NSLS-II Booster

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Budker Institute of Nuclear Physics

Presentation at SFR-2016

Novosibirsk

4 July 2016

Brookhaven **N**ational **L**aboratory

National **S**ynchrotron **L**ight **S**ource

and

National **S**ynchrotron **L**ight **S**ource **II**

Brookhaven Laboratory located in the center of Long Island, in 100 km from New York.
In the first three decades of operation , the NSLS has yielded many discoveries and two Nobel Prizes.
The new NSLS-II will produce x-rays more than 10,000 times brighter than the original NSLS.

NSLS (1982 – 2014)

NSLS-II main parameters

Energy	3 GeV
Ring circumference	792 m
Horizontal emittance	<1 π nm rad
Vertical emittance	8 π pm rad
Beam current	500 mA
Number of RF buckets	1320
Number of bunches	1056
Average bunch charge	1,25 nC
RF frequency	500 MHz
RMS energy spread	0,1%

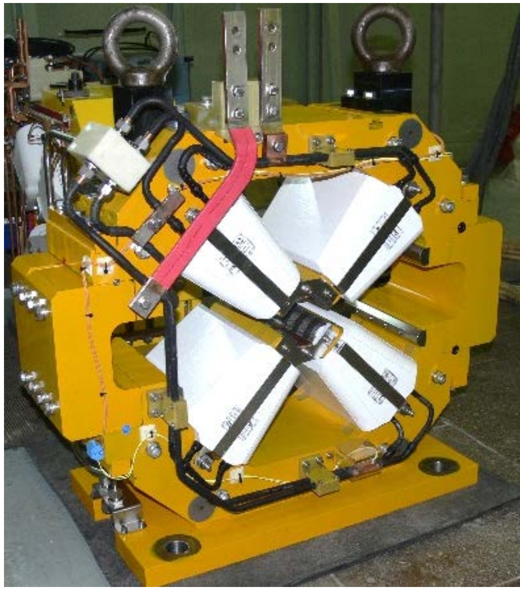
NSLS

BNL announced a tender on the booster synchrotron which shall be capable of accelerating electron bunches from the minimum linac energy of 170 MeV to a maximum extraction energy of 3,15 GeV for injection into the main storage ring.

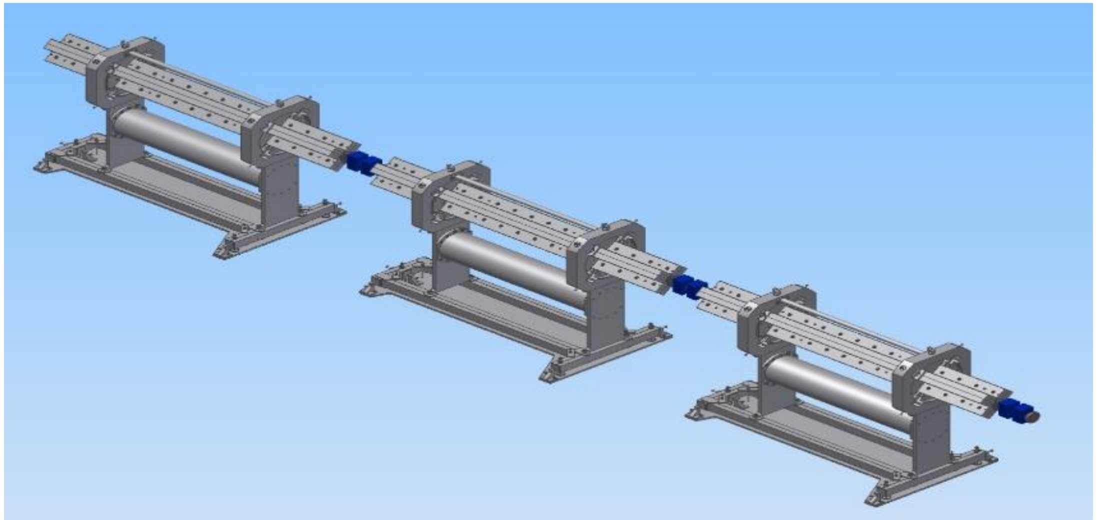
The proposal from BINP on the turn-key booster were the most attractive and the contract was signed in May 2010.

BNL and BINP cooperation

BINP produced 21 quadrupole magnets of the 30Q44 and 30Q58 types for the SNS, designed by BNL



BINP produced 128 quadrupole magnets of 6 types for the NSLS-II Main Ring



BINP produced three helical undulators for proof-of-principle experiment on coherent electron cooling.

Table 4.1. General Booster Specifications

Circumference	**158.4 m**	
Super-Periodicity	4	
Operating time per year	**6000 hr**	68%
Unscheduled Downtime	**0.4% (24 hr per year)**	
Repetition rate	**1 Hz (2 Hz)**	
RF frequency	499.68 MHz ± 10kHz	
RF voltage	200V - 1.2 MV	
RF Amplitude and phase jitter at 1.2 MV	±1% and ±1°	
Max RF power	72 kW	

Table 4.3: Parameters of the Electron Beam Extracted from the NSLS-II Booster

Nominal extraction energy	3 GeV
Horizontal Emittance	<40 nm rad at 3 GeV
Momentum Spread	<0.1%
Extracted Beam Angle Jitter	<20% of beam divergence
Coupling	<10% at 3 GeV
Charge (Long pulse/ Single pulse mode)	>10 nC/0.5 nC
Charge transport efficiency between ICTs in LB and BSR TL	**>75% (achieved up to 98%)**

Scope of work

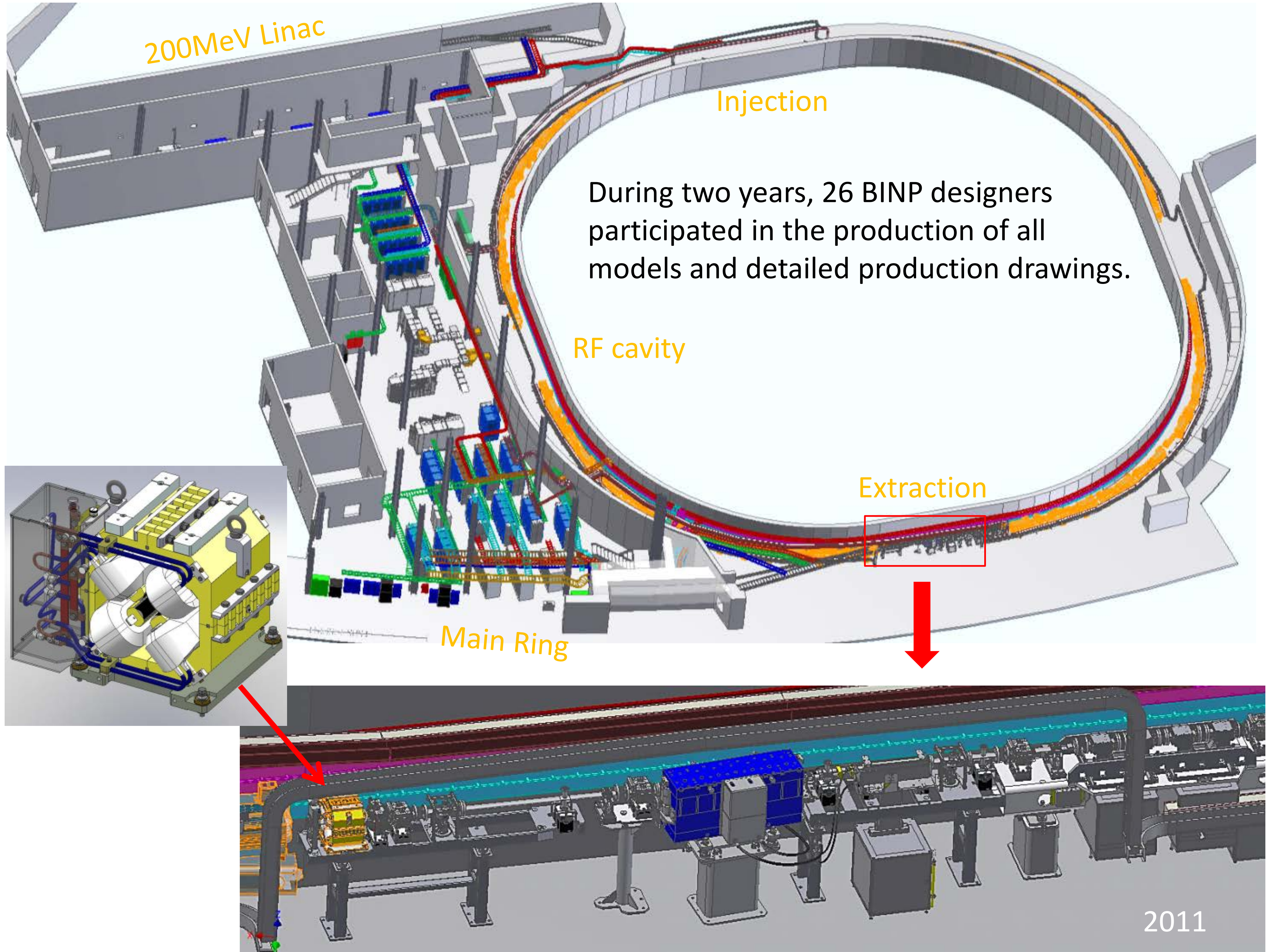
- Beam dynamics cross checking
- Design and production of booster ring (158 meters)

