Injector upgrade

23 Oct. 2015

Toshi Higo (on behalf of Injector linac group)

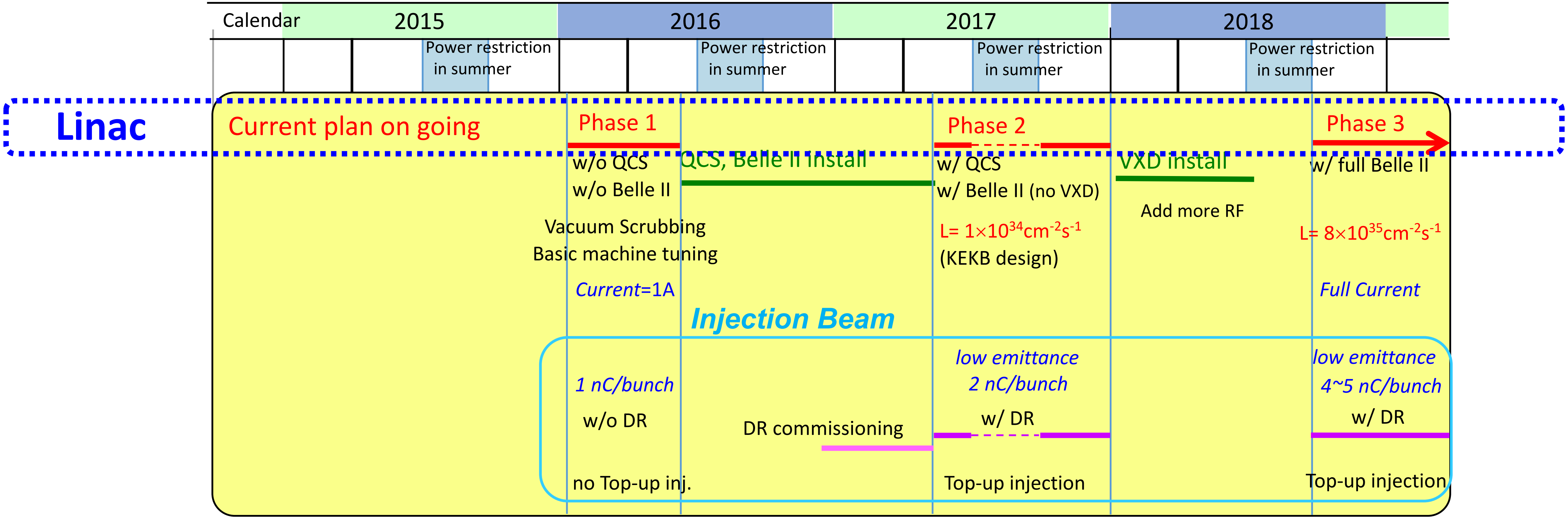
Contents

- Beam requirement
- Schedule and upgrade scenario
- Positron status and near future plan
- Emittance related issues
- Conclusion

Based on Miura-Furukawa, B2GM in June 2015

SuperKEKB schedule

Commissioning is divided into three stages. (phase1, phase2, phase3)



Required beam parameters

Stage	KEKB		Phase-I		SuperKEKB	
Item	e+	e-	e+	e-	e+	e-
Energy	3.5 GeV	8.0 GeV	4.0 GeV	7.0 GeV	4.0 GeV	7.0 GeV
Bunch charge	Primary e-10nC → 1 nC	1 nC	Primary e- 4nC → 0.2 nC	1 nC	Primary e-10nC → 4 nC	5 nC
Norm.Emittance ($\gamma\beta\varepsilon$) (μrad)	2100	100	2400	150	100/20 (Hor./Ver.)	50/20 (Hor./Ver.)
Energy spread	0.125%	0.125%	±0.5%	±0.5%	0.1%	0.1%
Num. of Bunch / Pulse	2	2	2	2	2	2
Repetition rate	50 Hz		50 Hz		50 Hz	
Simultaneous top-up injection	3 rings (KEKB e-/e+, PF)		3 rings (KEKB e-/e+, PF)		4 rings (SuperKEKB e-/e+, PF, PF-AR)	

What and when to be improved from KEKB to SuperKEKB

- Present in late 2015
  - Prepare low-emittance electron & positron to be cooled at DR
- Phase-I in early 2016
  - Supply for initial ring tuning and beam-duct baking
  - Investigate the strategy for emittance-preserved high charge
- Phase-II in 2017
  - Gradually improve emittance preservation
  - Make effort for higher charge
- Phase-III in late 2017
  - Emittance to be fully minimized with maximum charge

Upgrades of Injector LINAC

Thermionic gun @A1

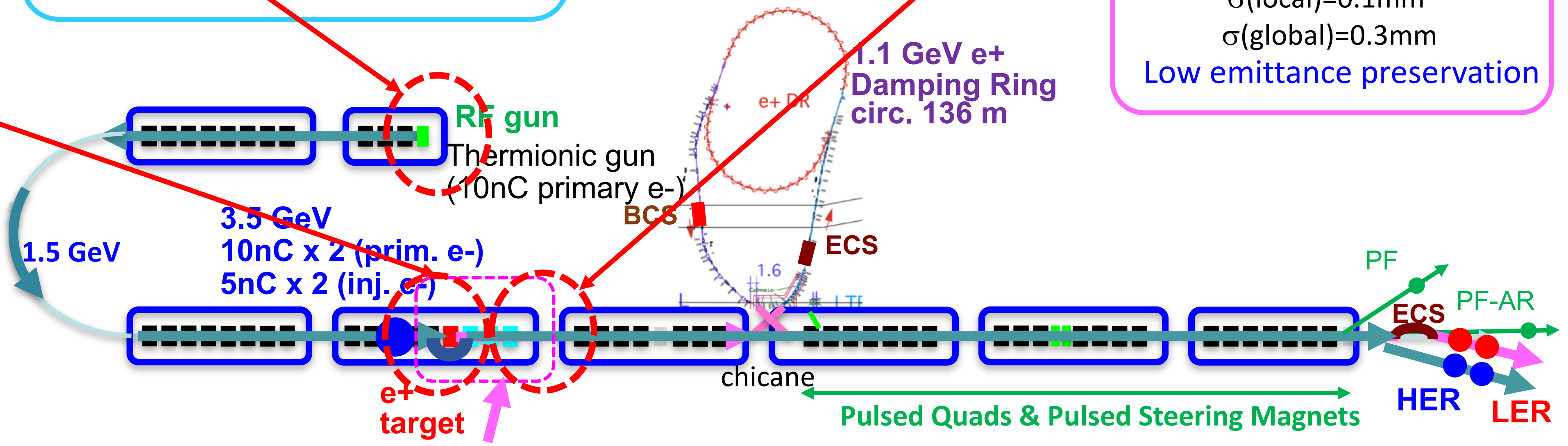
Photo-cathode RF gun system
< e- beam>
Low emittance ($\gamma\varepsilon \leq 20$ mm·mrad)
high bunch charge ($\geq$ 5nC)

Positron Damping Ring (DR)
Low emittance e+ beam

Collimation @18

Positron production @14

Alignment error tolerance
σ(local)=0.1mm
σ(global)=0.3mm
Low emittance preservation



Positron Capture Section
- Flux concentrator (FC)
- Large aperture S-band accel. Structures (LAS)

4 times higher e+ yield

Event Timing System and Pulsed Modules
- Synchronization for 5-rings including DR
- 200 parameters are switched at 50Hz each mode
- Optics at the downstream of DR is switched by using pulsed magnets

Electrons

- Electrons
  - for HER
  - for making positrons
- Development on RF gun for electrons has been much advanced
  - Targeting ultimately low-emittance, high-charge beam
  - RF gun cavity seems well developed but operation in full spec is required for actual use.
  - Considerable work is needed to make stable laser system.
- We decided to bring thermionic gun for Phase-I to life
  - For positron generation and possibly for electrons in phase-I
  - Thermionic gun and RF gun were set in parallel at A1

Beam Commissioning of RF Gun

Miura, Furukawa in B2GM in June 2015

Operation Condition

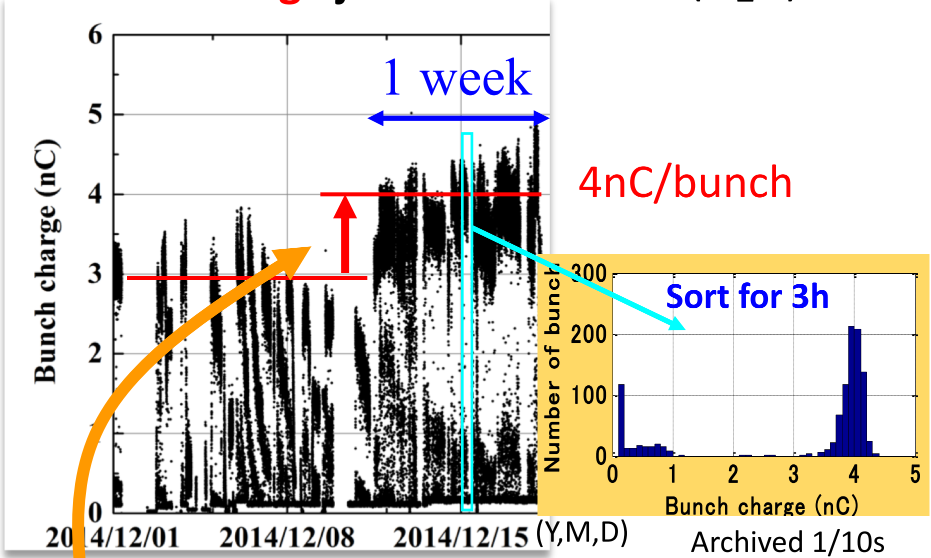
- Laser: 2bunch, 25 Hz
- RF gun acc. voltage: limited to 6.5 MV by breakdown (13.5 MV@design)

Target : 5nC

$\gamma\varepsilon_x$=50 mm·mrad, $\gamma\varepsilon_y$=20 mm·mrad @ LINAC end

$\gamma\varepsilon_x$, $\gamma\varepsilon_y$ = 10 mm·mrad @ Gun

Bunch charge just after RF GUN (A1_C5)



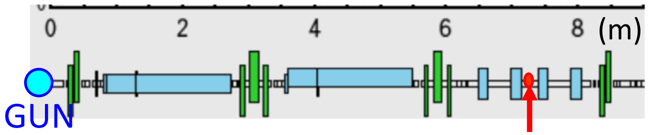
Bunch charge stability depends on the laser stability.

Yb:YAG Thin-disk cooling by soldering Cu plate was Improved.

R. Zhang, TUPWA071

Laser power increased and stability was also improving.

Emittance measurement by Quad-scan

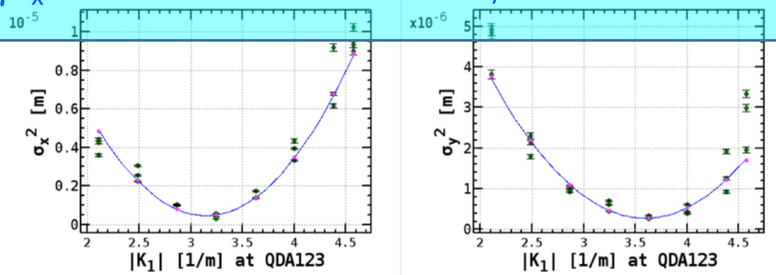


Bunch charge: 3nC@Screen

Beam size was measured shot by shot.

