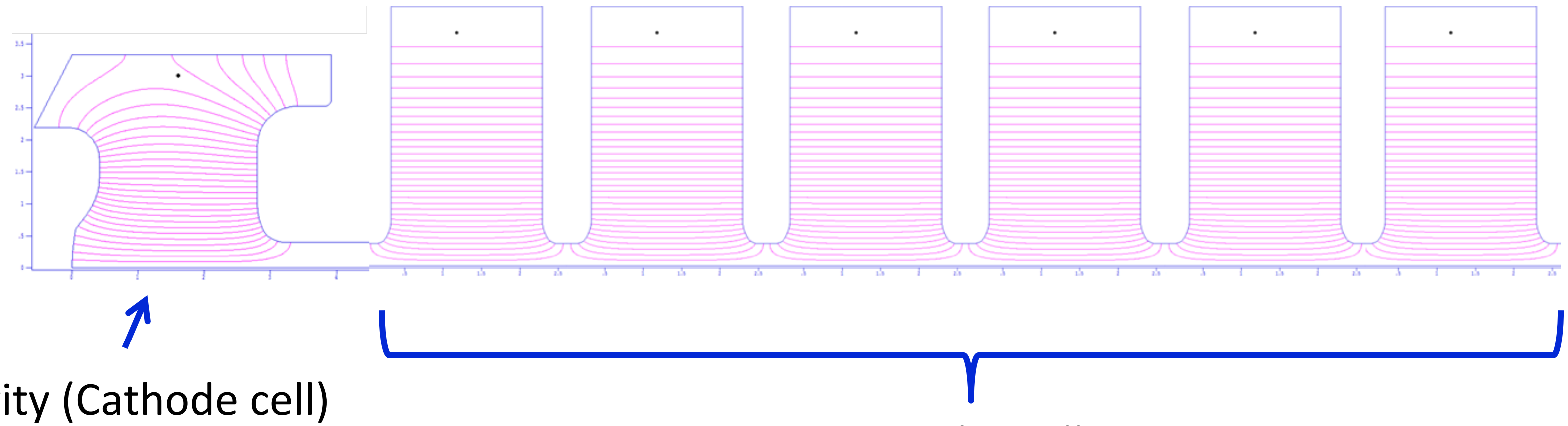






Whole cavities design

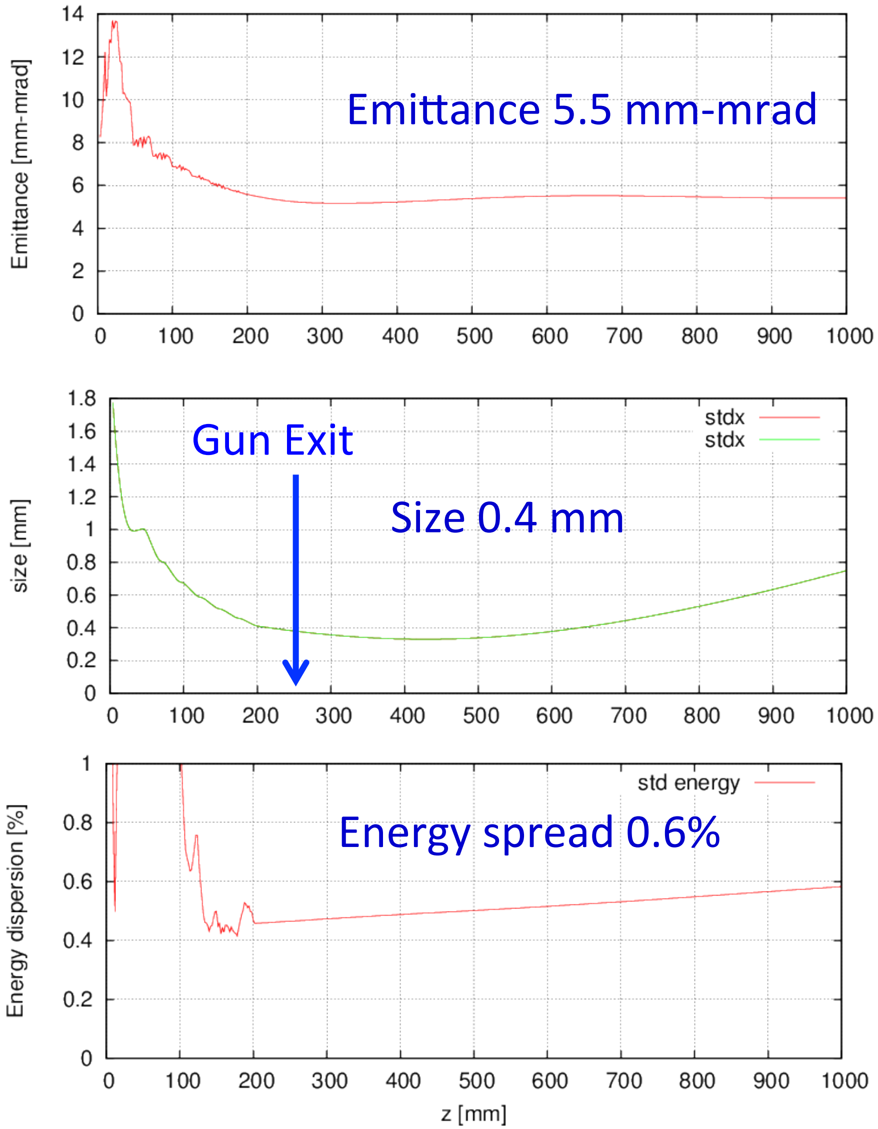
This RF gun has total of seven acceleration cavities. These are divided into two standing wave structure of 3 and 4 side coupled cavities respectively.