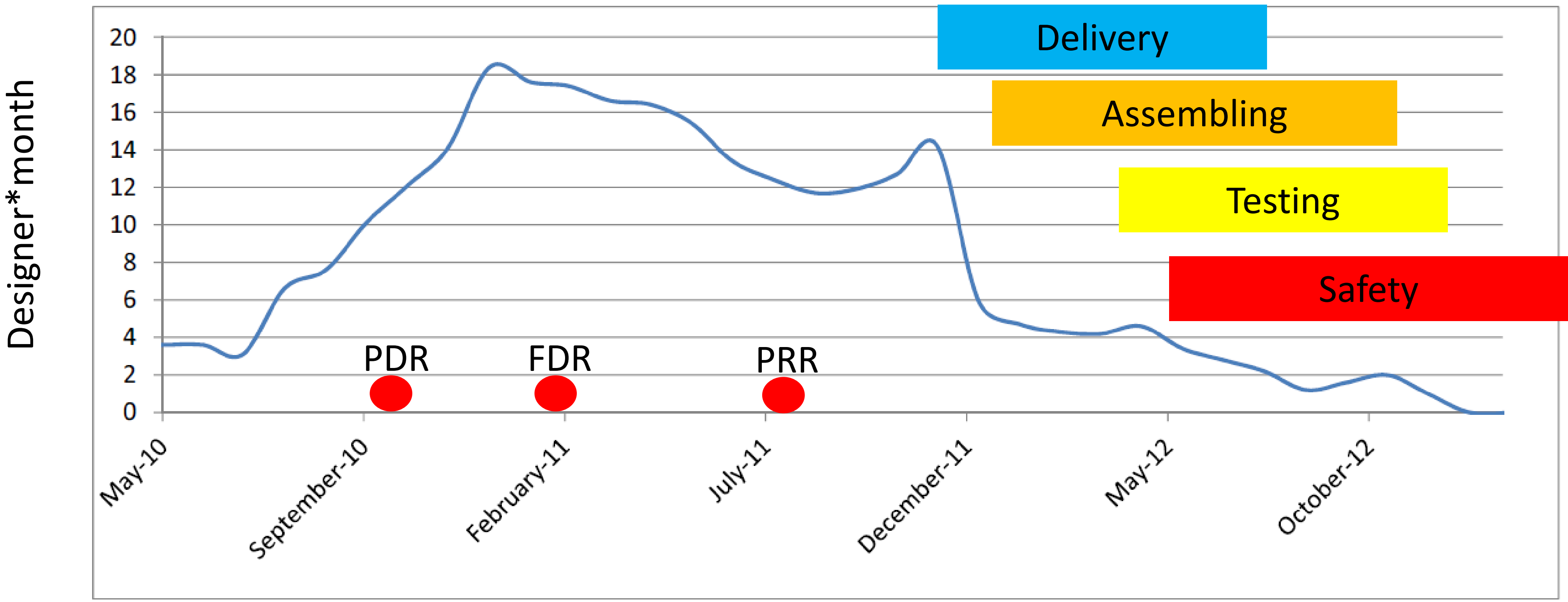
  Including:

  - Magnets (28+32 dipoles, 24 quadrupoles, 16 sextupoles, and 36 correctors)
  - 160 meters of vacuum channels
  - Injection and extraction (bumps, kickers, pulsed and DC septums)
  - Power supplies
  - Diagnostics
  - Control System and software (together with BNL)
  - Infrastructure (cables, water, and air) (together with BNL)

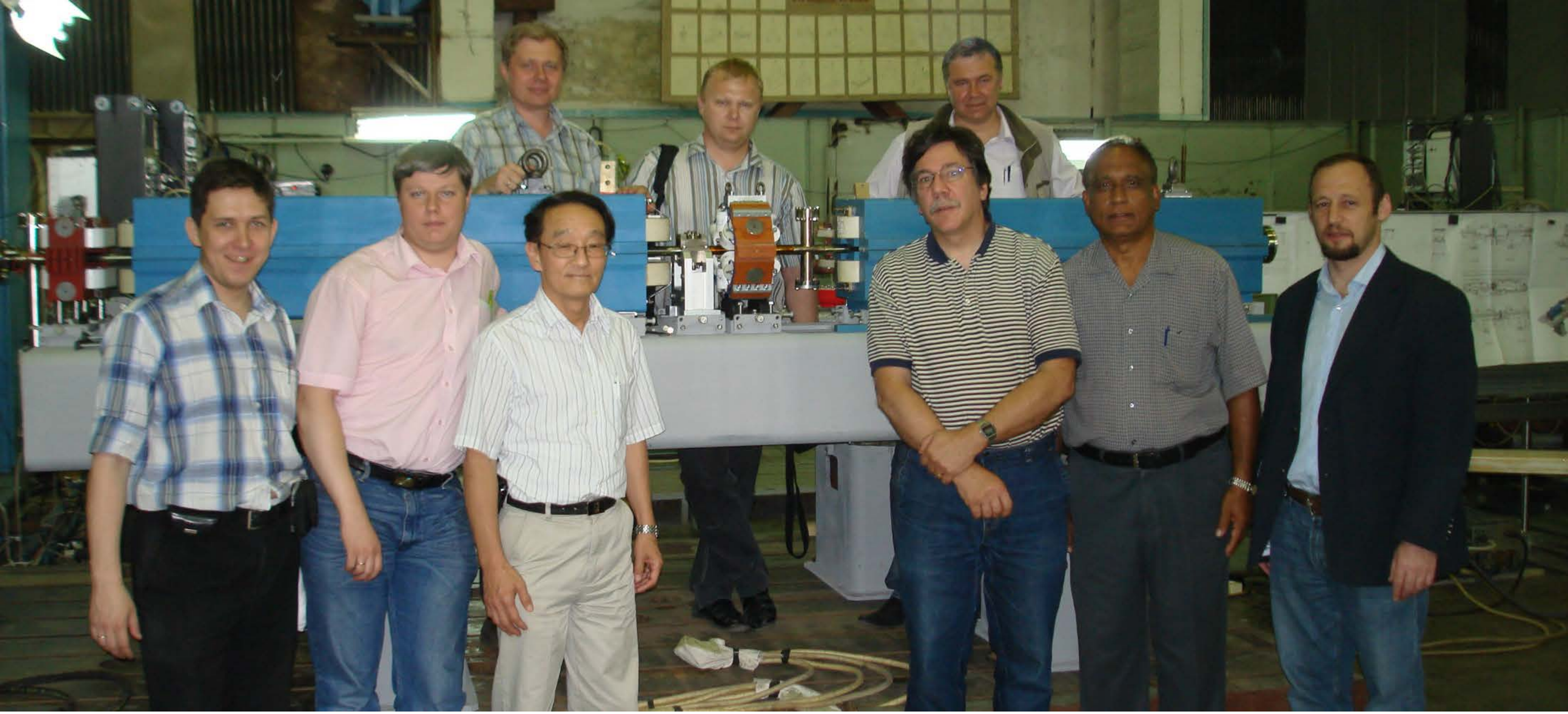
  Excluding: RF system (PETRA 7-cell 500MHz Cu-cavity)

- Installation (together with BNL)
- Testing (together with BNL)
- Commissioning (together with BNL)
- 2 year warranty


200MeV Linac
Injection
During two years, 26 BINP designers participated in the production of all models and detailed production drawings.
RF cavity
Extraction
Main Ring
2011



Tender	February – March 2010
Contract signing	07.05.2010
Preliminary Design Review	October 2010
Final Design Review	February 2011
Production Readiness Review	July 2011
Booster Delivery	December 2011 – June 2012
Assembling	February – November 2012
Testing	May 2012 – January 2013
Extending Integrated Testing	February – October 2013
Commissioning	09.12.2013 – February 2014



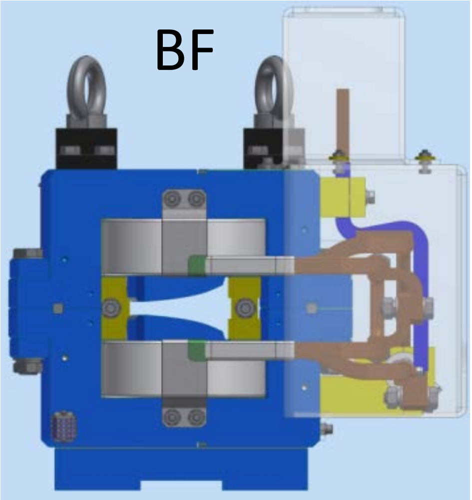
Contract has been signed on 7 May 2010

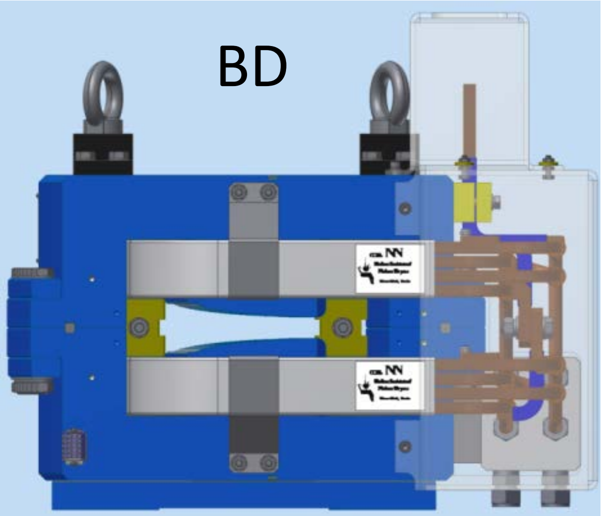
After 14 months booster was designed
and all first article is ready: BD and BF dipoles,
quadrupole, sextupole,
CX and CY correctors,
girder, 6A power supplies.