=> Position jitter is not included

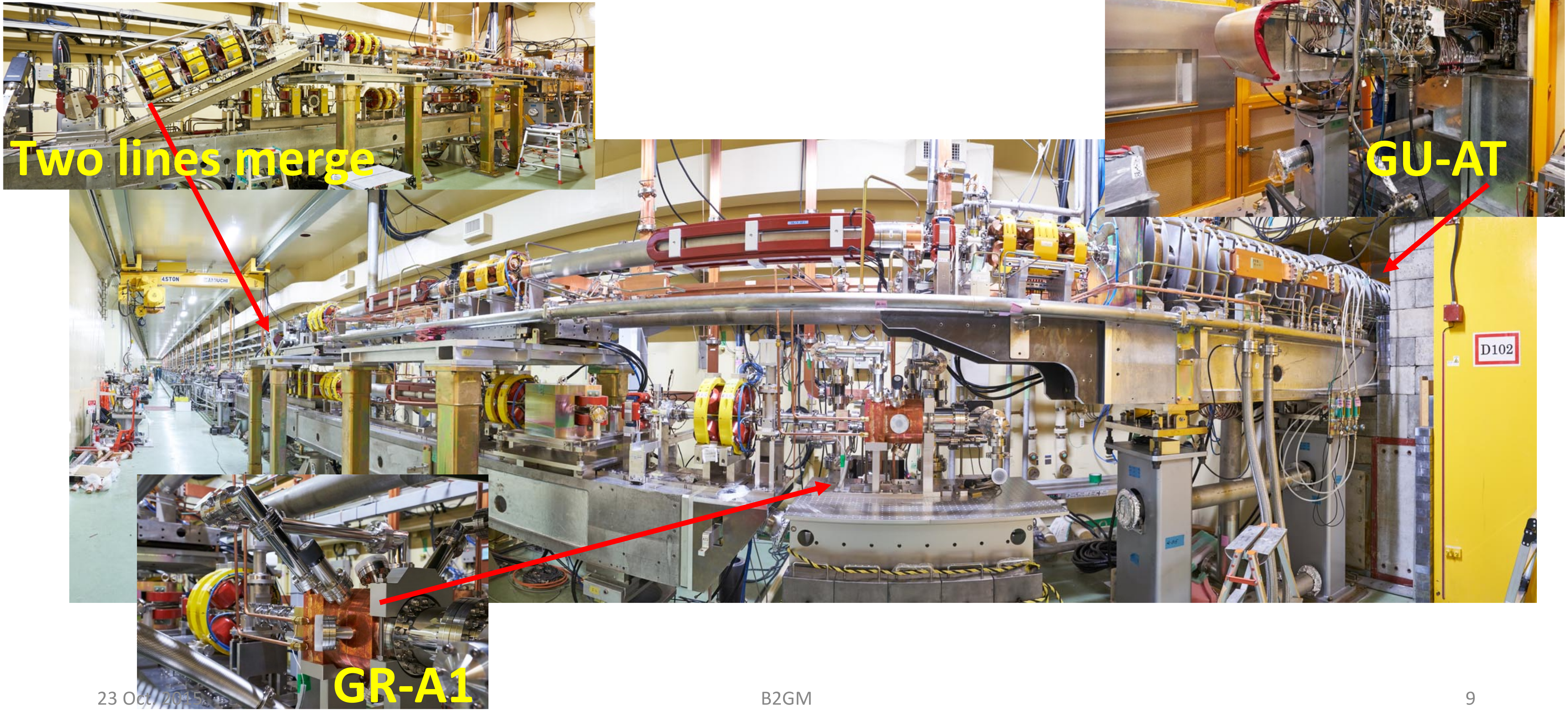
$\gamma\varepsilon_x$=49.2 mm·mrad±10% $\gamma\varepsilon_y$=26.2 mm·mrad±10%



- Measured emittances were higher than target values.
- Higher horizontal emittance is due to laser incident angle.

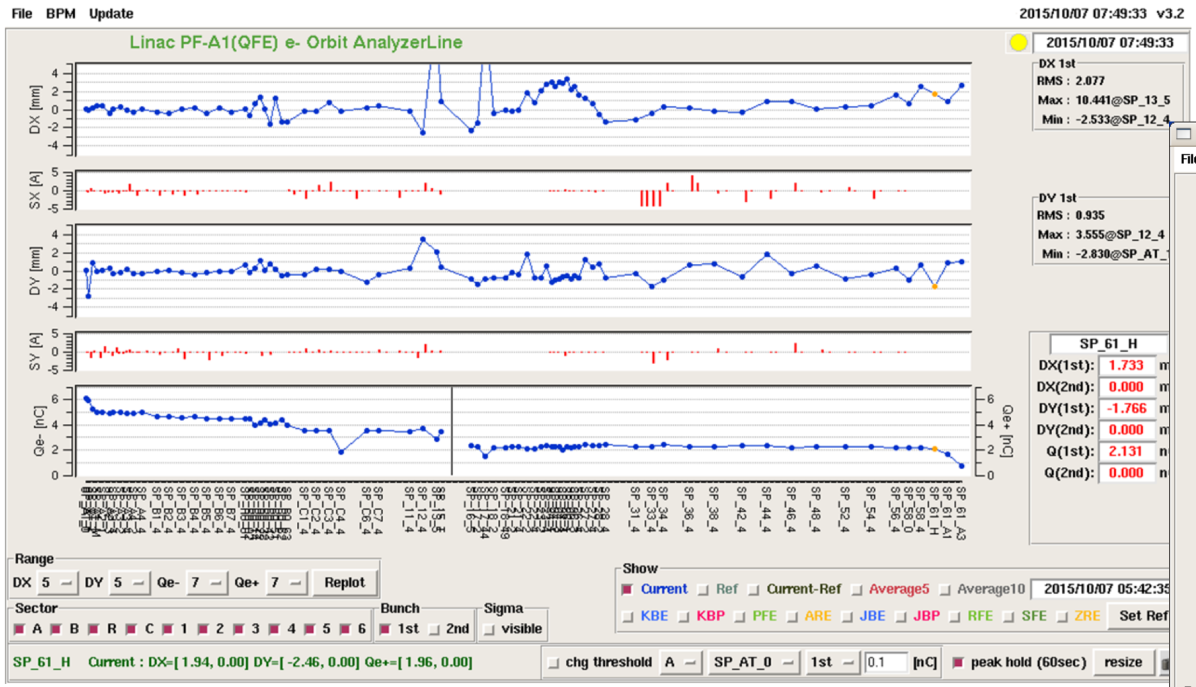
Need high acc. voltage of RF gun for small emittance