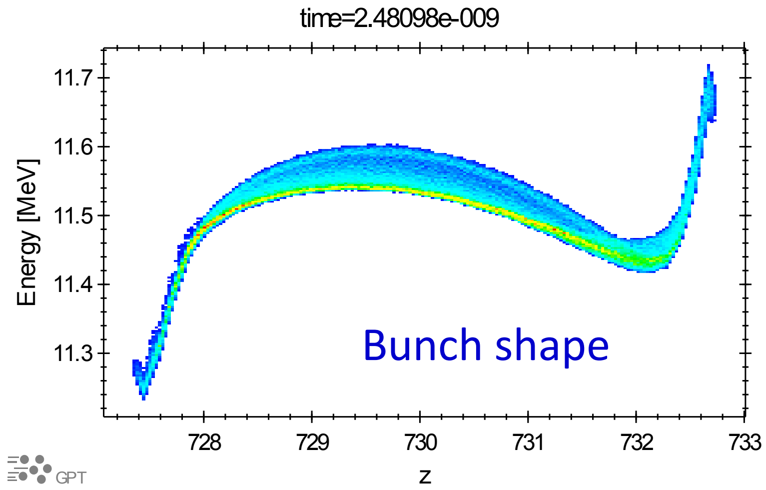


Emittance: 5.5 mm-mrad @ 5 nC

This RF gun can generate 10 nC beam

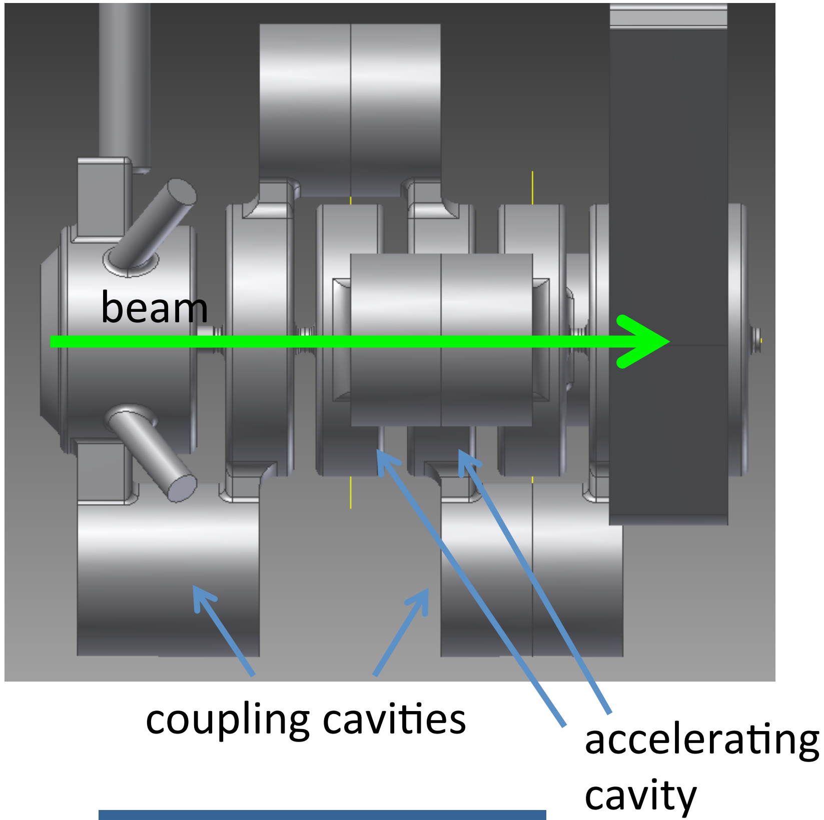
Beam tracking simulation result（5 nC）

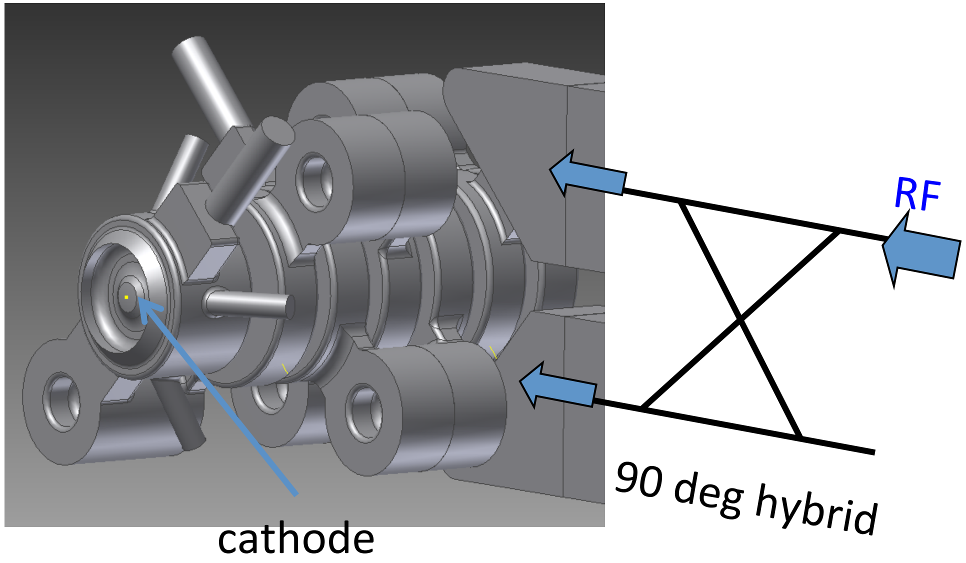


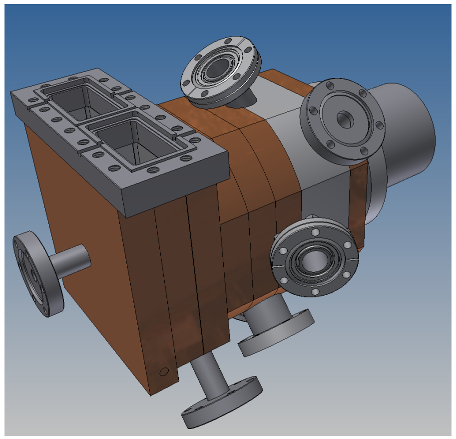


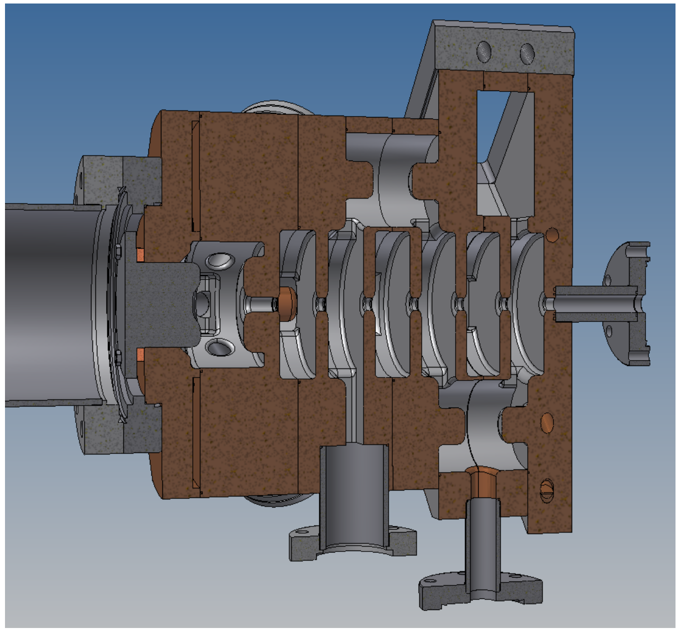