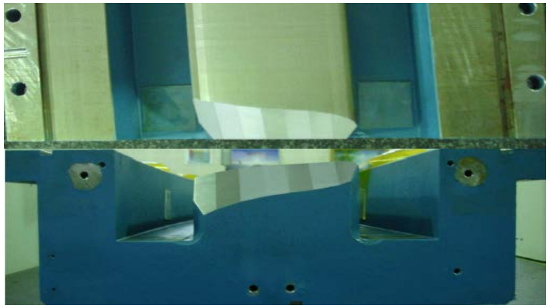
After 28 months in August 2012 all booster components have been delivered to BNL (New-York)

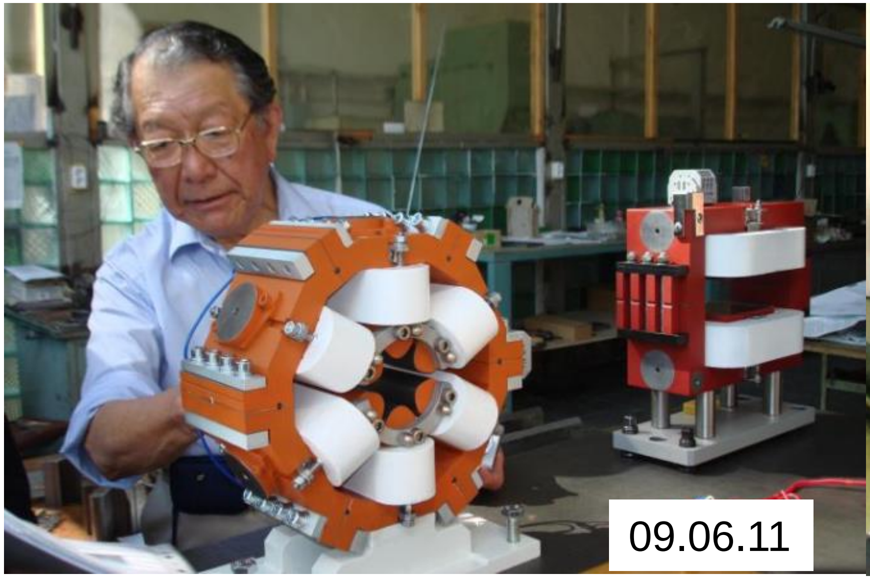
Magnets

BF dipoles, 28 BD dipoles, 32	S. Sinyatkin A. Sukhanov
Quadrupoles, 24	A. Philipchenko V. Kobets
Sextupoles, 16	A. Utkin N. Nefedov
CX Correctors, 20 CY Correctors, 16	V. Petrov V. Konstantinov
Girders, 44	A. Polyanskiy L. Shegolev

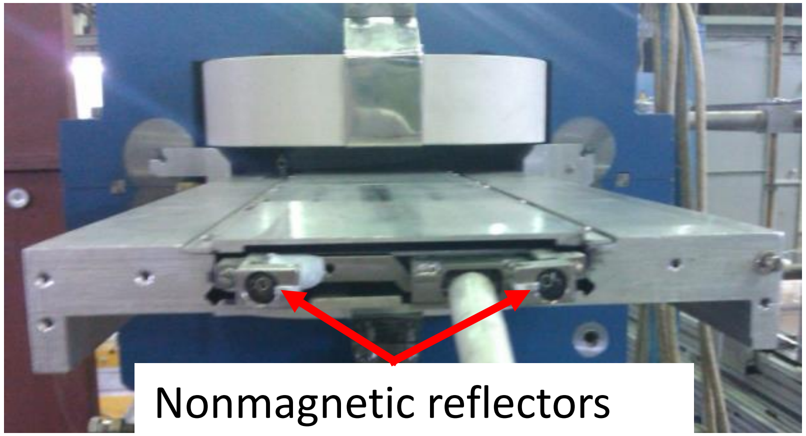


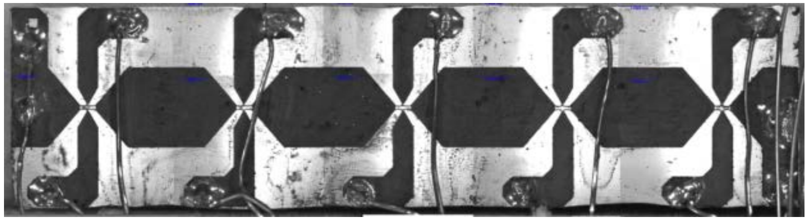


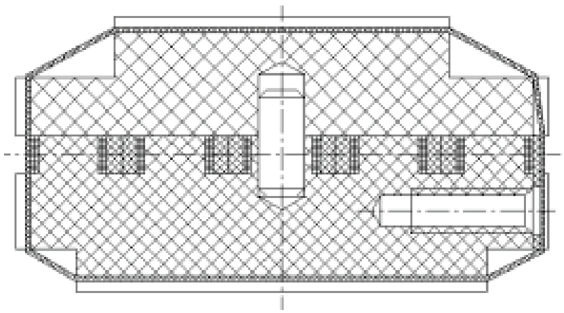




Magnetic measurements



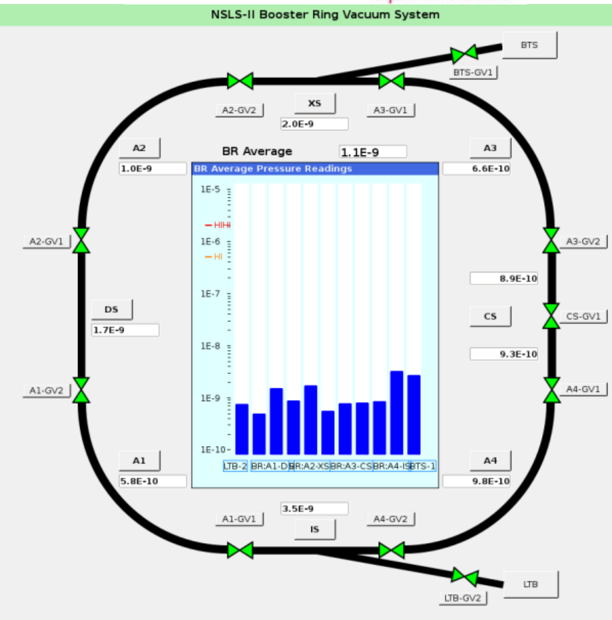


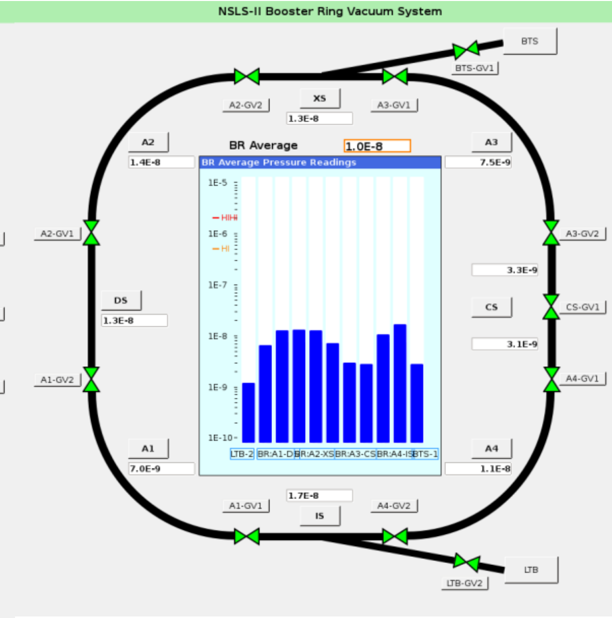


Vacuum system

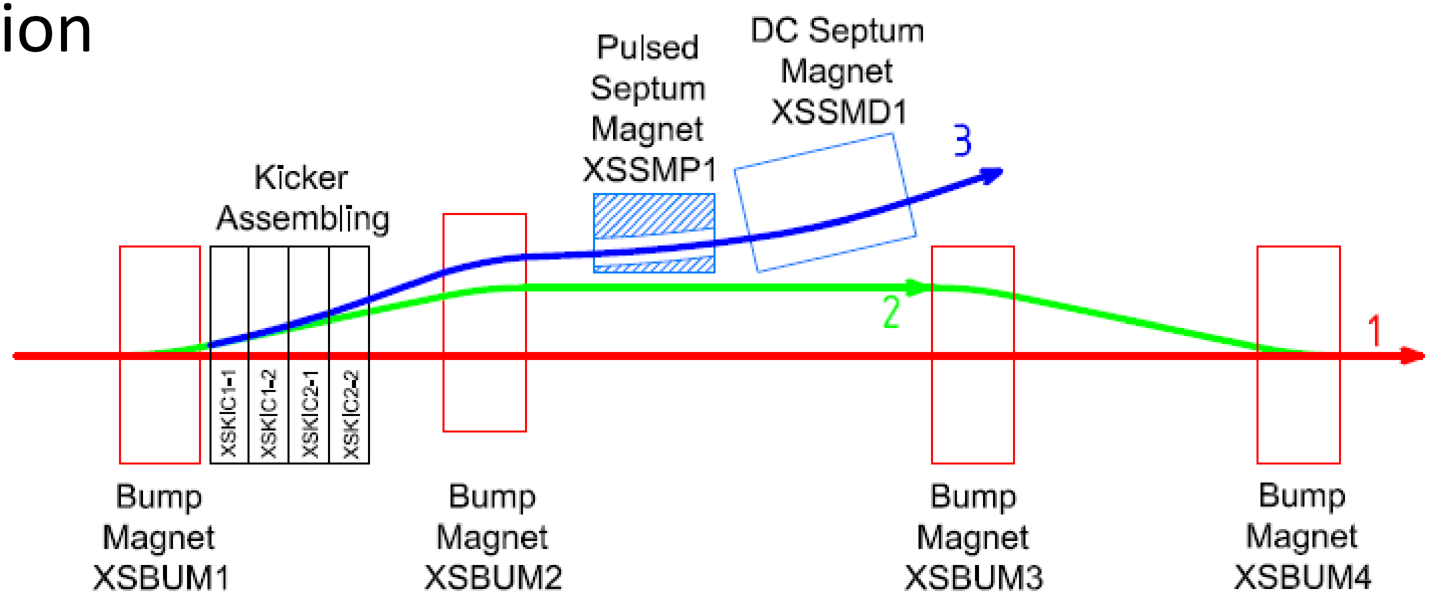
Special transition from an ellipse 43mm x 21mm tube to a round 46 mm tube