A1 electron gun area in double-deck configuration

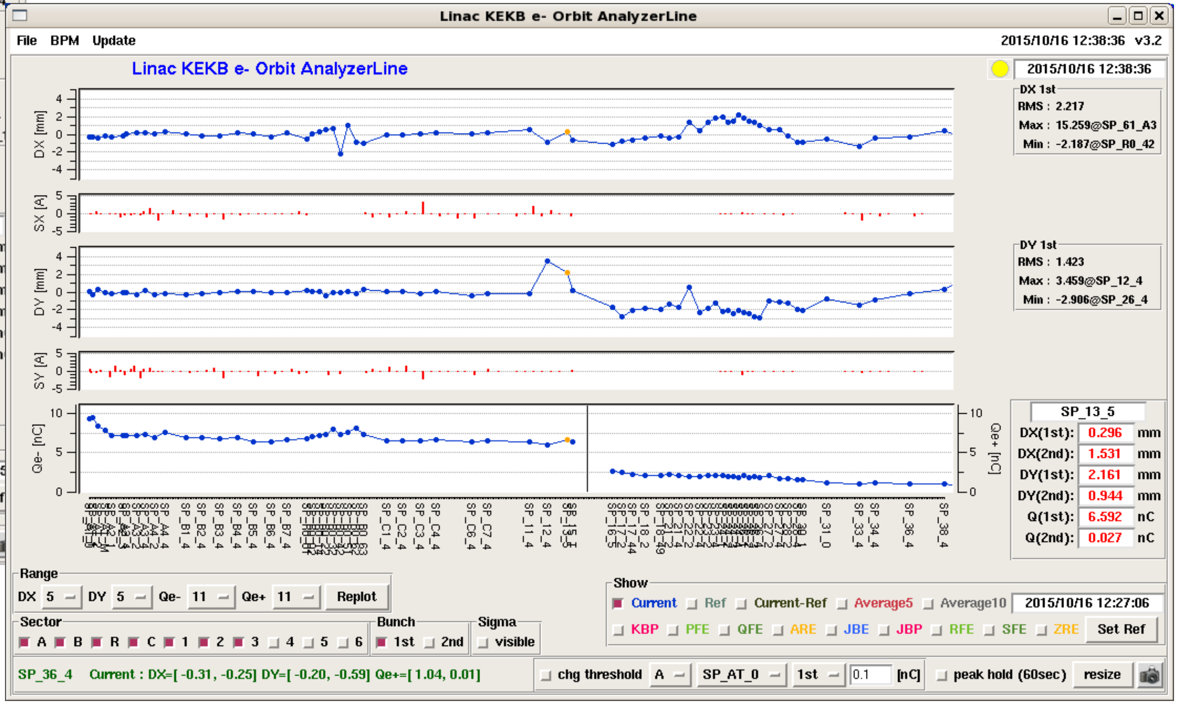


Recent electron bunch charge

Out of 6nC, 2 nC was transported through target center hole to linac end



6 nC was delivered to target



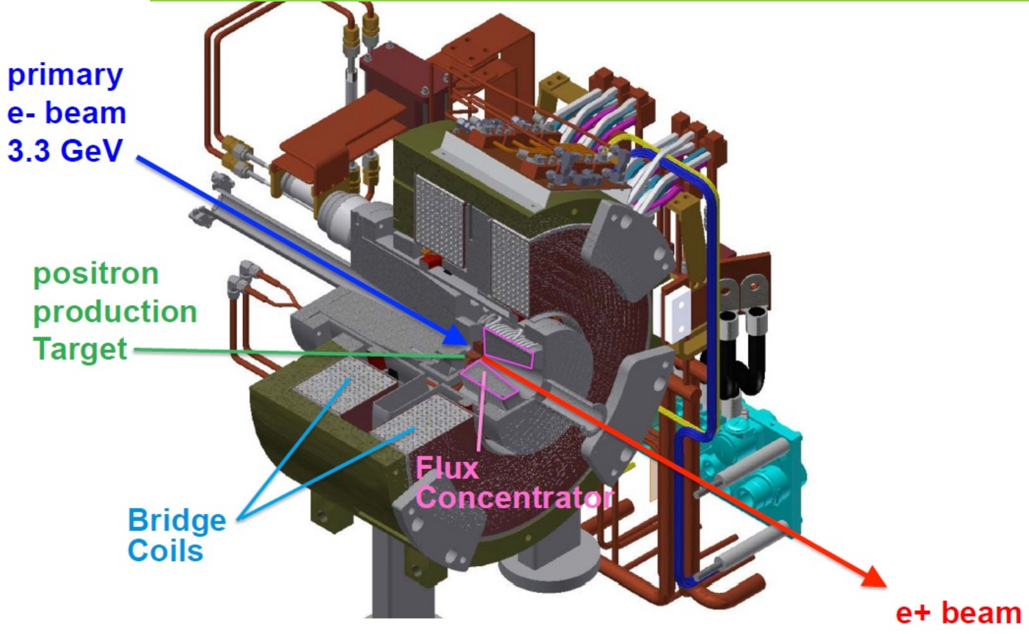
In late January, 2016

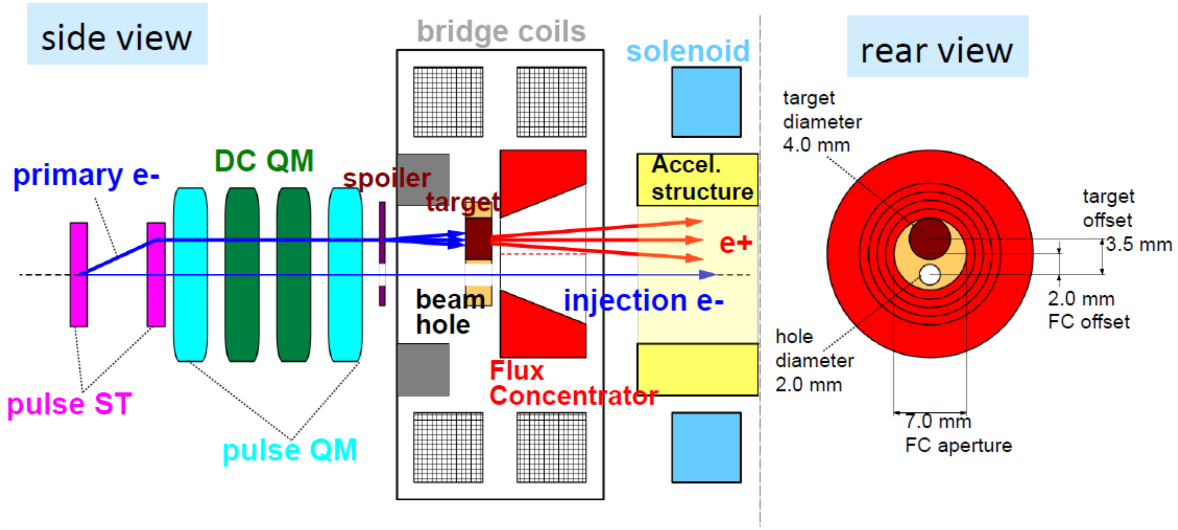
Radiation shield at target area will be reinforced

Target drive current of 200nA at present will be increased to 800nA with adding iron shield around target area

It allows drive electron with 8nC/bunch in 2 bunched at 50Hz.

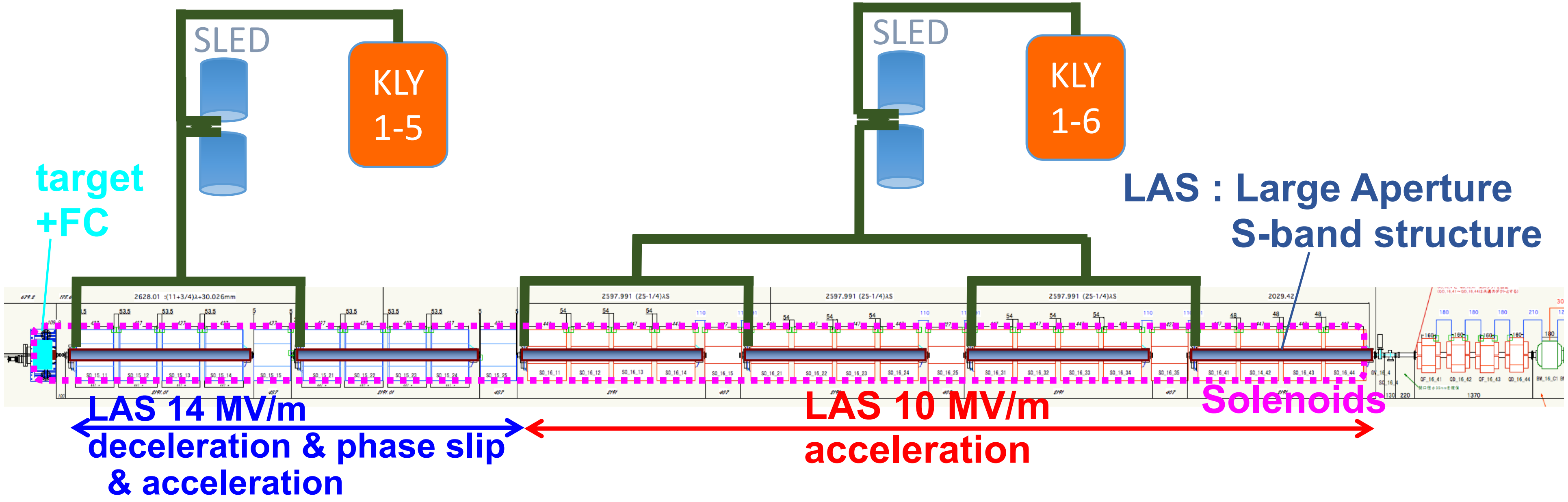
Positron system

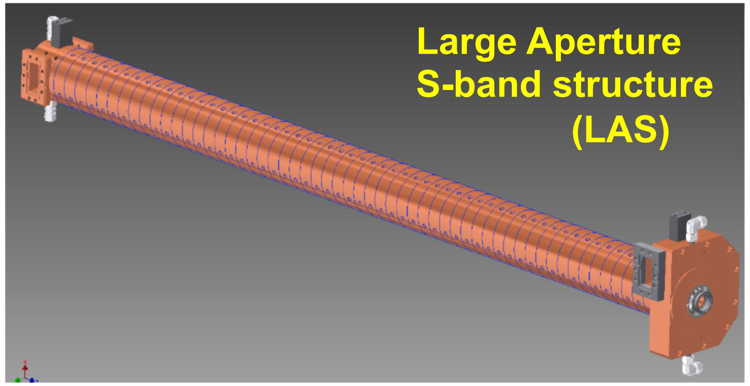




- **For phase-I (without DR)**
  - Primary drive electron intensity will be increased
  - Radiation safety under 800 nA for phase-I will be allowed in late Jan. 2015
  - Production rate will be increased with using
  - flux concentrator, high solenoid field and large aperture accelerator tube
  - Emittance will be reduced by collimation
  - Big shield is being prepared for radiation safety