5 nC 11.5 MeV parallel beam

3D design

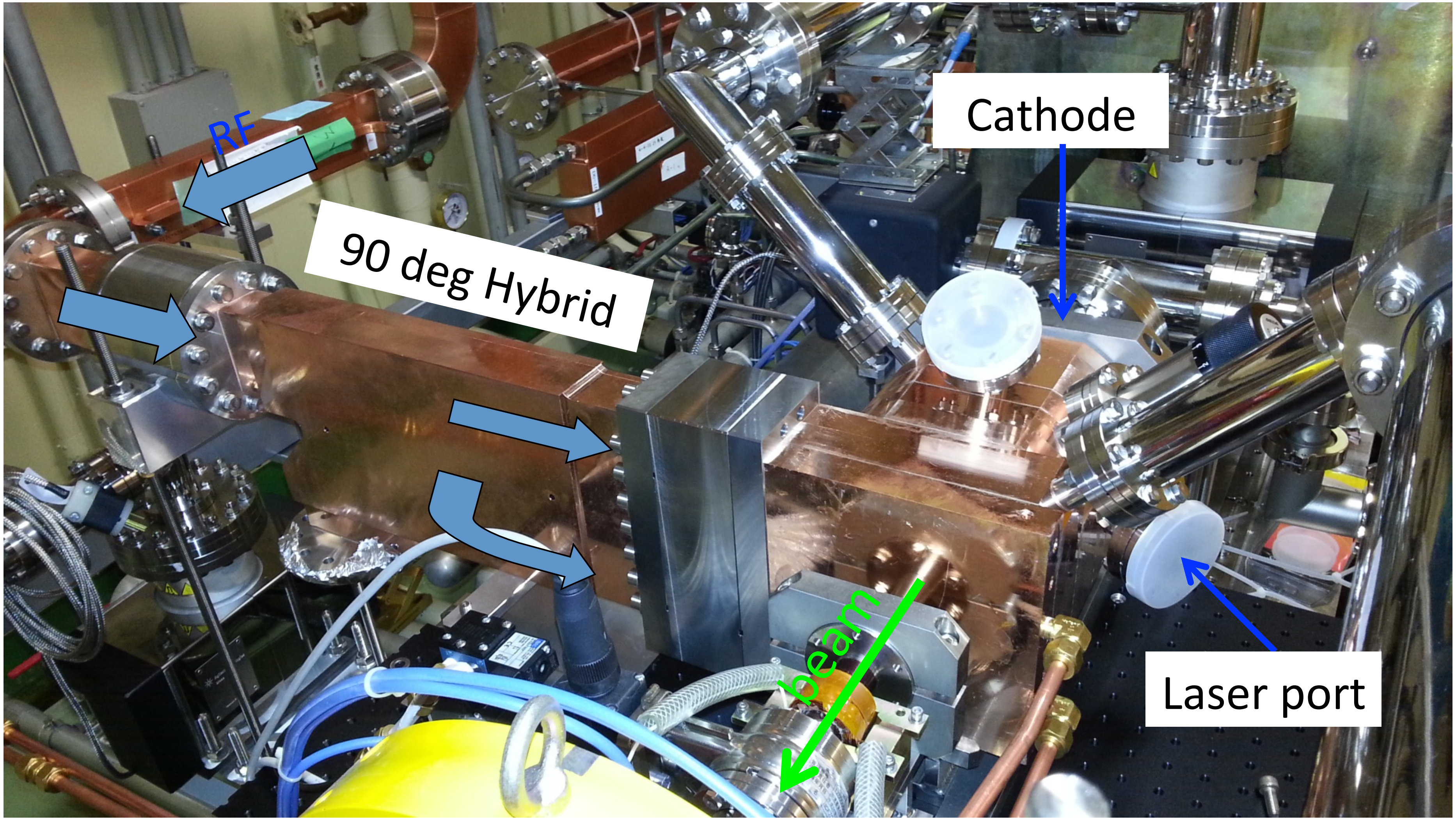

beam
coupling cavities
accelerating cavity


RF
90 deg hybrid
cathode

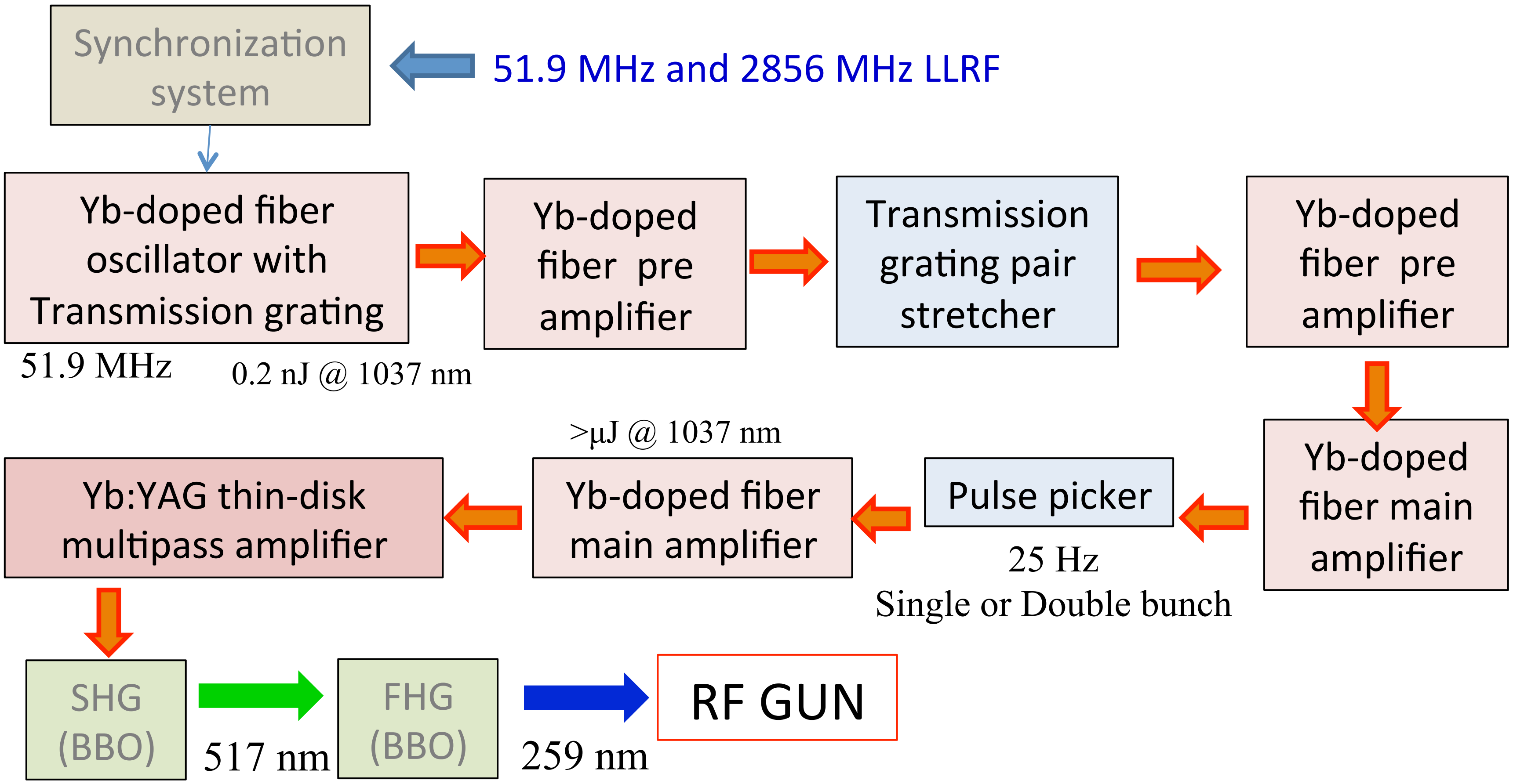




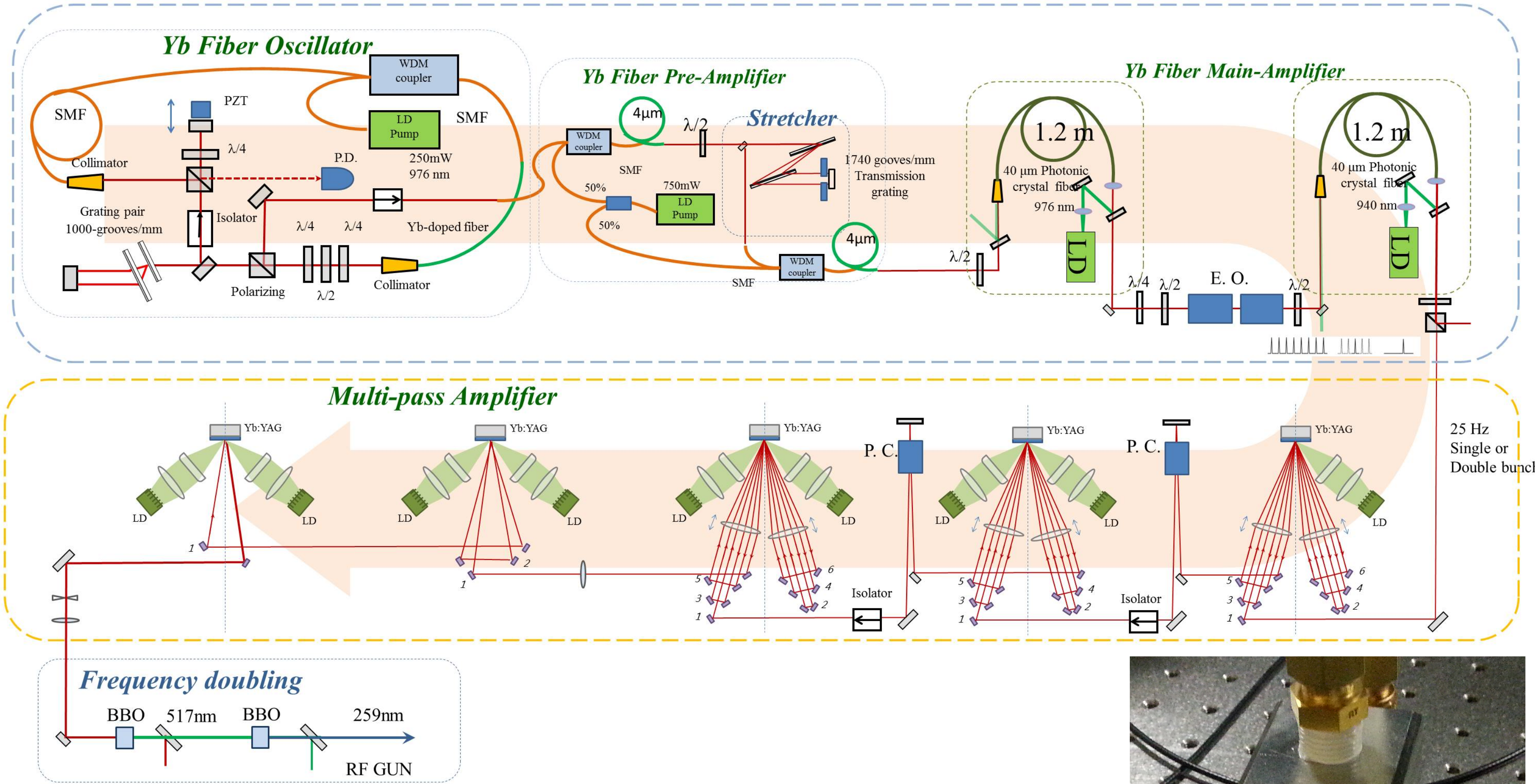
Installed RF gun at A1

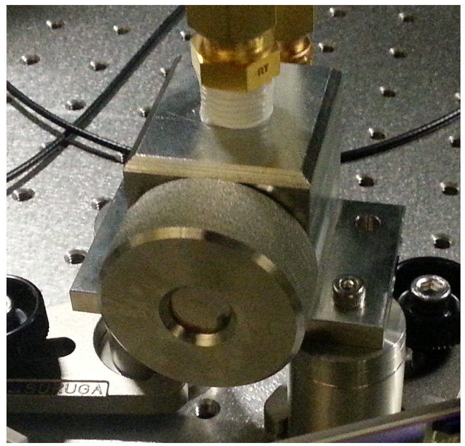


Layout for 25 Hz Yb:YAG Laser system