Vacuum chamber for bump magnet with 62 mm x 22 mm aperture and stiffening plates

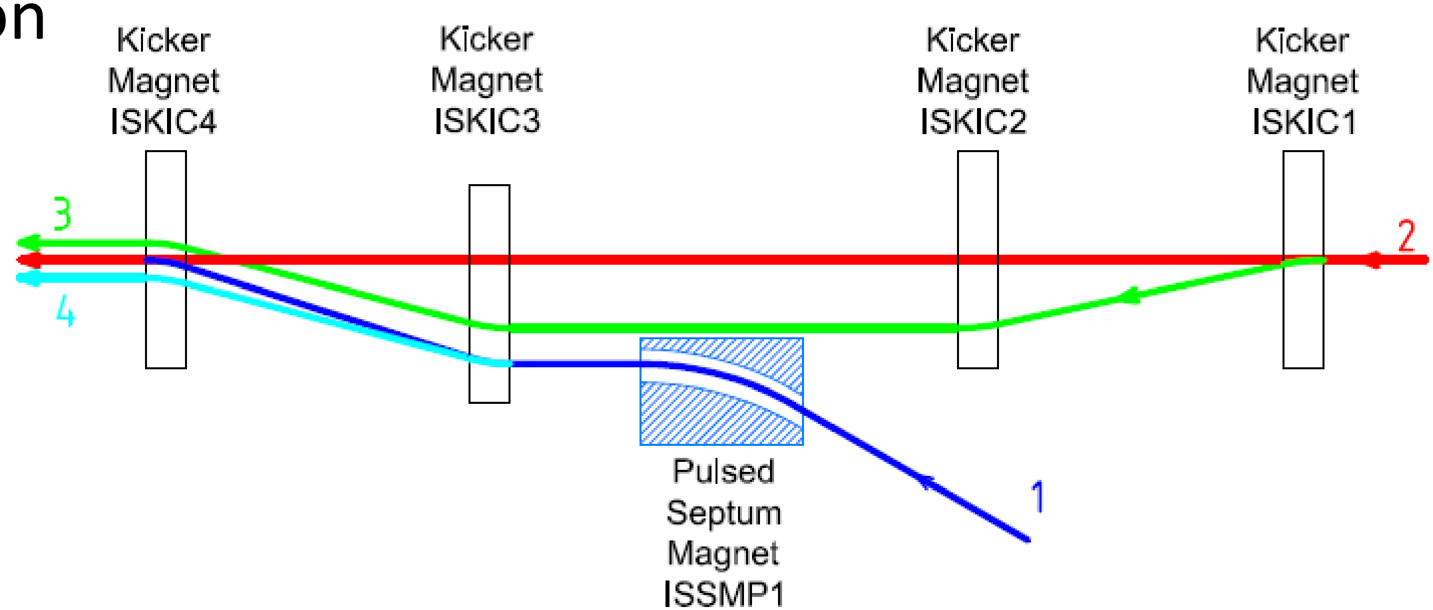




Extraction



Injection



Main technical parameters of the injection magnets

	Leff [mm]	h gap [mm]	Fi [mrad]	H [T]	I [A]	U [V]	T/4 [μcek] (Flat-top)	Stability dH/H [%]
IS-KIC3	20.5	38	15	0.0488	1 477	20 500	(0.3)	± 0.5
IS-KIC4	20.5	38	15	0.0488	1 477	20 500	(0.3)	± 0.5
IS-SMP1	750	30	125	0.1112	2 660	195	52	± 0.1

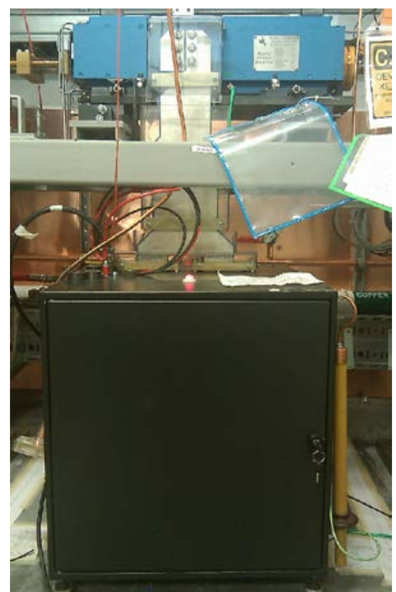
Main technical parameters of the extraction magnets

	Leff [mm]	h [mm]	Fi [mrad]	H [T]	I [A]	U [V]	T/4 [μcek] (Flat-top)	Stability dH/H [%]
XS-BUMPS	16.9	33	7.9	0.465	1 530	846	728	± 0.02
XS-KIS1	2*20.5	38	0.283	0.069	**2 088**	**22 000**	**0.3**	**± 0.2**
XS-KIS2	2*20.5	38	0.283	0.069	**2 088**	**22 000**	**0.3**	**± 0.2**
XS-SMP1	600	16	48	0.8	10 200	470	78	± 0.02
XS-SMD1	1252	20	106	0.847	322	10	----	± 0.02