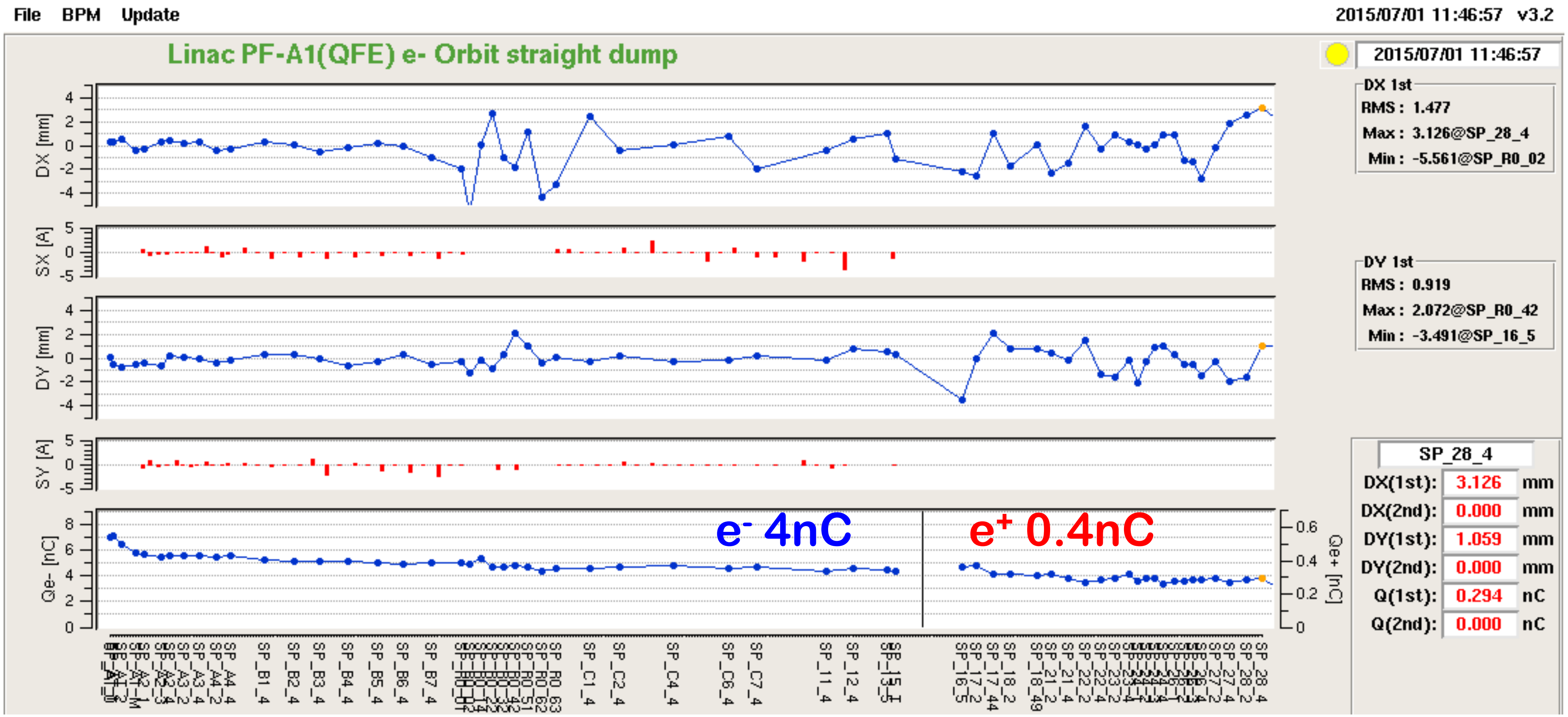
Schematic of positron Capture Section





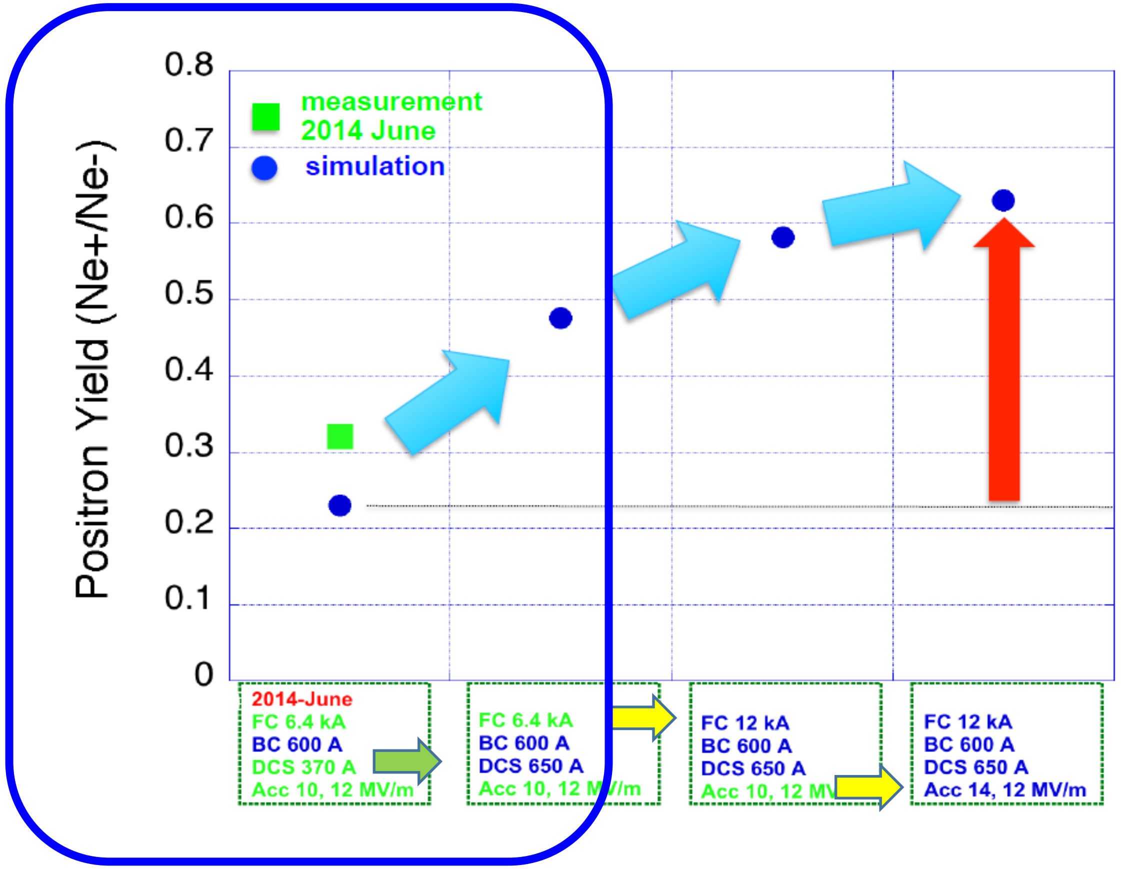
- LAS with SLEDs for sufficient field gradient
- breakdown issue of LAS in solenoid field
- needs careful RF conditioning

Positron intensity achieved in 1 July, 2015

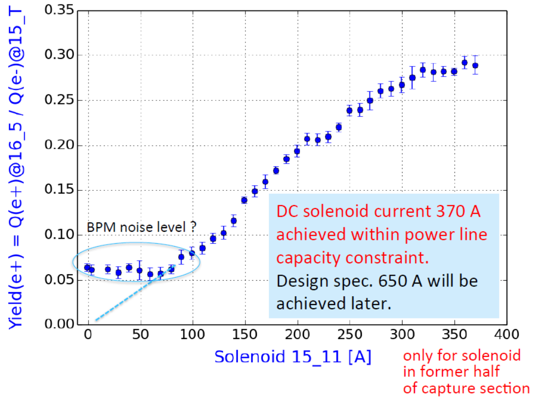


Reached η=0.1 before summer shutdown in this year

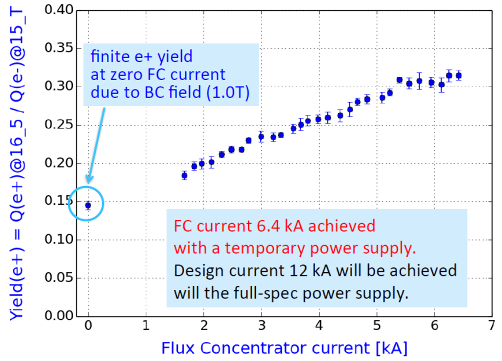
Boosting positron yield and intensity



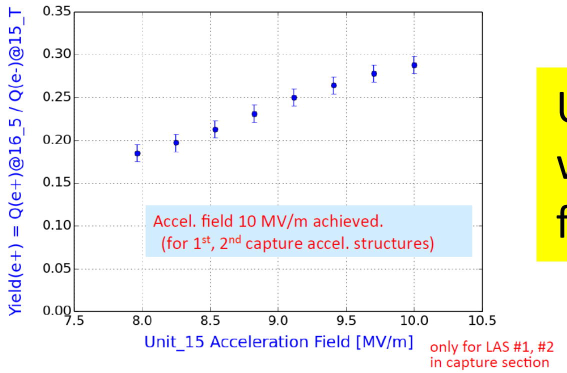
For Phase-I



Done with electricity power up

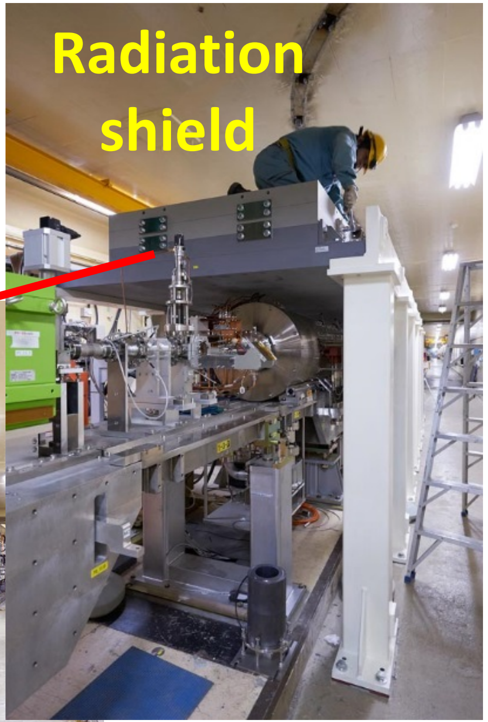


Under processing with magnetic field



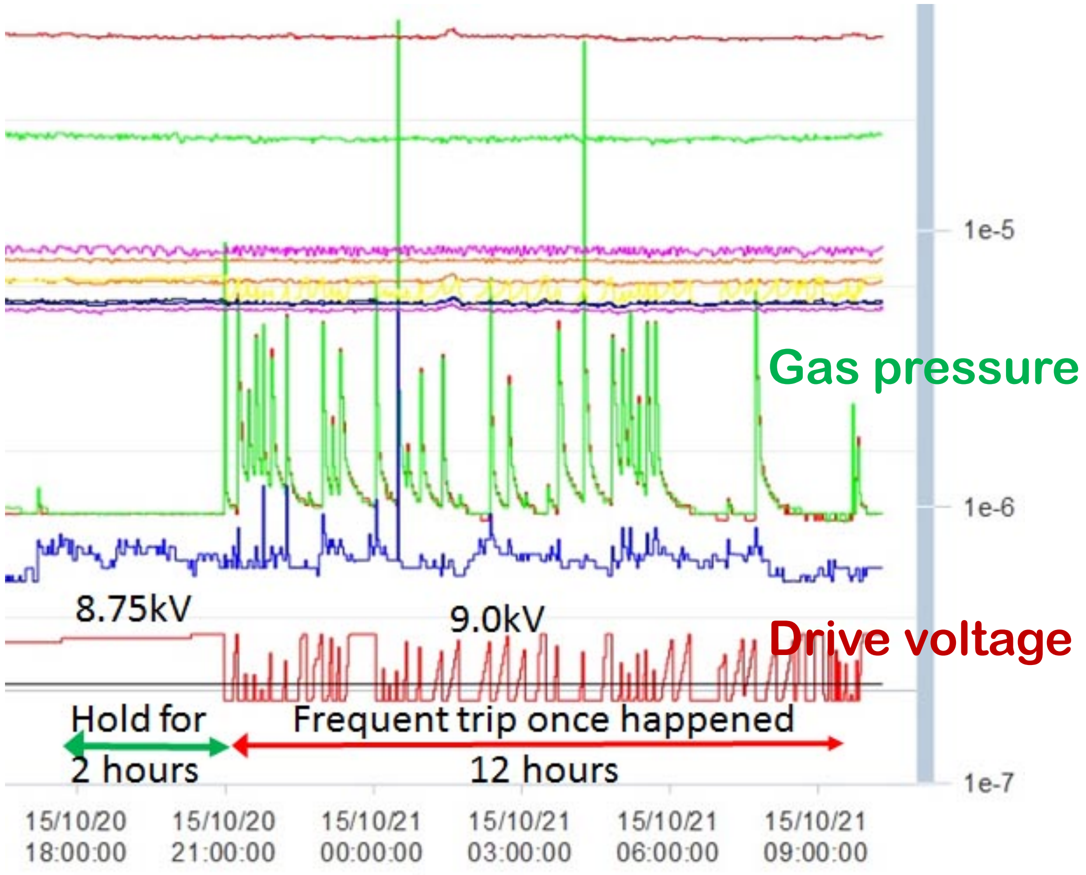
Under processing with magnetic field

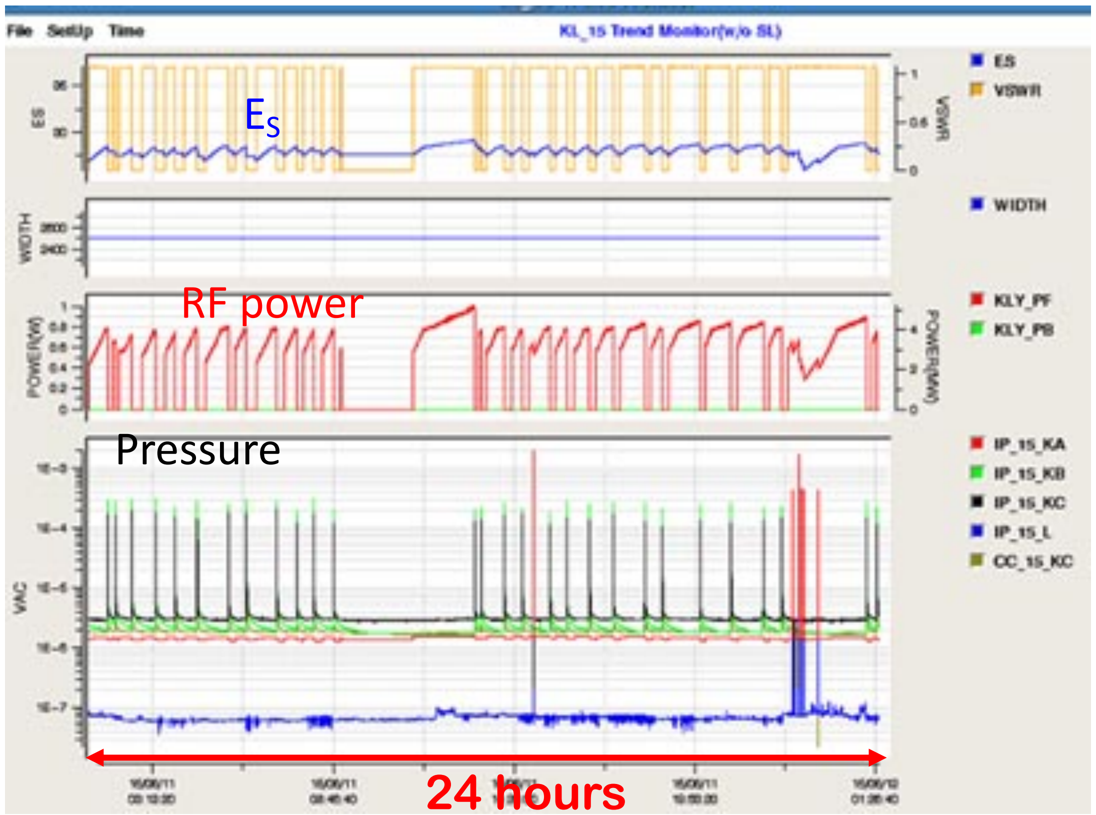
Target / FC / LAS / Solenoid



- FC drive current capacity was doubled in summer 2015
- Radiation shield will further increased before phase-I in Jan. 2016