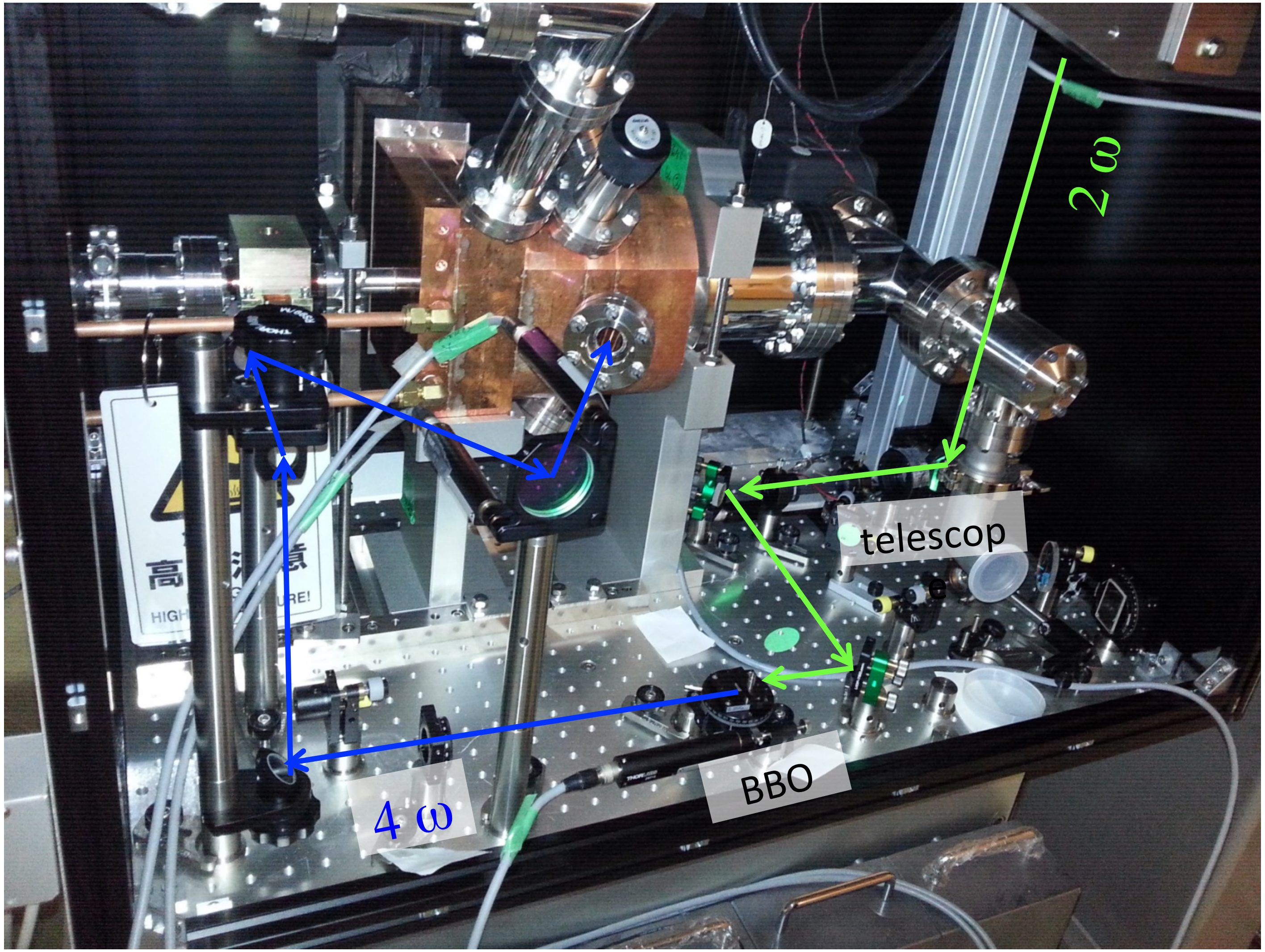
Layout for 25 Hz Yb:YAG Laser system





Yb:YAG thin disk

Laser injection to RF gun



Laser injection component near the RF gun.
Laser pulse is transported as 2nd harmonics, and convert to 4th harmonics by BBO.
Injection angle is adjusted with remote control mirror to angled laser port.