Power supplies of injection and extraction kicker, septum and bump magnets

Extraction Straight

Equipment Protection System



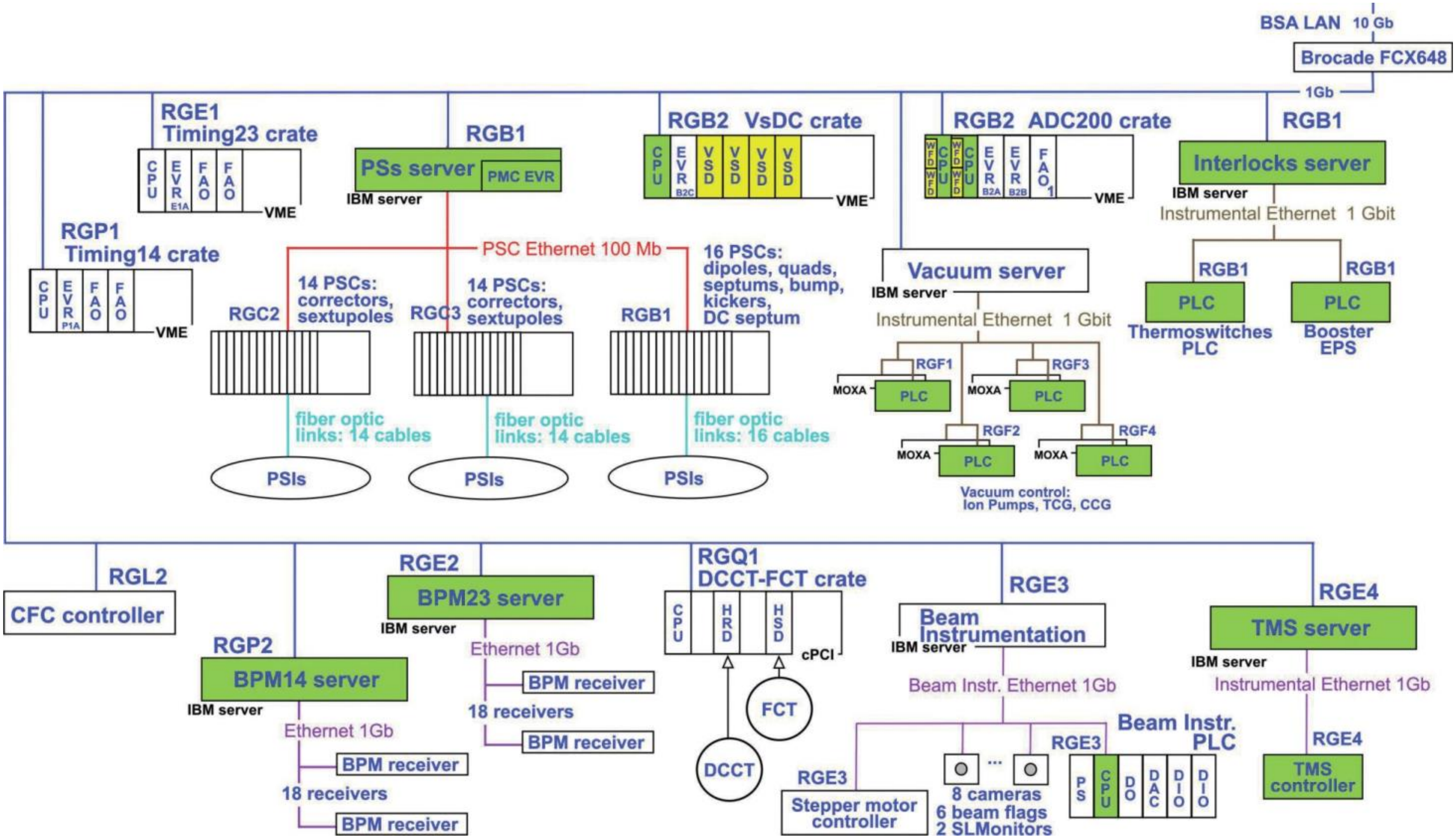
Power supplies for ramped magnets

Power supplies for DC septum and quadrupole magnets

MPS6 – 8 channel crate for corrector and sextupole magnets

Power supplies for dipole magnets from our subcontractor Danfysik

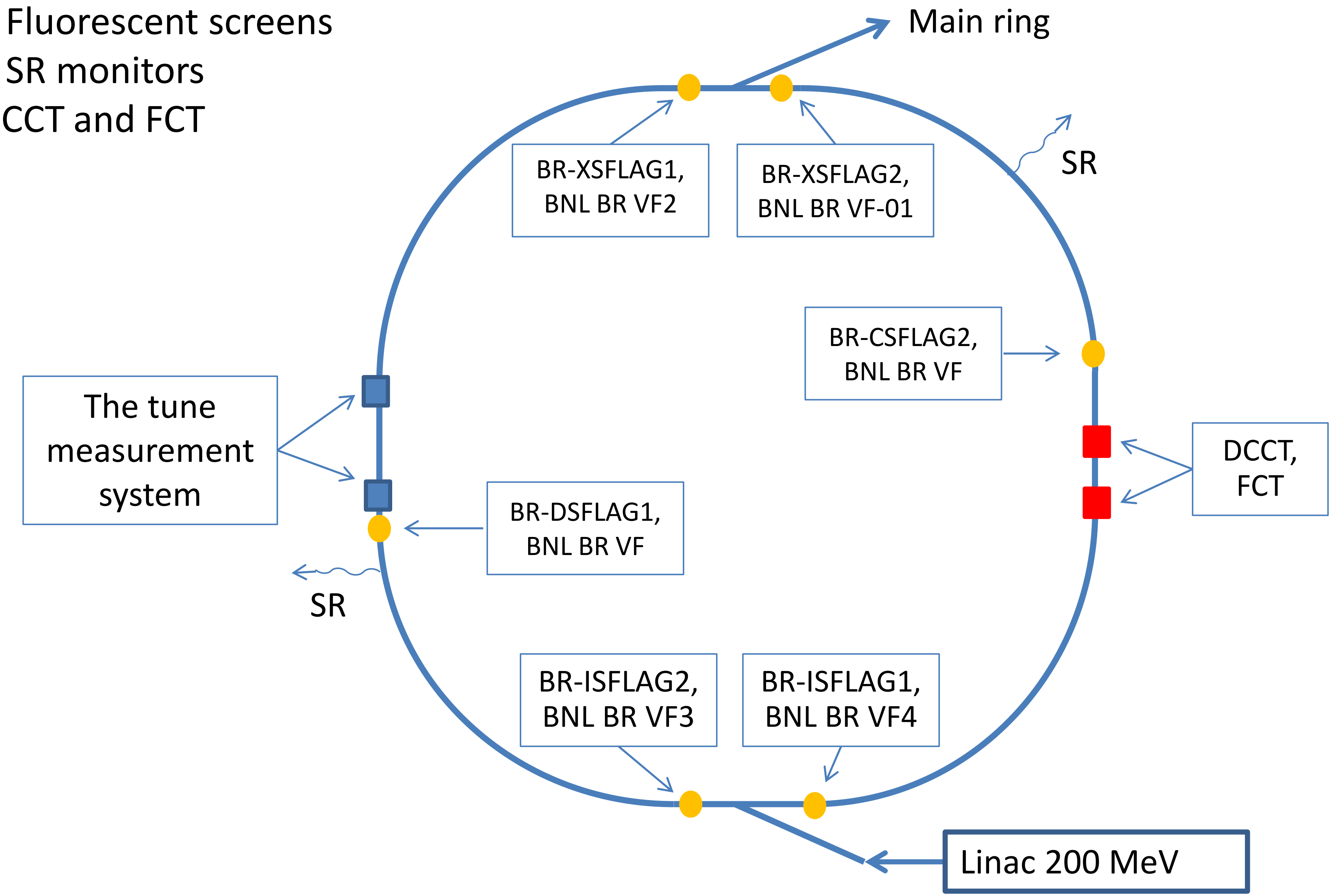
Booster Control System



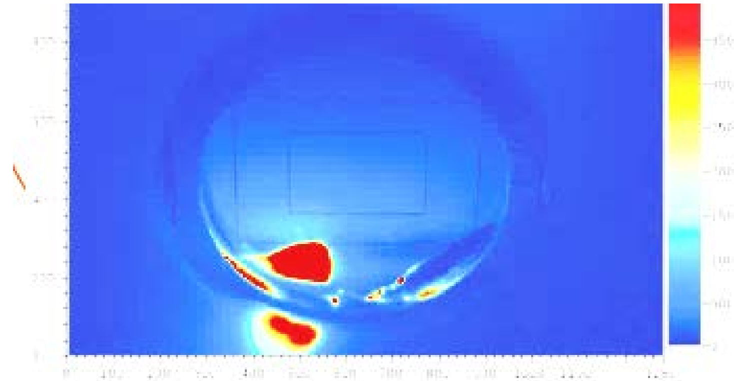
PSC and PSI

Diagnostics

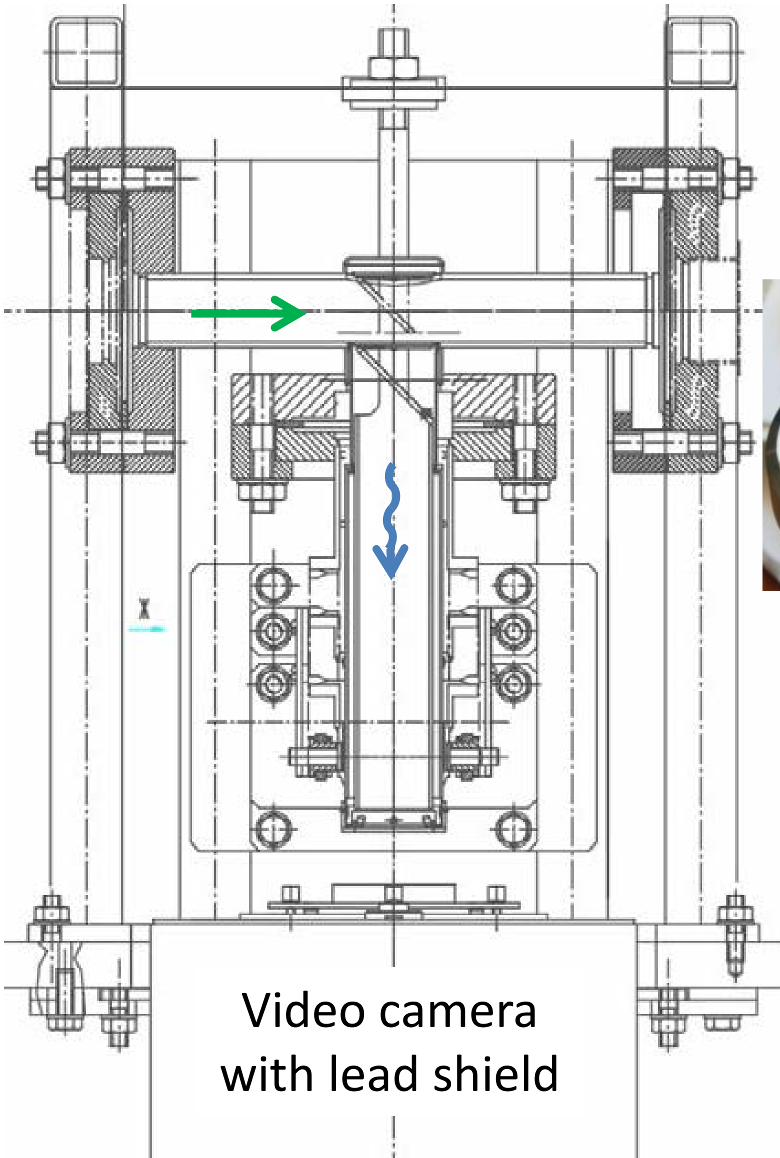
- 36 BPMs
- The tune measurement system
- 6 Fluorescent screens
- 2 SR monitors
- DCCT and FCT