Struggling against gas burst





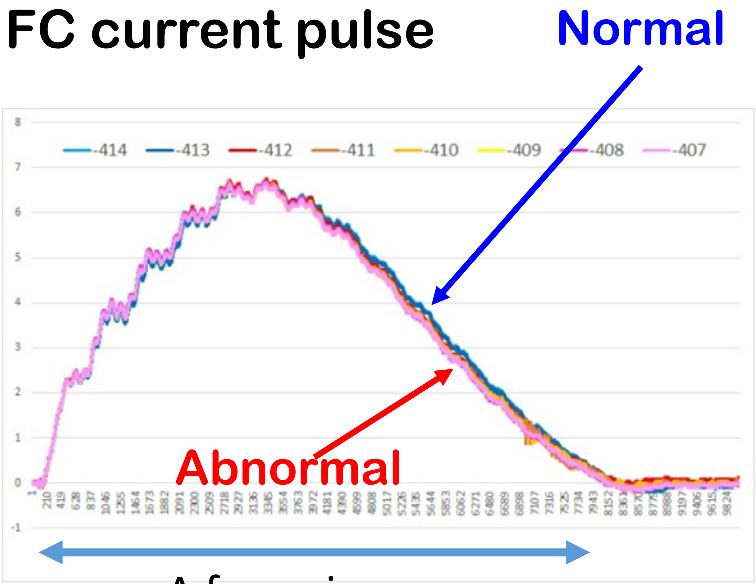
Frequent **gas burst prevents FC** with solenoid field from higher current operation than half-design.

Frequent **gas burst and vacuum breakdown prevents LAS** in solenoid field from higher field operation than 10 MV/m.

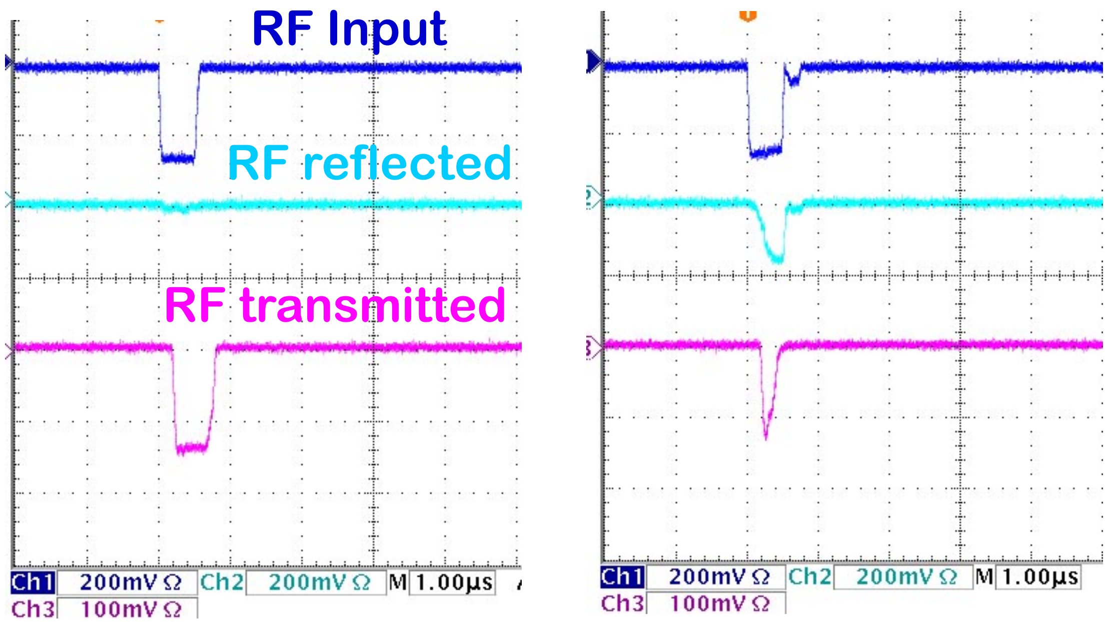
For both, processing is kept under way.

Breakdown(?) to be understood and suppress

FC current pulse



RF power for LAS

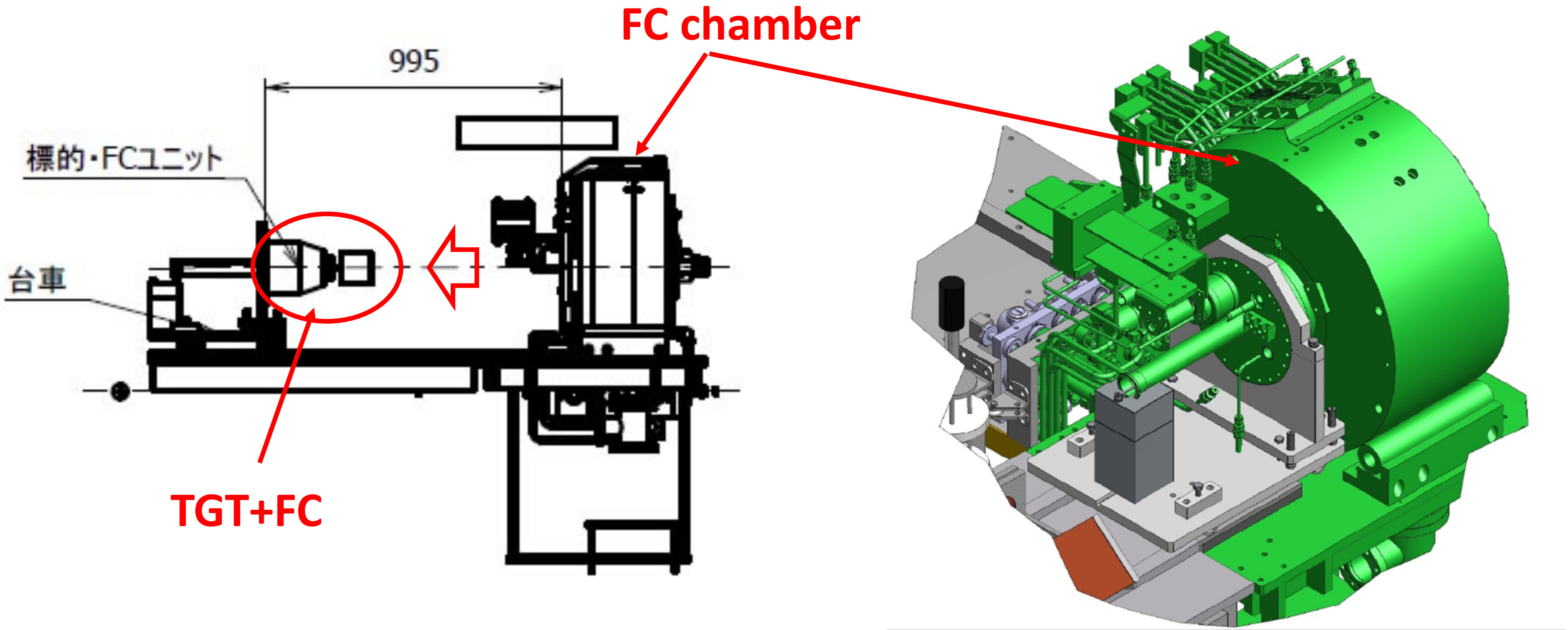


Normal pulse Abnormal pulse

Trailing half was reduced, showing reduction of inductance.

RF power was reflected back to klystron and interrupting transmission through accelerator tube.

Further development on FC



- Replacement of TGT+FC is under consideration for phase-I.
- Complete exchange mechanism of the TGT + FC + LAS may be in hand before Phase-II.

Positron at present and near future

- Positron yield of 10% of drive electron was established.
- Higher-charge drive electron makes more positrons.
- High voltage cabling and other peripheries are approaching to their final ones.
- Frequent gas burst is observed especially with solenoid magnetic field at more than 6kA current for FC.
- Processing is a bit slow and we need to understand what is happening to overcome this phenomenon and operate at design current.
- LAS (Large-aperture S-band) accelerator tubes are also subject to gas burst and sometimes with RF breakdown. More conditioning time is needed to reach the full accelerator field with SLED.
- Exchange mechanism of target and FC was designed.
- Exchange mechanism of fully replacing FC system is underway for final phase. This makes possible to replace any of the TGT/FC/LAS/Solenoid hard wares.

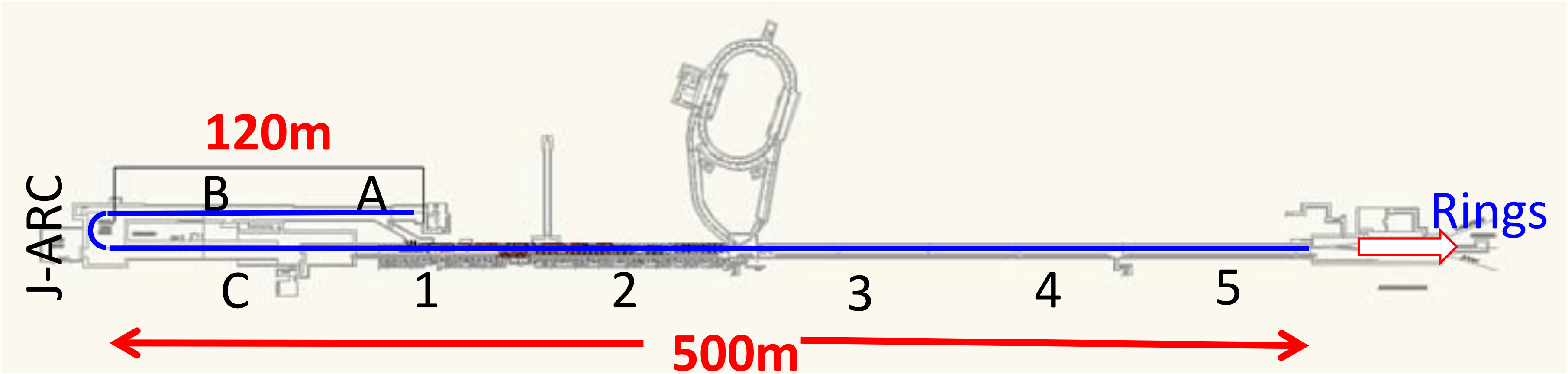
Collimation for phase-I

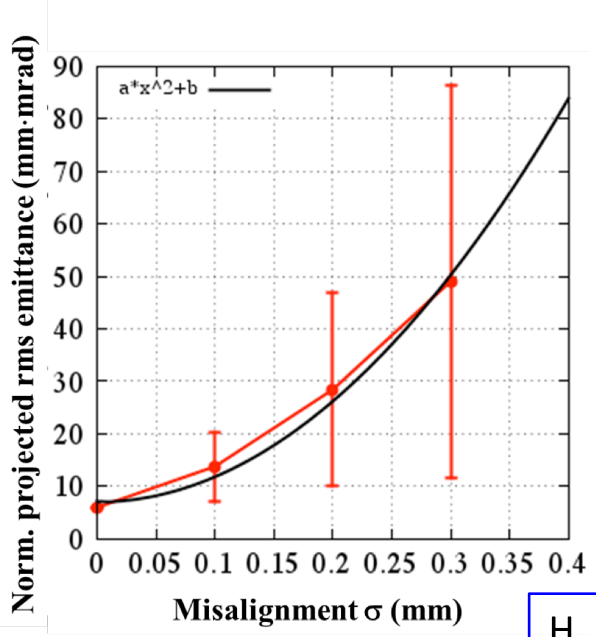
- A set of three collimators were prepared for cutting beam tail for DR injection at the end of sector 1.
- These can be used for cutting positron beam tail for Phase-I without DR.
- Additional shield is being prepared.