Phase 1 commissioning in RF gun

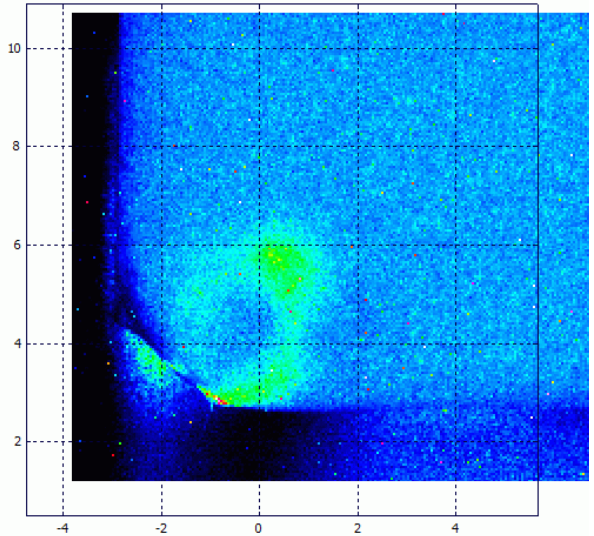
Beam charge stability

- Target of RF gun study in Phase1 was HER injection at 1 nC.
- Charge stability is most important point.

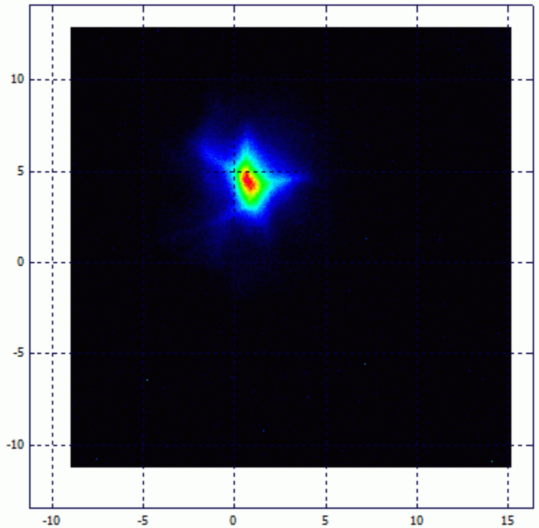
7 hours beam charge stability. (5/19)

We achieve 5% charge stability at 1 nC.