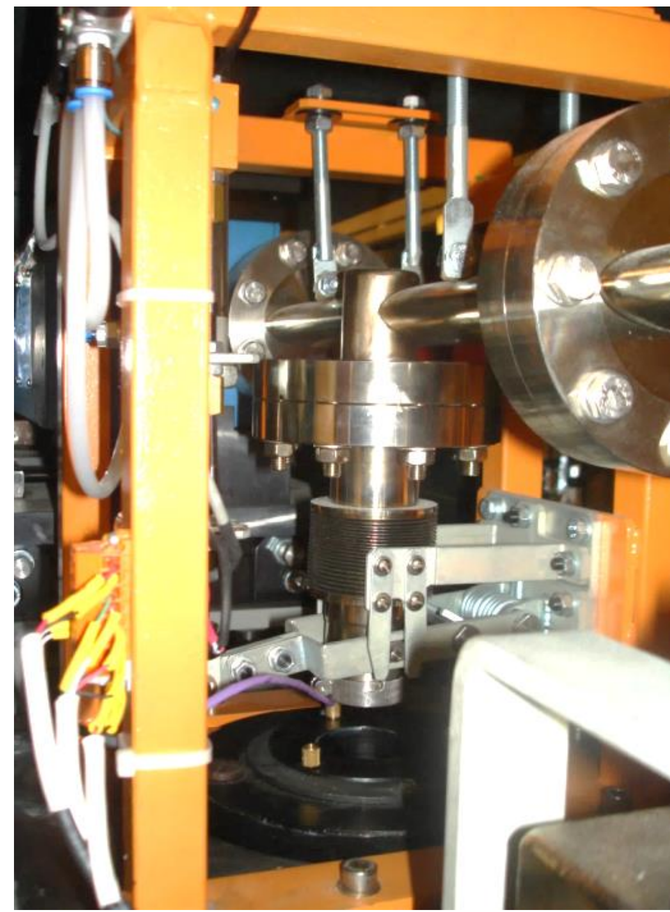


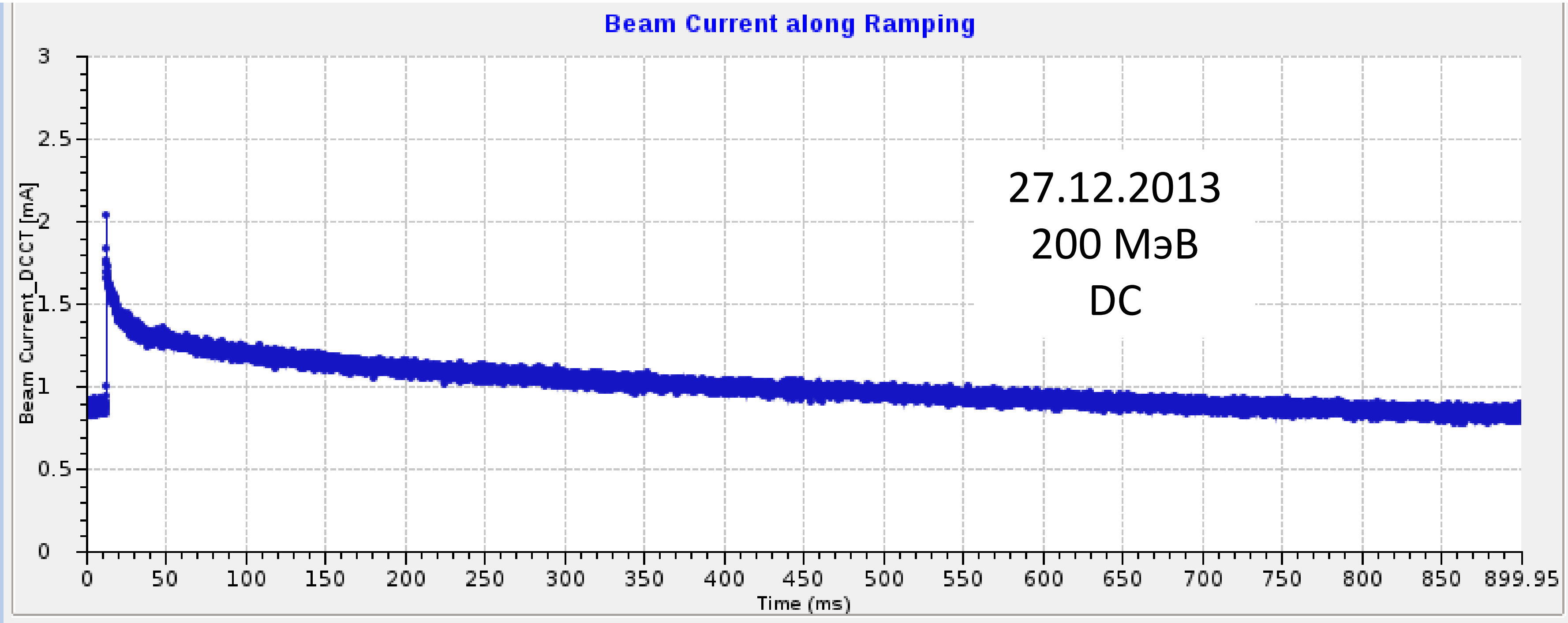
Six fluorescent screens

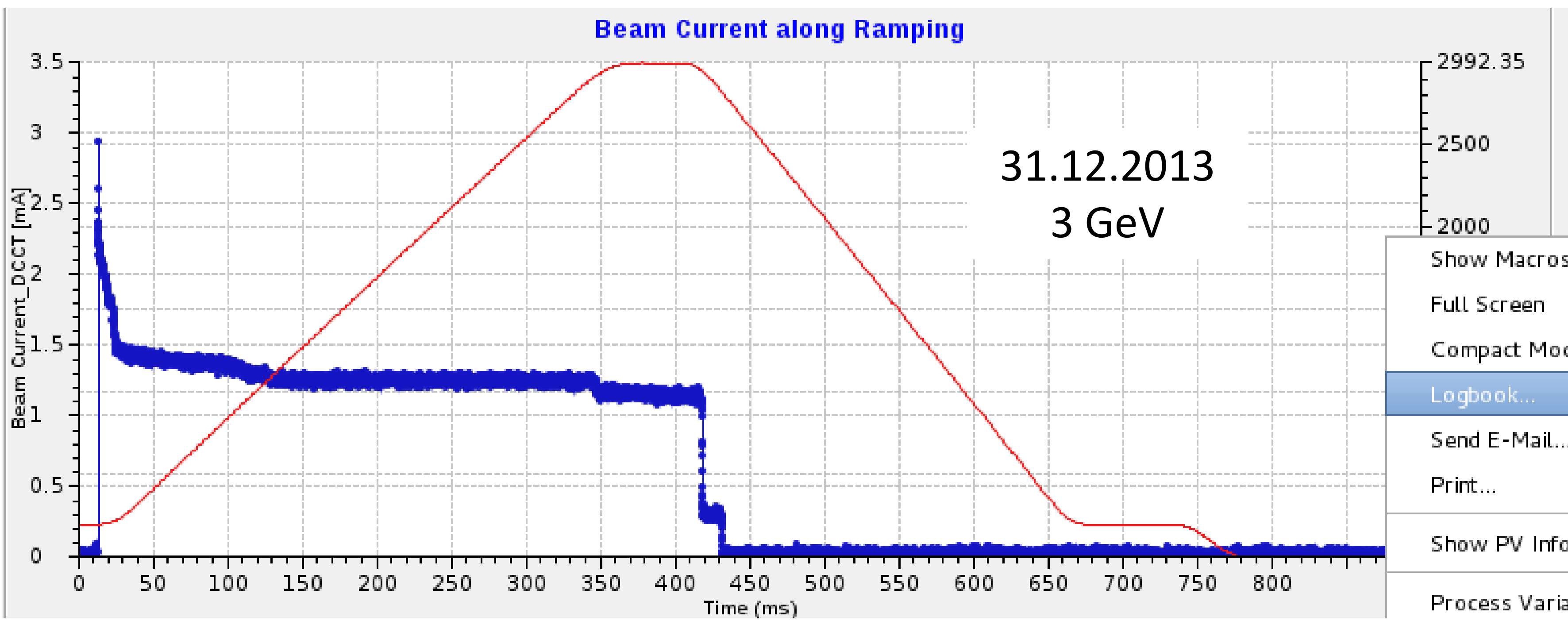


ISVF2 – fluorescent screen after injection.
Central bar is 6 mm x 9 mm

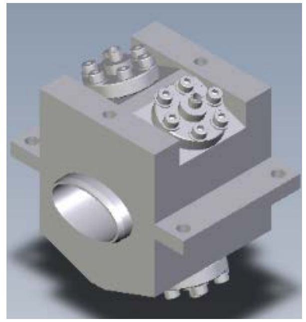


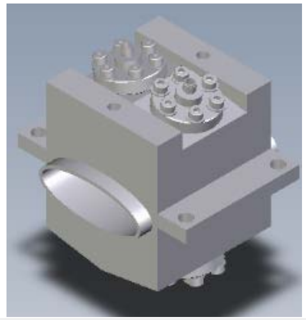


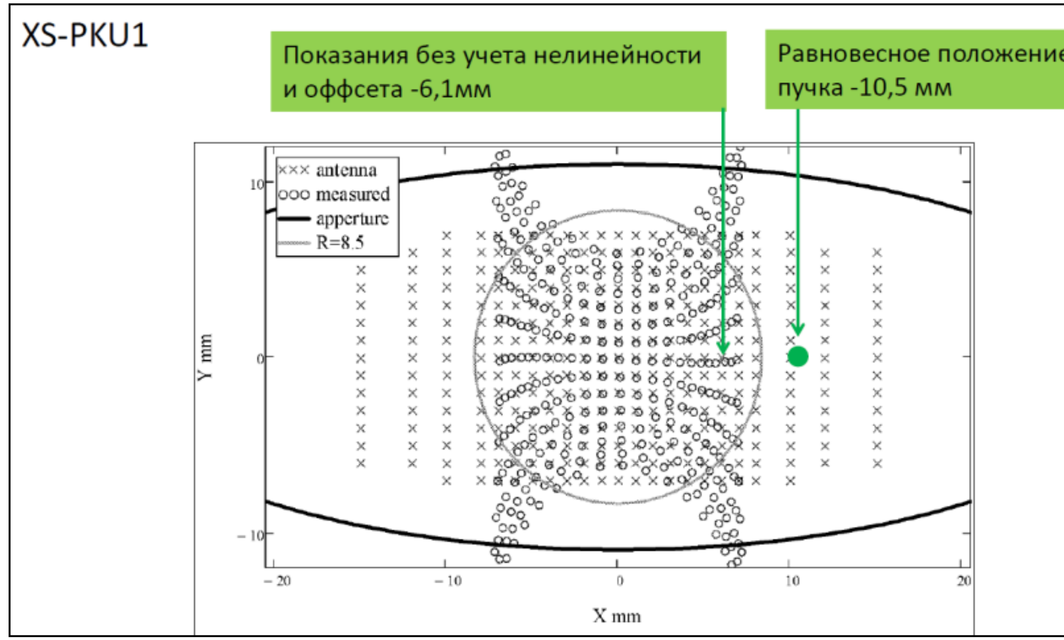

Beam Current along Ramping
Beam Current_DCCT [mA]
Time (ms)
27.12.2013
200 МэВ
DC

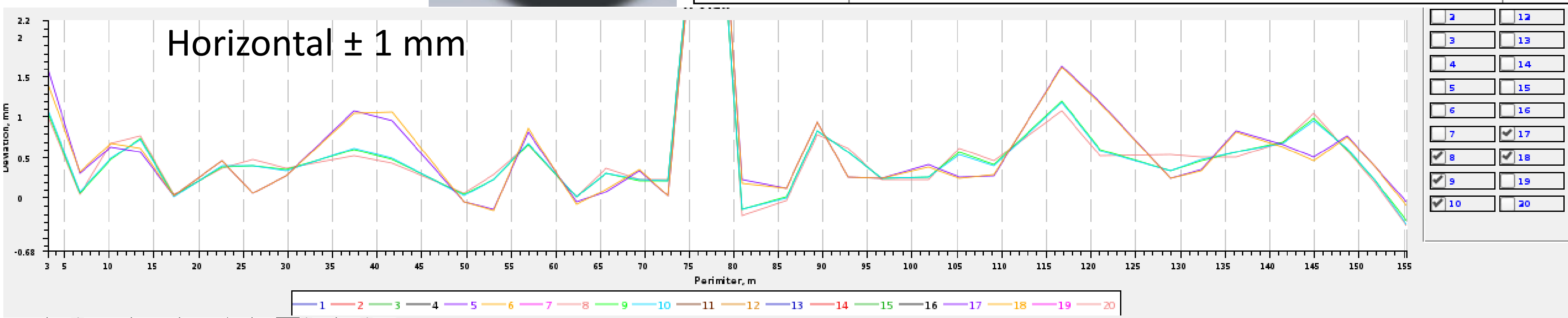

Beam Current along Ramping
Beam Current_DCCT [mA]
Time (ms)
31.12.2013
3 GeV
Show Macros
Full Screen
Compact Mode
Logbook...
Send E-Mail...
Print...
Show PV Info
Process Variab