Emittance issue for phase-II and beyond

1. Hard wares aligned on a girder by measuring positon by laser tracker
2. Girder are aligned by using laser PD referred to laser light passage
3. Hard ware alignment are to be smoothly improved by measuring with laser tracker
4. Beam evaluation and evaluation to be integrated in the alignment process
5. Suppression of emittance growth due to the floor movement

Alignment Requirement





H. Sugimoto

σ < 0.1 mm: $\beta\gamma\varepsilon$ 20 mm·mrad is almost satisfied.

σ > 0.1 mm: emittance preservation is required by some methods.

Requirement

Local σ < 0.1mm

Global σ < 0.3mm

Laser PD system as a reference to align girders

500m laser line

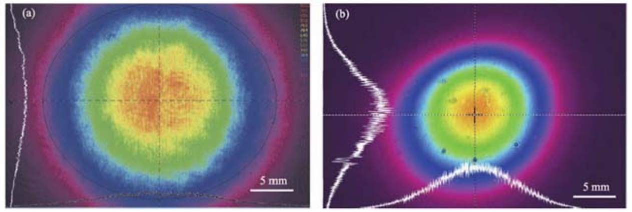
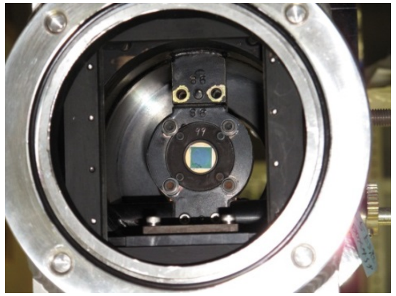
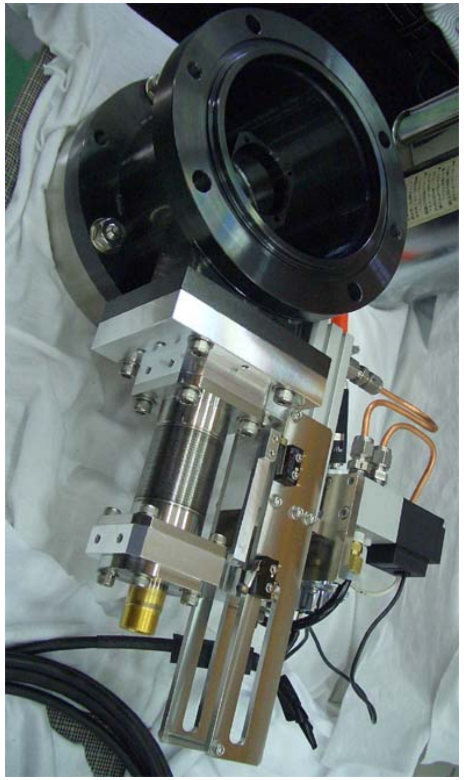


FIG. 5. Intensity profiles of the laser beam at (a) $z = 0$ m and (b) $z = 500$ m. Scale bars are 5 mm.

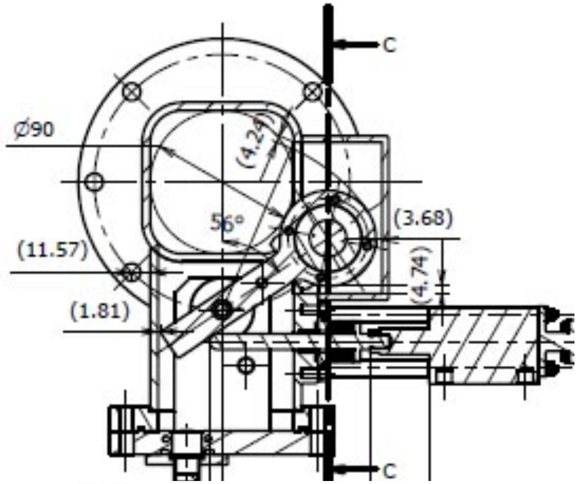


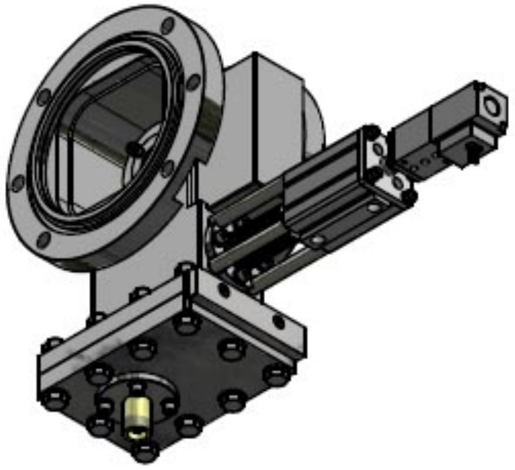
4-segmented silicon PD (dia.=10mm)

Manual ON/OFF



Automatic ON/OFF
Linear type
2+8 installed now

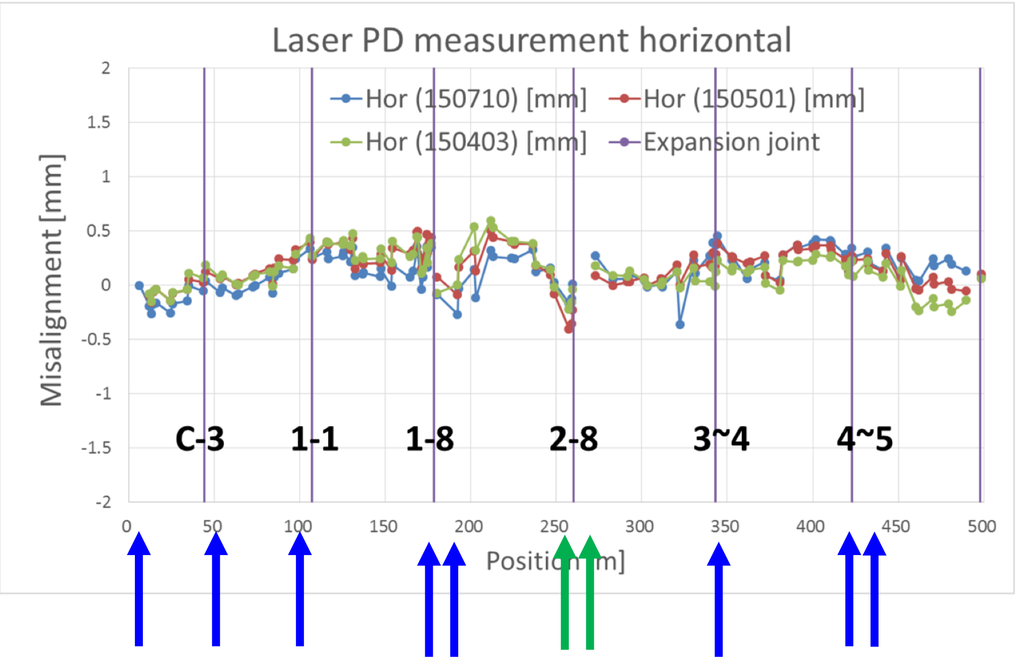




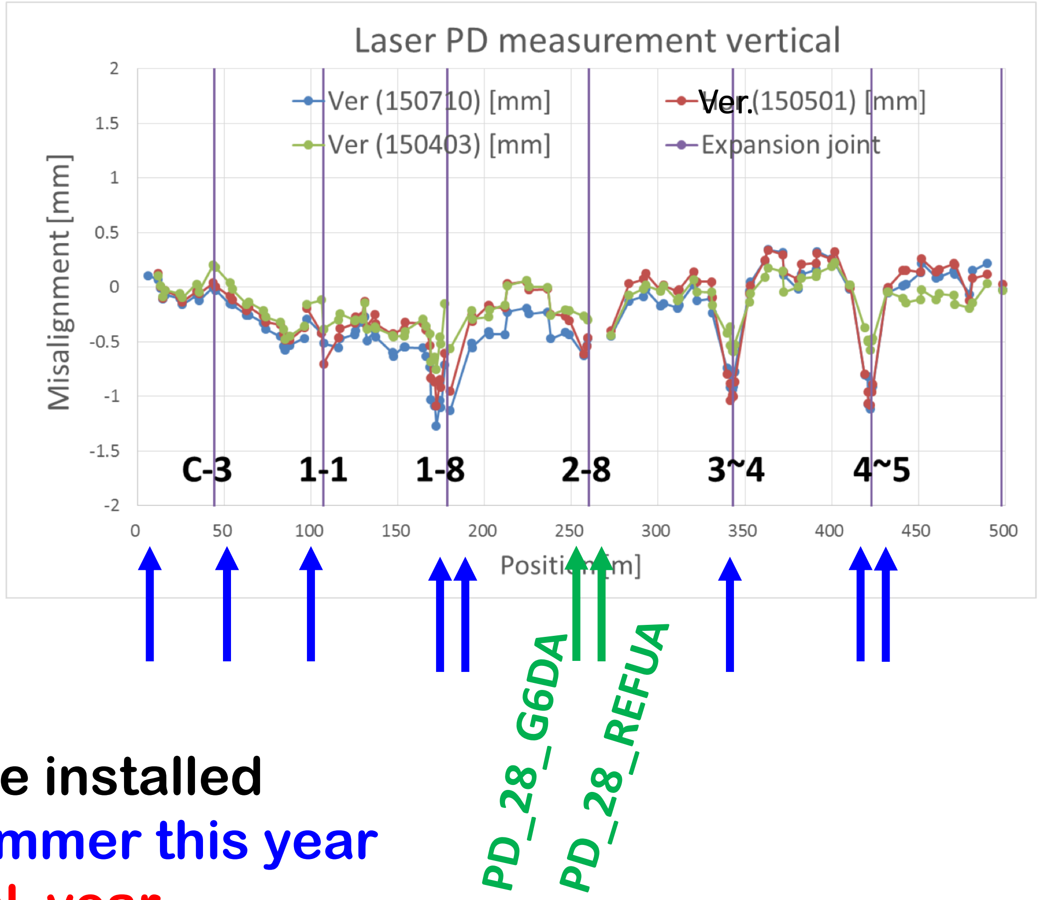
Foresee more installation considering pendulum type and/or present type as candidate