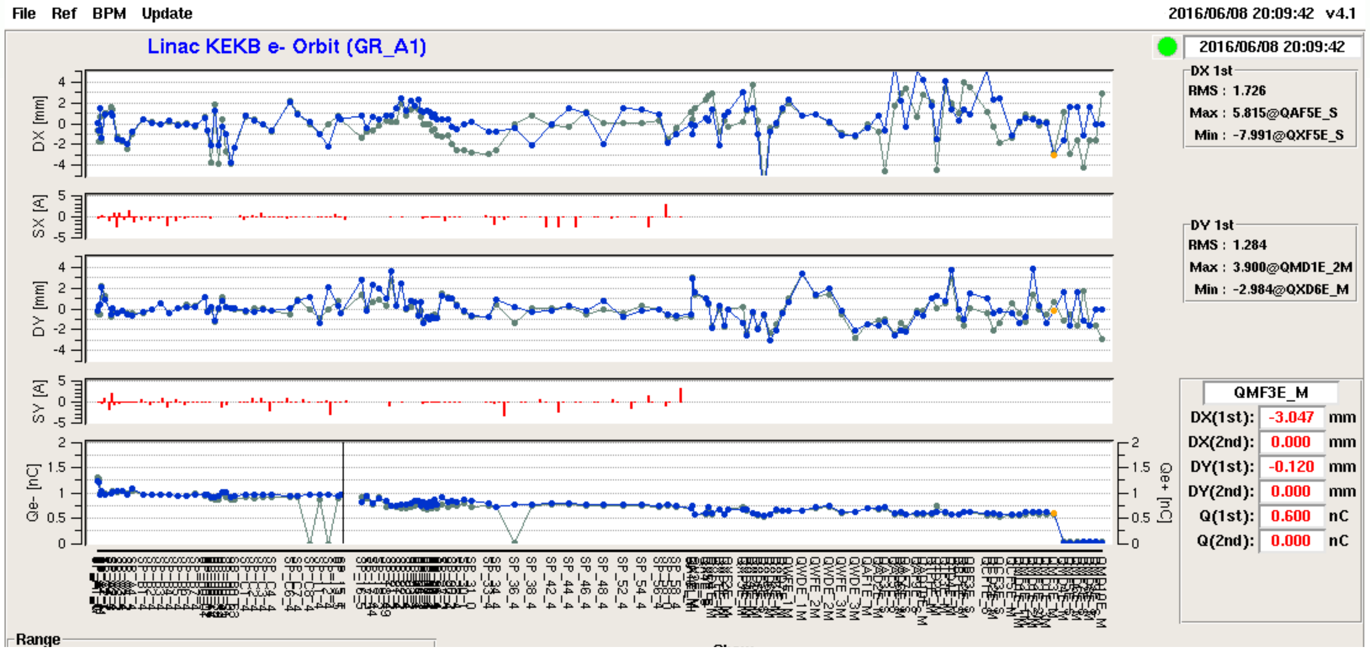
Laser and beam profile stability



Laser profile



Beam profile
A1-M screen



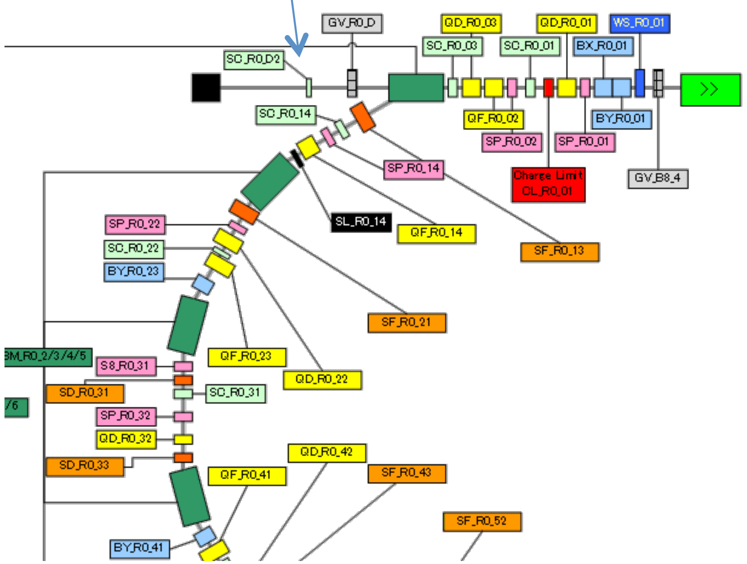
Laser profile should be improved.
Position jitter is also one of problem. (Horizontal 0.5 mm, Vertical 0.2 mm)

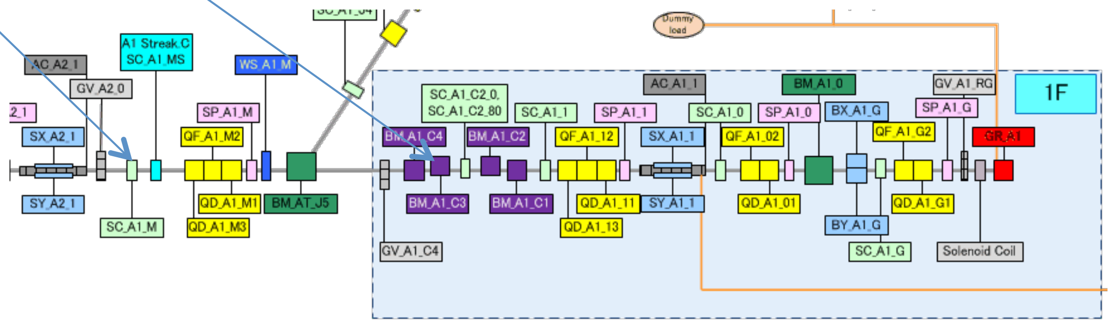
Emittance measurement by using Q scan method

1 nC beam

	Horizontal (projection)	Vertical (projection)
A1 chicane	28.3 (31.8)	26.4 (29.4)
A1 M	20.3 (20.8)	17.7 (18.3)
B sector dump	48.5 (52.7)	21.7 (22.2)

[mm-mrad]