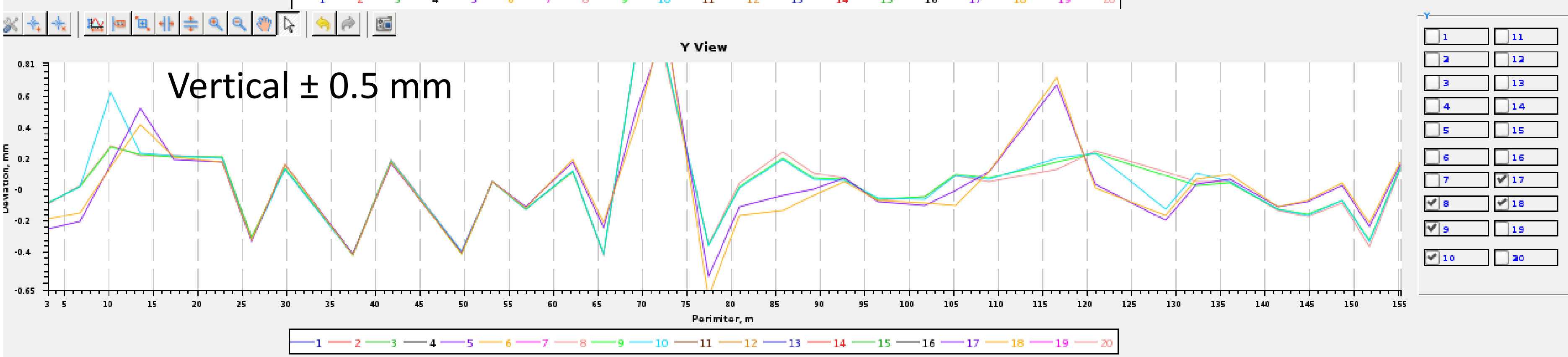
36 BPMs



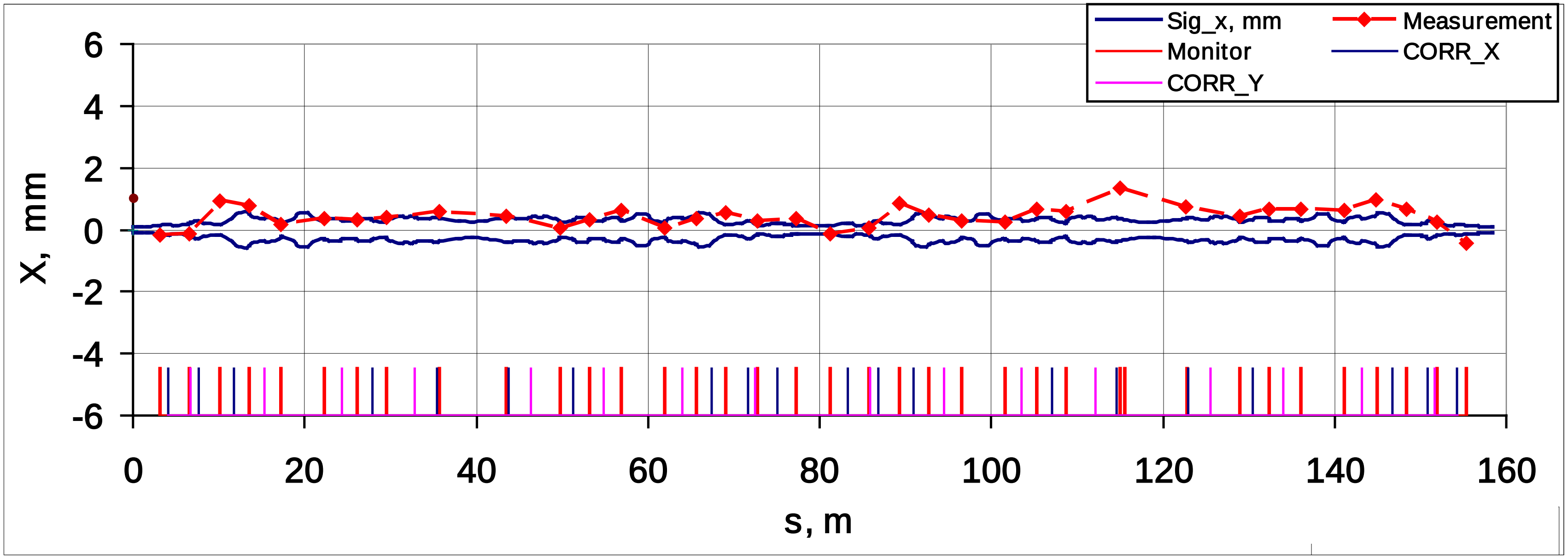


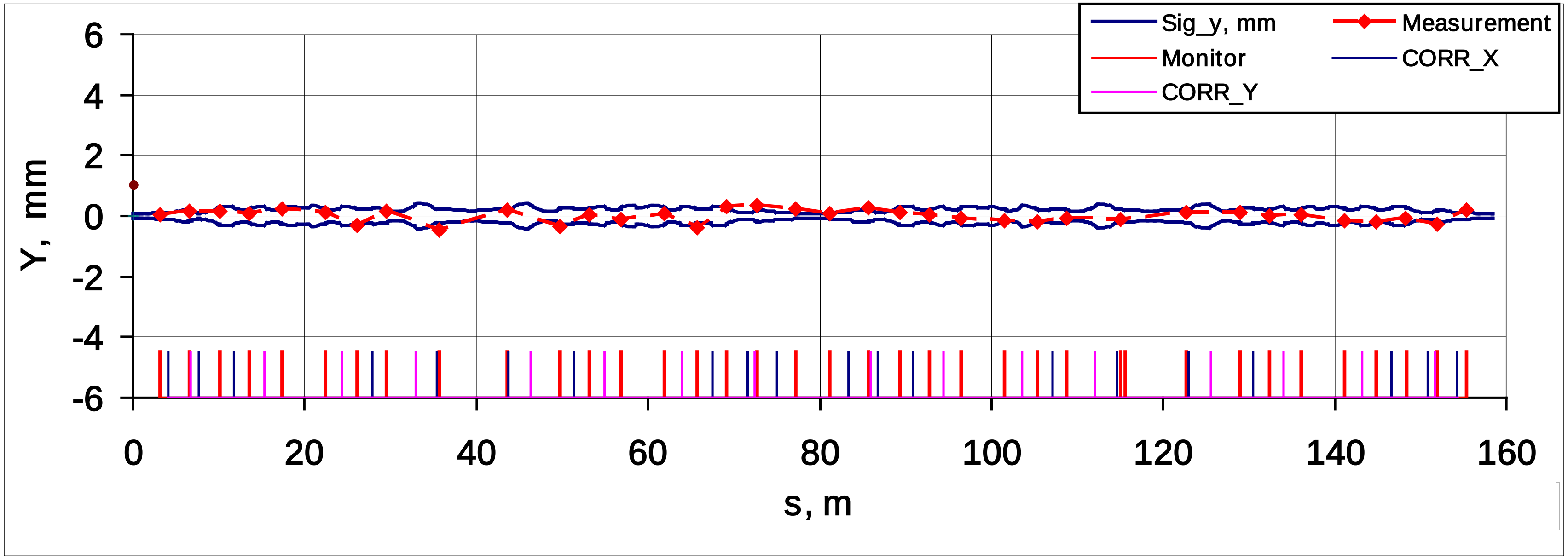

XS-PKU1
Показания без учета нелинейности
и оффсета -6,1мм
Равновесное положение
пучка -10,5 мм
antenna
measured
apperture
R=8.5
Y mm
X mm