Laser PD measurement
Mostly aligned by a year ago, summer in 2014

Horizontal



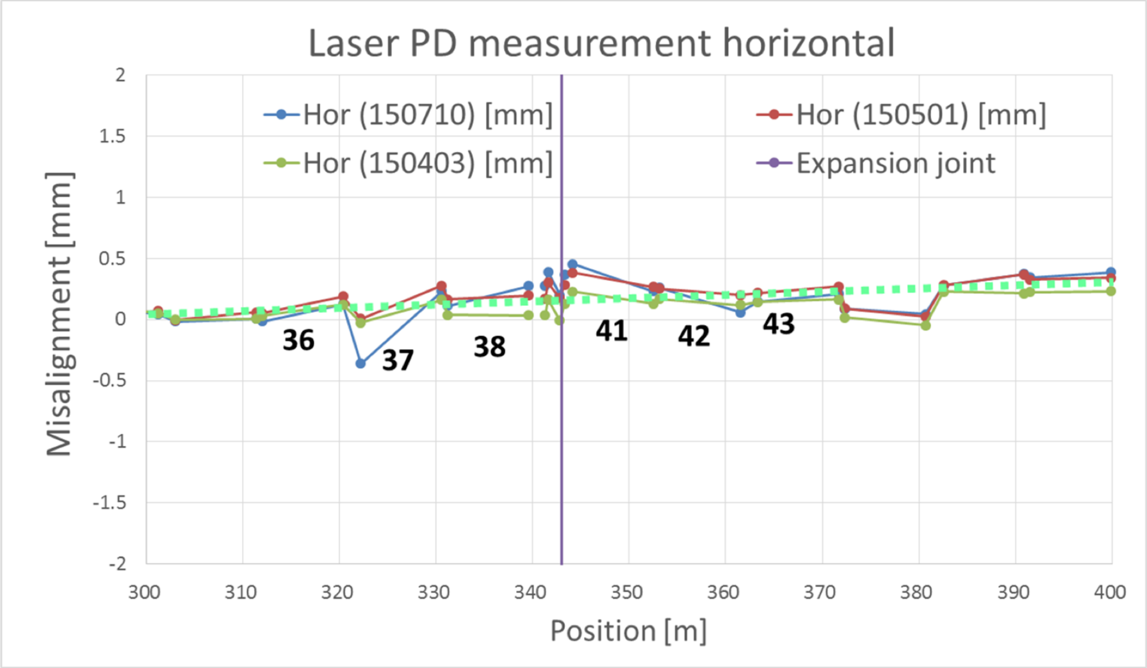
Vertical



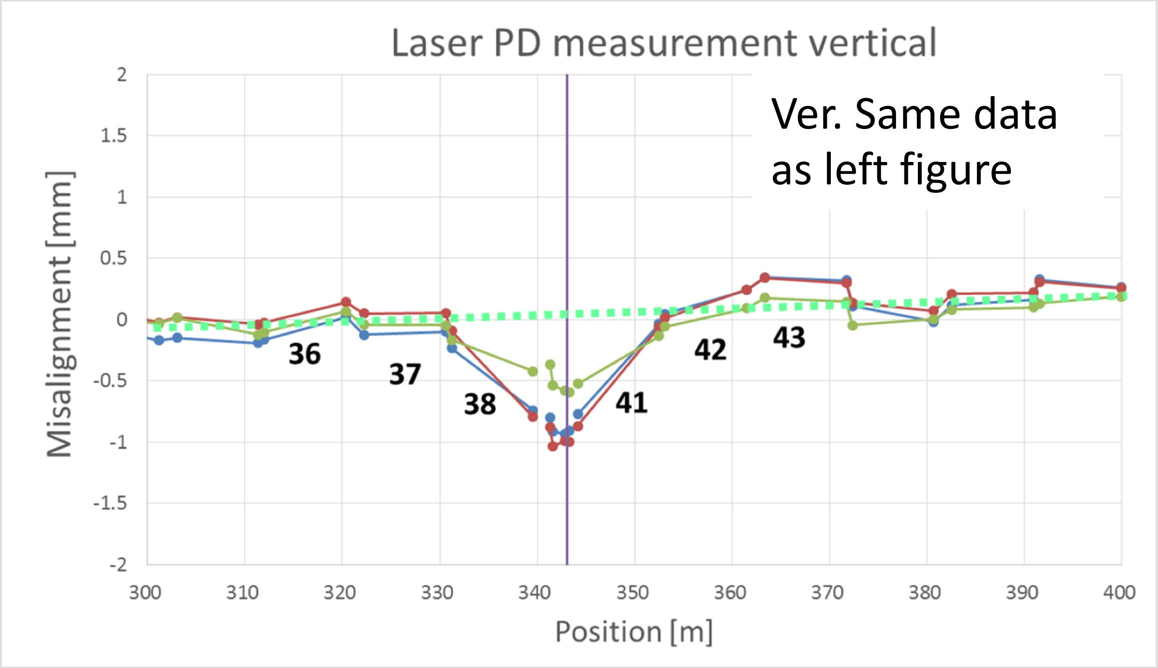
PD in automatic measurement system are installed
two in autumn last year and eight in Summer this year
and more to be installed in this fiscal year

Laser PD more near expansion joint

Horizontal

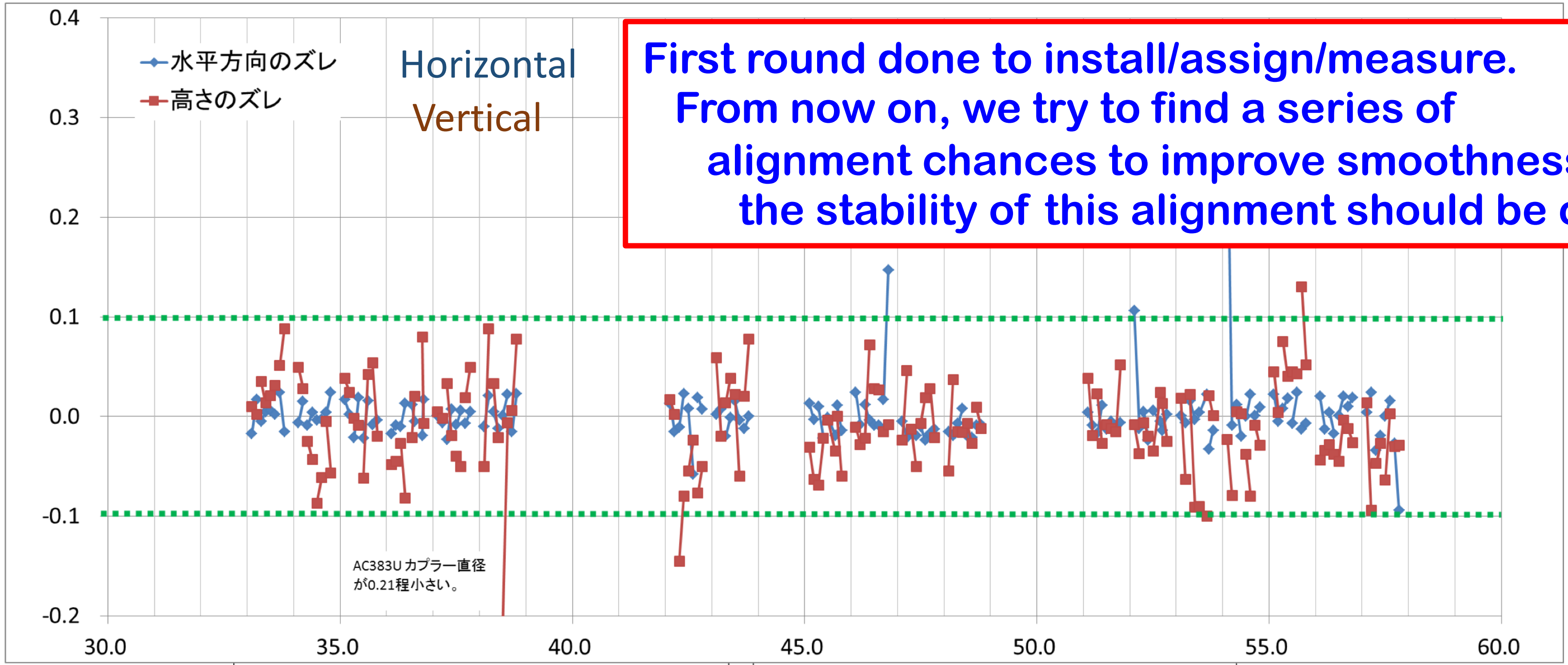


Vertical



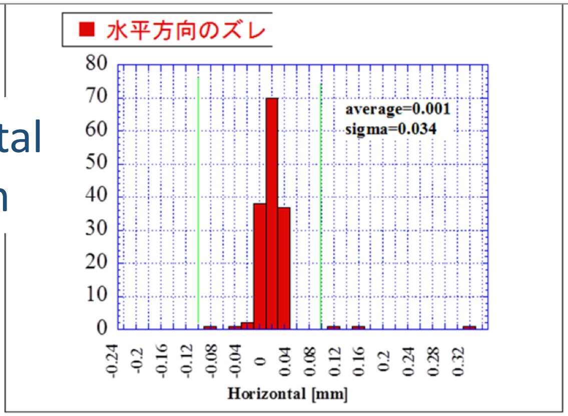
Movement near joint is big.
Mover or some passive support structure to be developed.

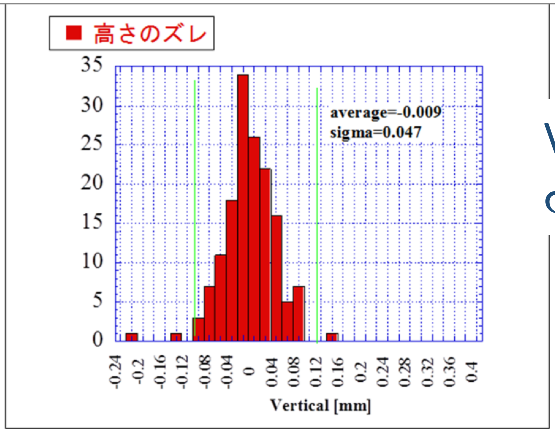
Hard ware initial alignment on a girders in sector 3 - 5



First round done to install/assign/measure.
From now on, we try to find a series of alignment chances to improve smoothness.
the stability of this alignment should be confirmed.