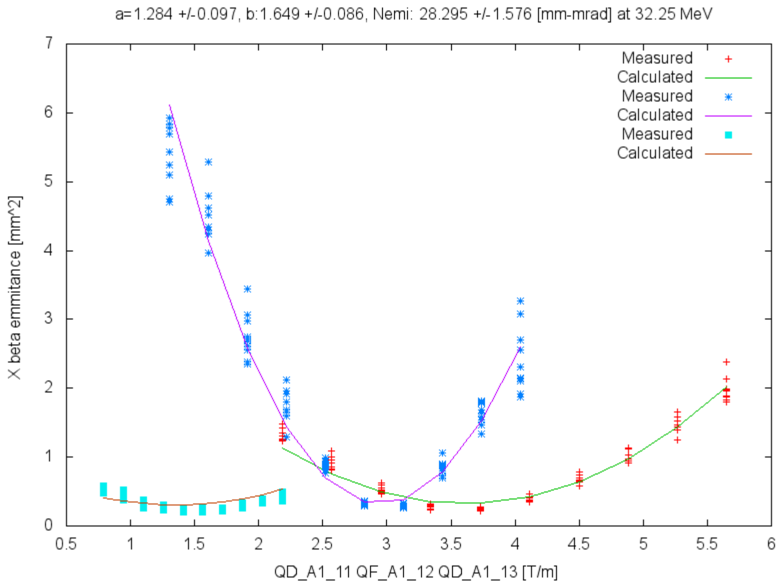


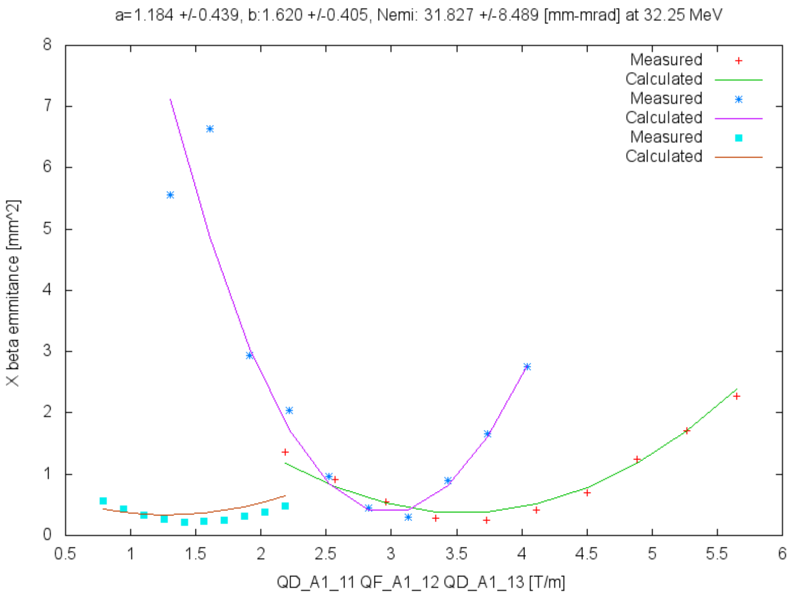
Measurement emittance is larger than simulated emittance.
Due to laser pulse quality.

A1 chicane Q scan

Horizontal

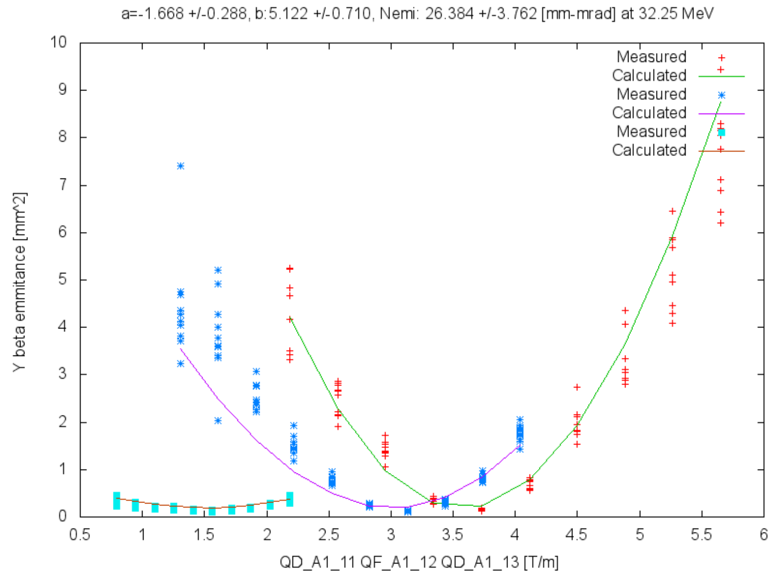
Emittance 28.3 (31.8) mm-mrad

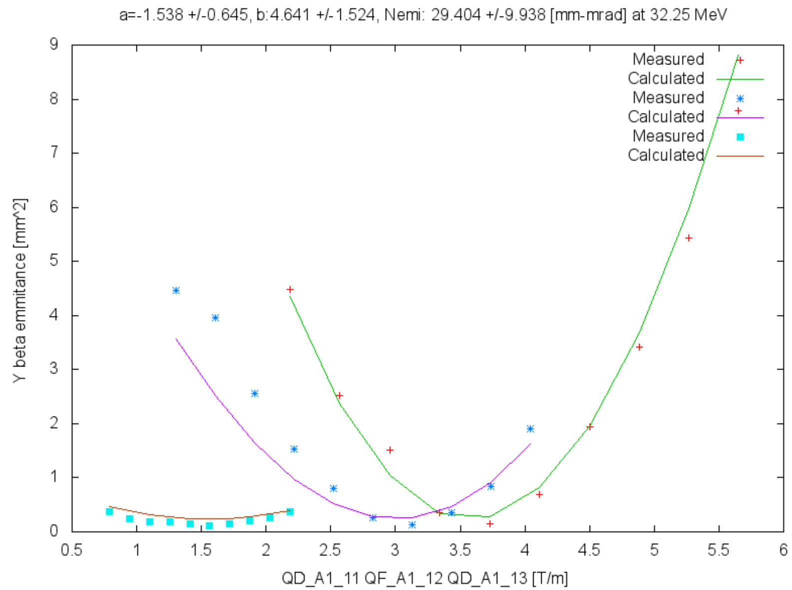




Vertical

Emittance 26.4 (29.4) mm-mrad



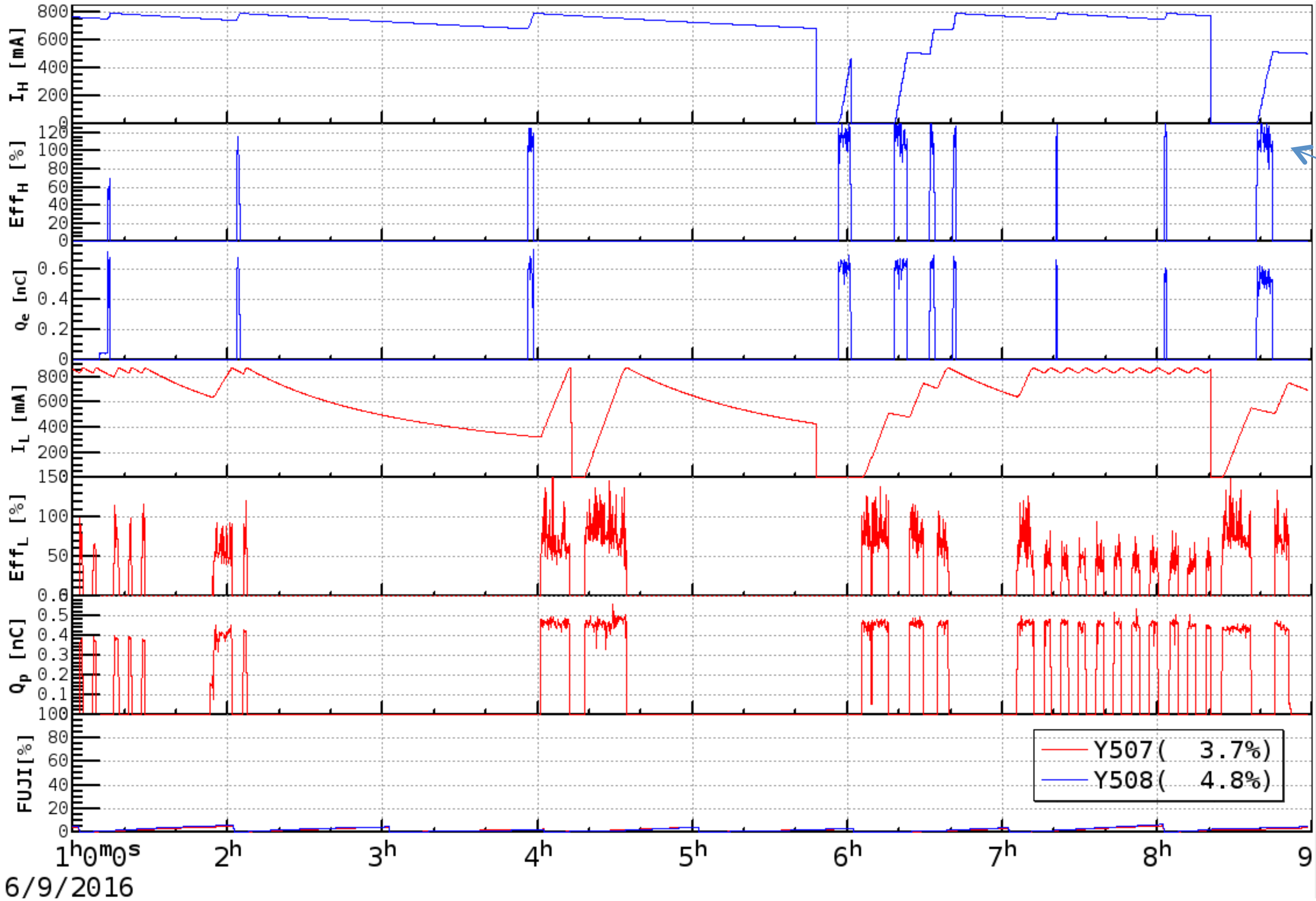


HER injection with RF gun

We achieved HER injection with RF gun.

It was continuous 10 days injection.

Beam quality and stability are almost same as thermionic gun.



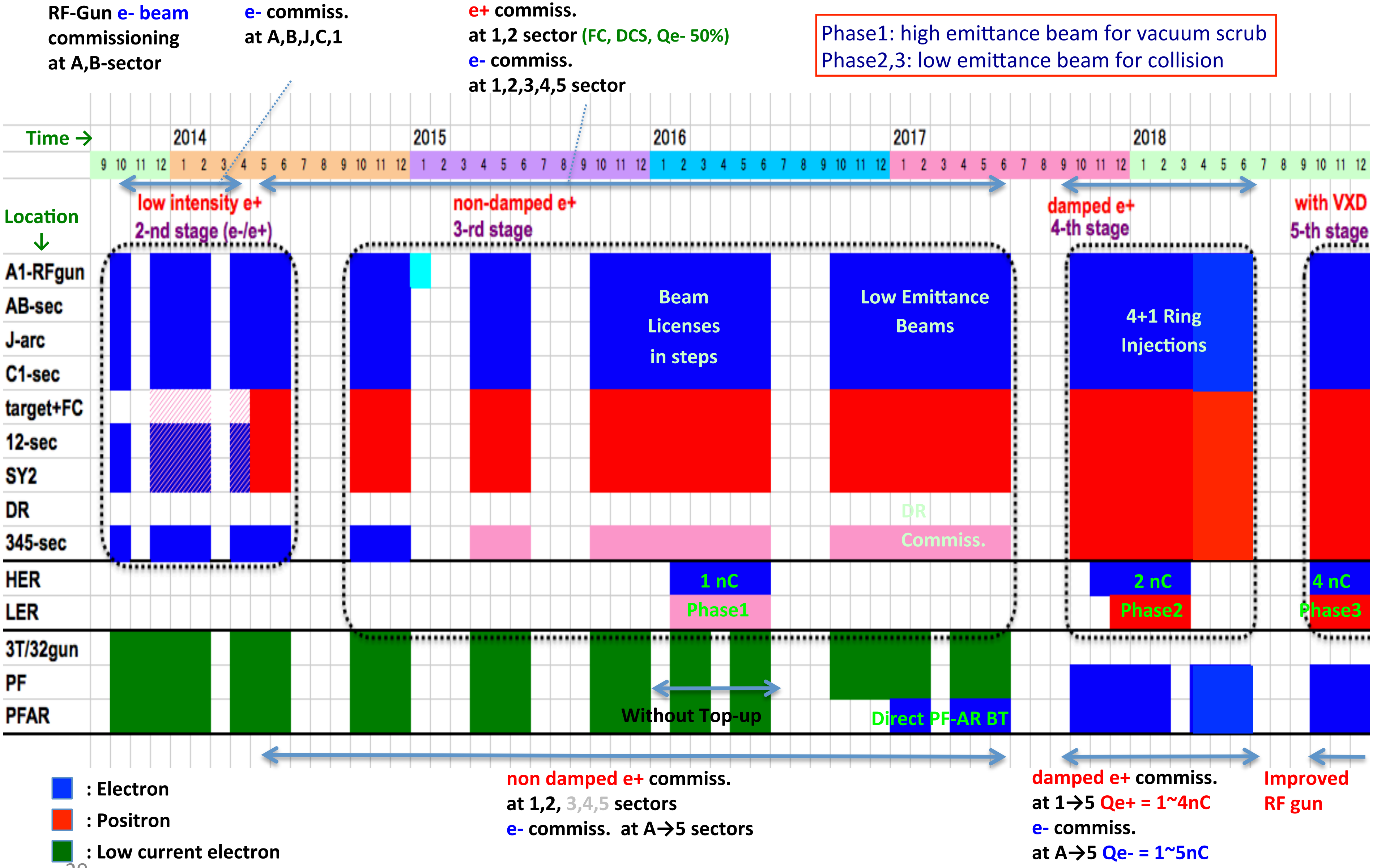
Efficiency is almost 100 %

Conclusion

- In KEK injector, several upgrade was carried out.
- Thermionic gun was used for Phase1. Charge of electron beam is 1 nC. Charge of positron beam is 1 nC with FC.
- We achieved charge of 1 nC beam generation by using the new RF gun.
- Laser power stability is acceptable. (charge stability : 5%)
- Position stability is still not so good at RF gun.
- Emittance is approximately 20 mm-mrad.
- SuperKEKB HER Ring injection test was succeeded with the RF gun. We achieved 10 days stable injection.

Linac Schedule Overview

Phase1: high emittance beam for vacuum scrub
Phase2,3: low emittance beam for collision



: Electron
: Positron
: Low current electron

Thank you for your attention