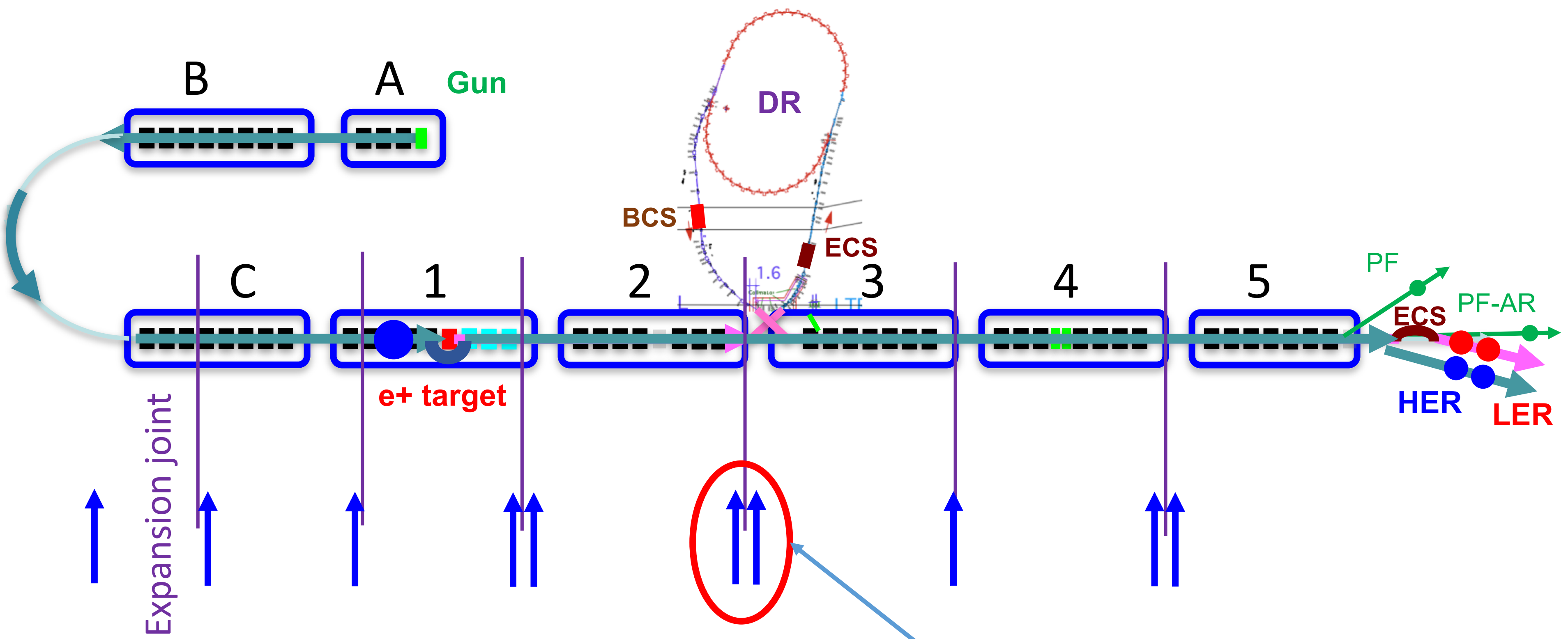
Horizontal
σ=34μm





Vertical
σ=47μm

Floor configuration



Laser PD continuous measurement devices

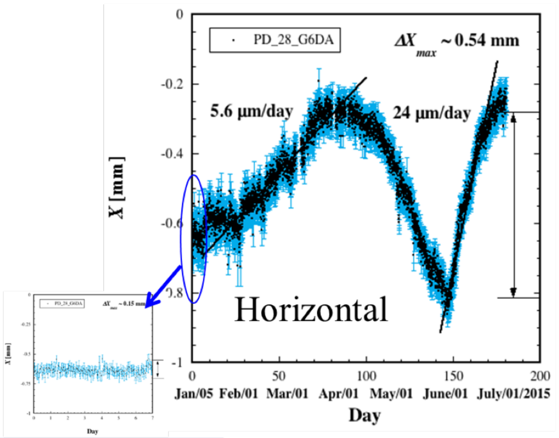
Half a year data in next page

Movement in half a year

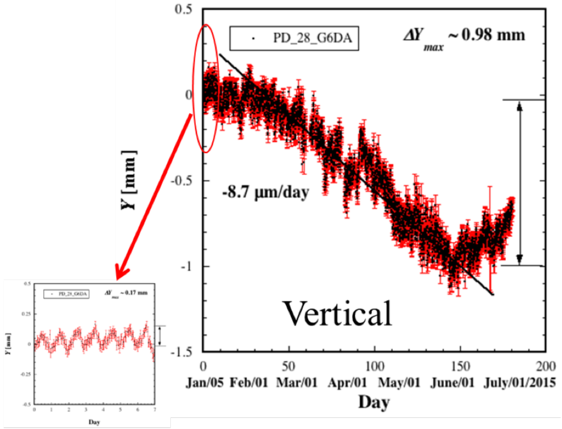
4.25 m

← Upstream PD_28_G6DA ⟷ PD_28_REFUA Downstream →

Half a year (2015 5/Jan.-1/July)

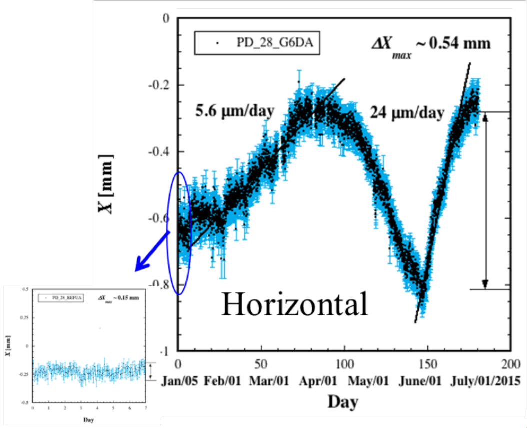


ΔX_{pp}~0.15 mm

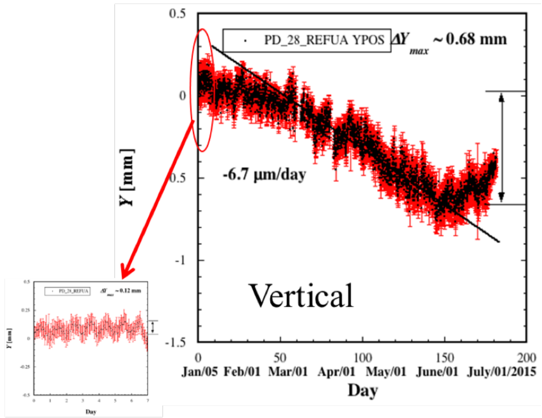


ΔY_{pp}~0.17 mm

Half a year (2015 5/Jan.-1/July)



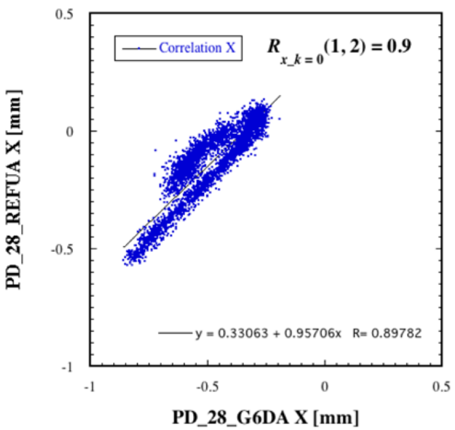
ΔX_{pp}~0.15 mm

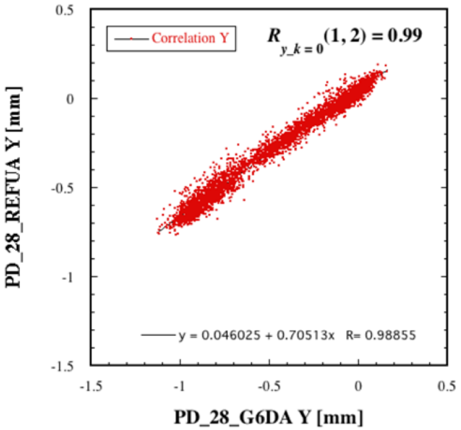


ΔY_{pp}~0.12 mm

1. Movement of 1mm order was observed in half a year.
2. Daily movement is of the order of +/- 0.15mm.
3. Positive correlation was observed.

Correlation between these two positions.



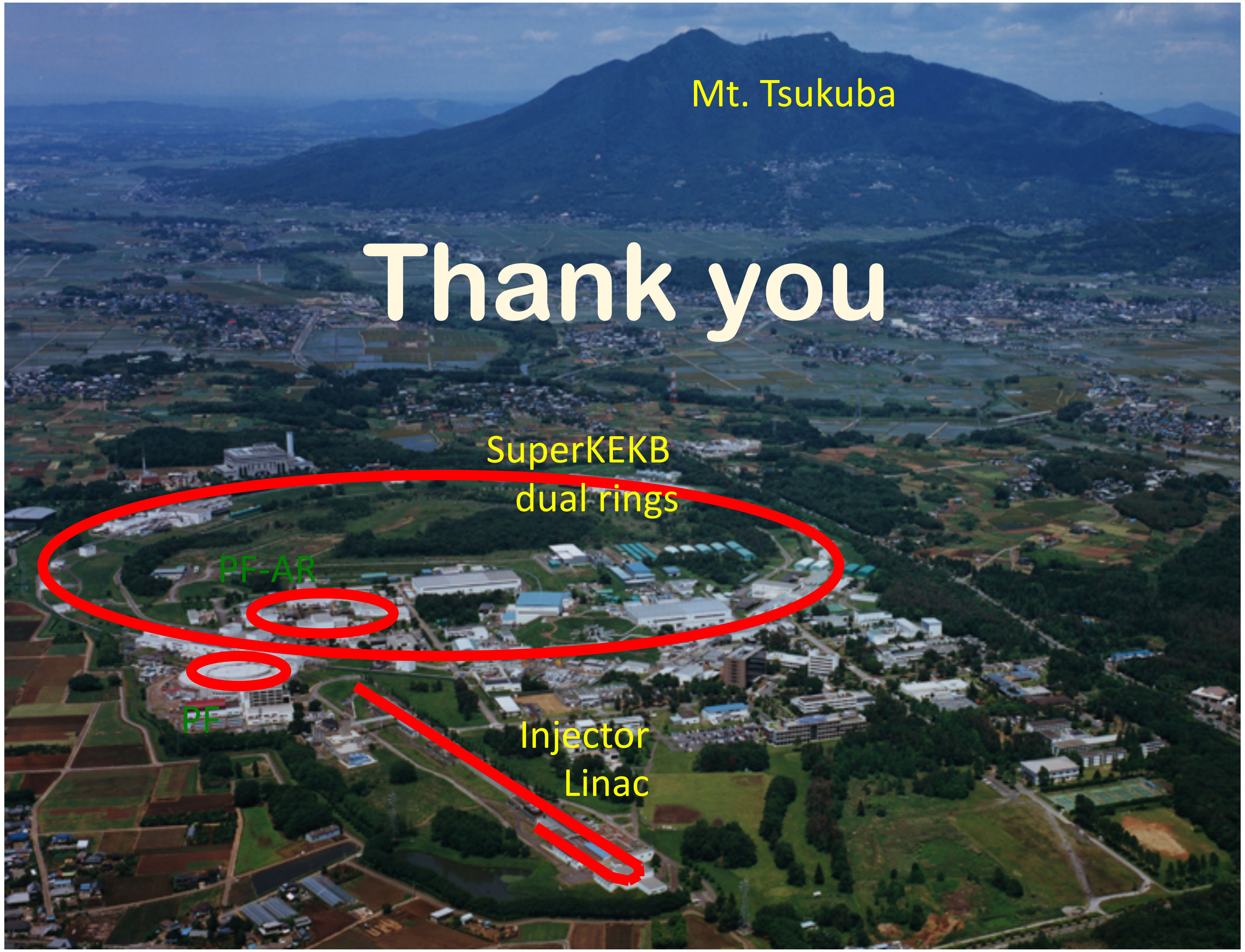


Status and near future strategy

- Monthly measurement of relevant PD's are kept in best effort base for more than a year.
- Continuous PD measurement at 10 points are in progress and acquire data over a year.
- More automatic PD's will be made and installed.
- Movement at joint is underway to understand movement.
- Beam study will be performed to acquire the feasibility of floor movement information by beam.
- Feasibility of mover will be studied in mechanism, time, cost.
- These efforts should be integrated to make a system before Phase-III, in two years from now.

Conclusion

- Phase-I beam, both electrons and positrons, can be delivered in time in 2016.
  - Thermionic gun, positron production, shield reinforcement, ….
- Preparation for DR will be made by next summer and supply "low" emittance beam will be delivered in Phase-II from 2017.
  - RF-gun, LTR/RTL, pulse magnet, …..
- Floor movement should be understood and we develop a suppression / compensation scheme to meet Phase-III operation in 2018.
  - Floor movement and emittance control, ultimate laser RF-gun, …


Mt. Tsukuba
Thank you
SuperKEKB
dual rings
PF-AR
PF
Injector
Linac