Horizontal ± 1 mm
Deviation, mm
Perimiter, m

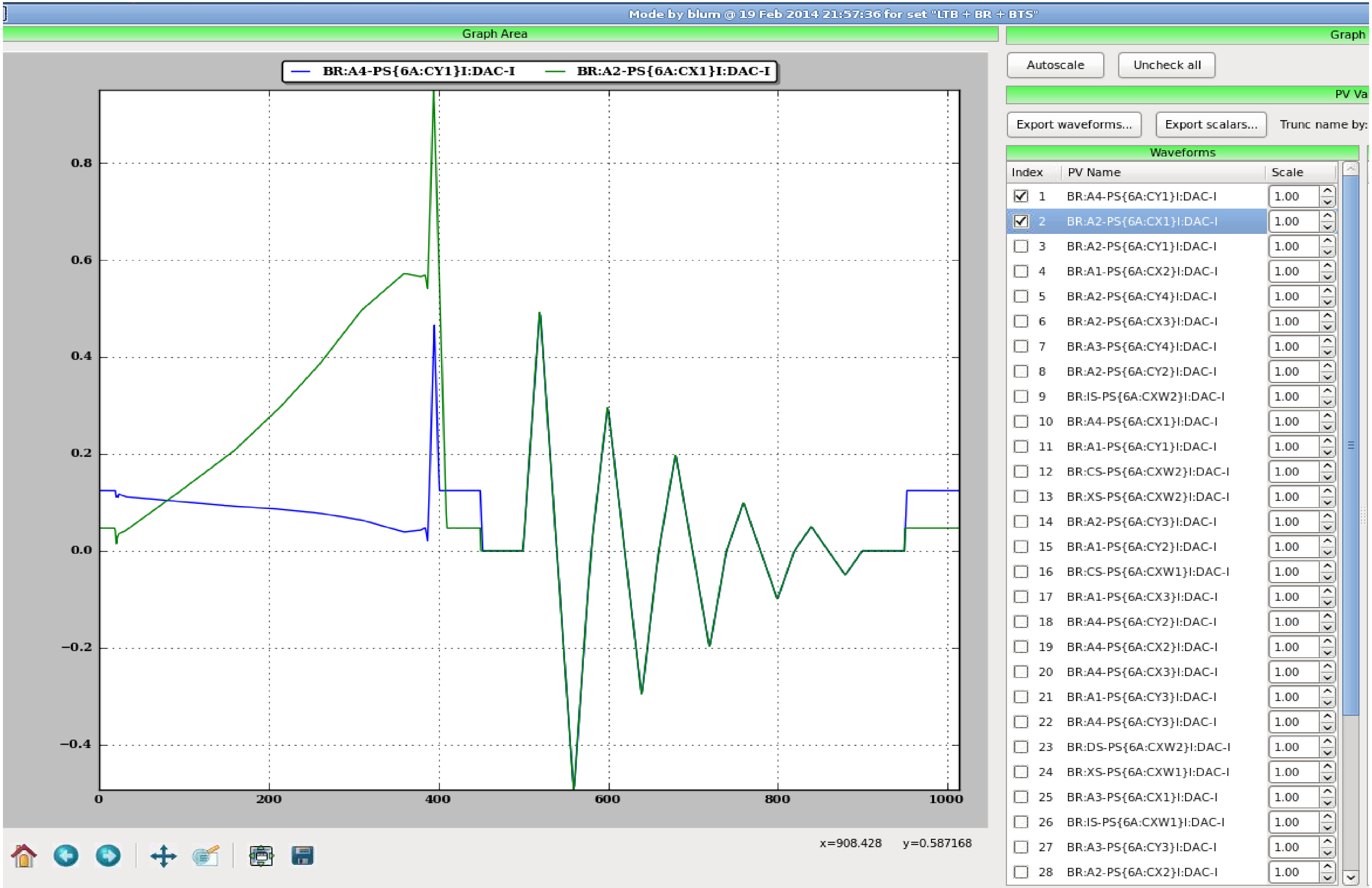

Y View
Vertical ± 0.5 mm
Deviation, mm
Perimiter, m

Beam orbit after correction

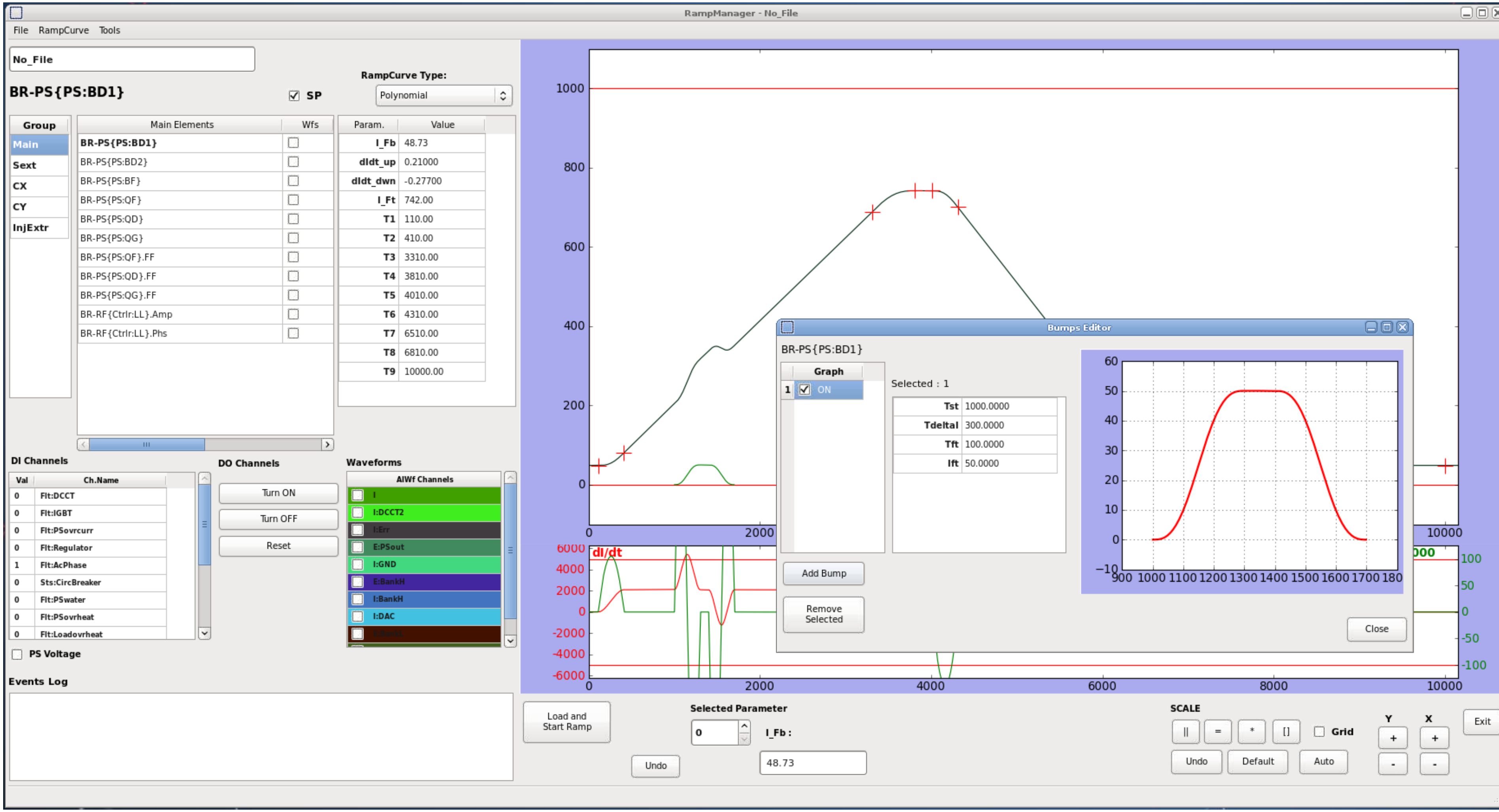




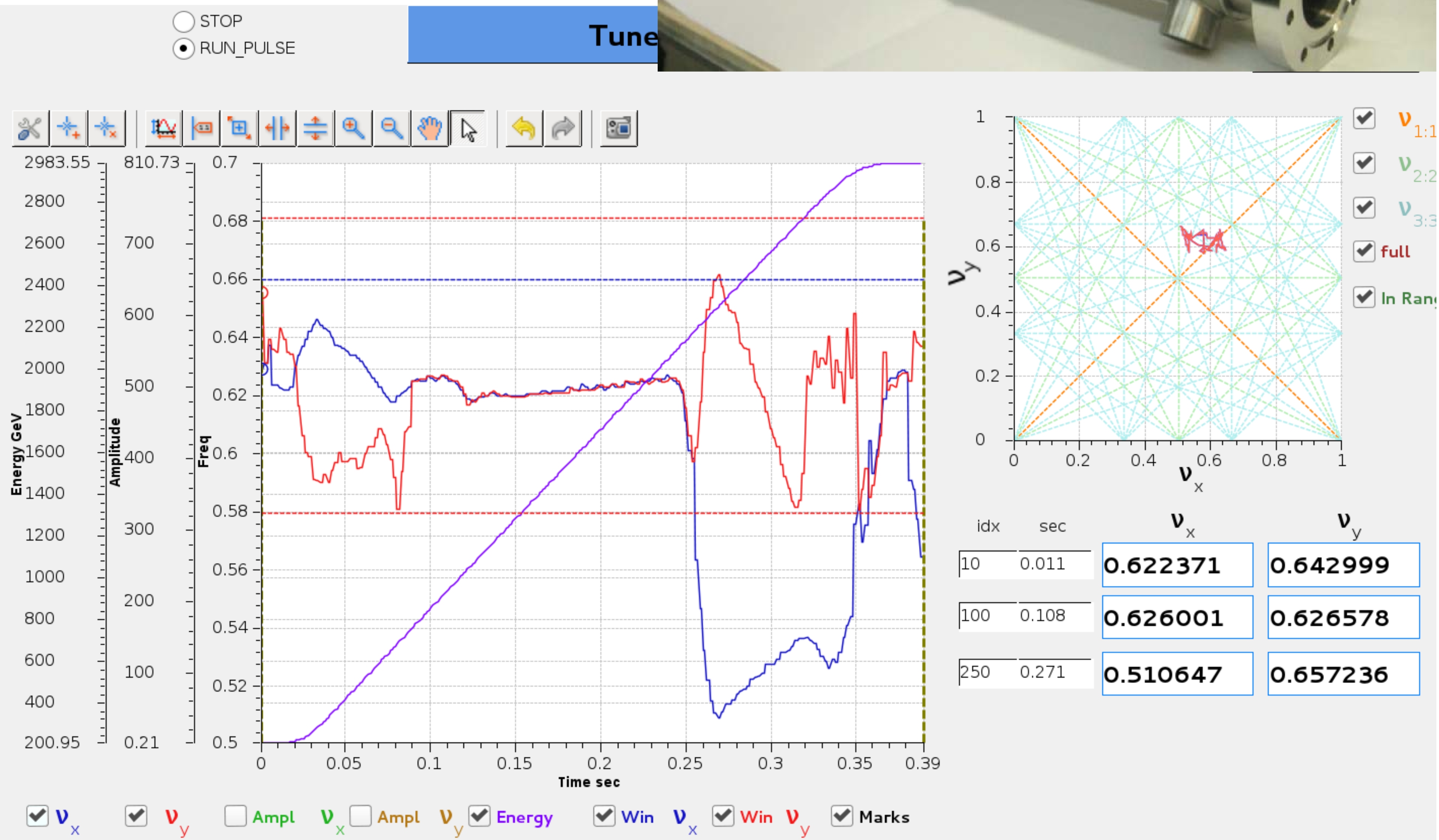
Ramp manager and degauss of magnets



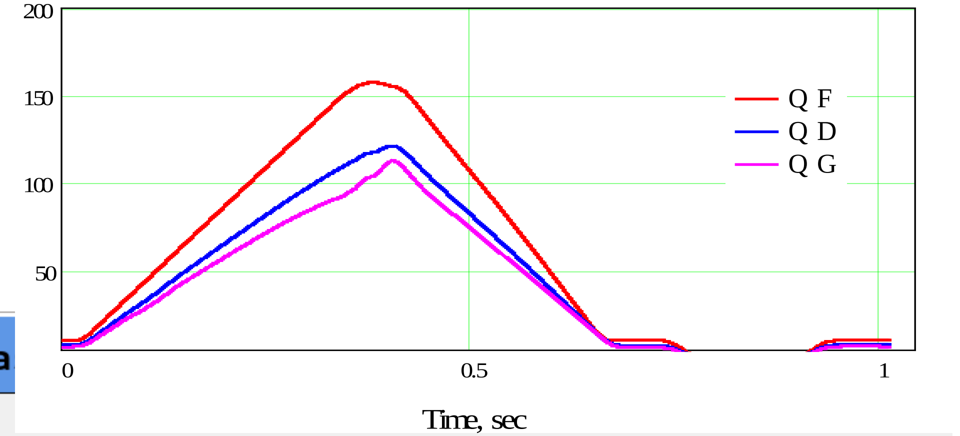
Ramp Manager

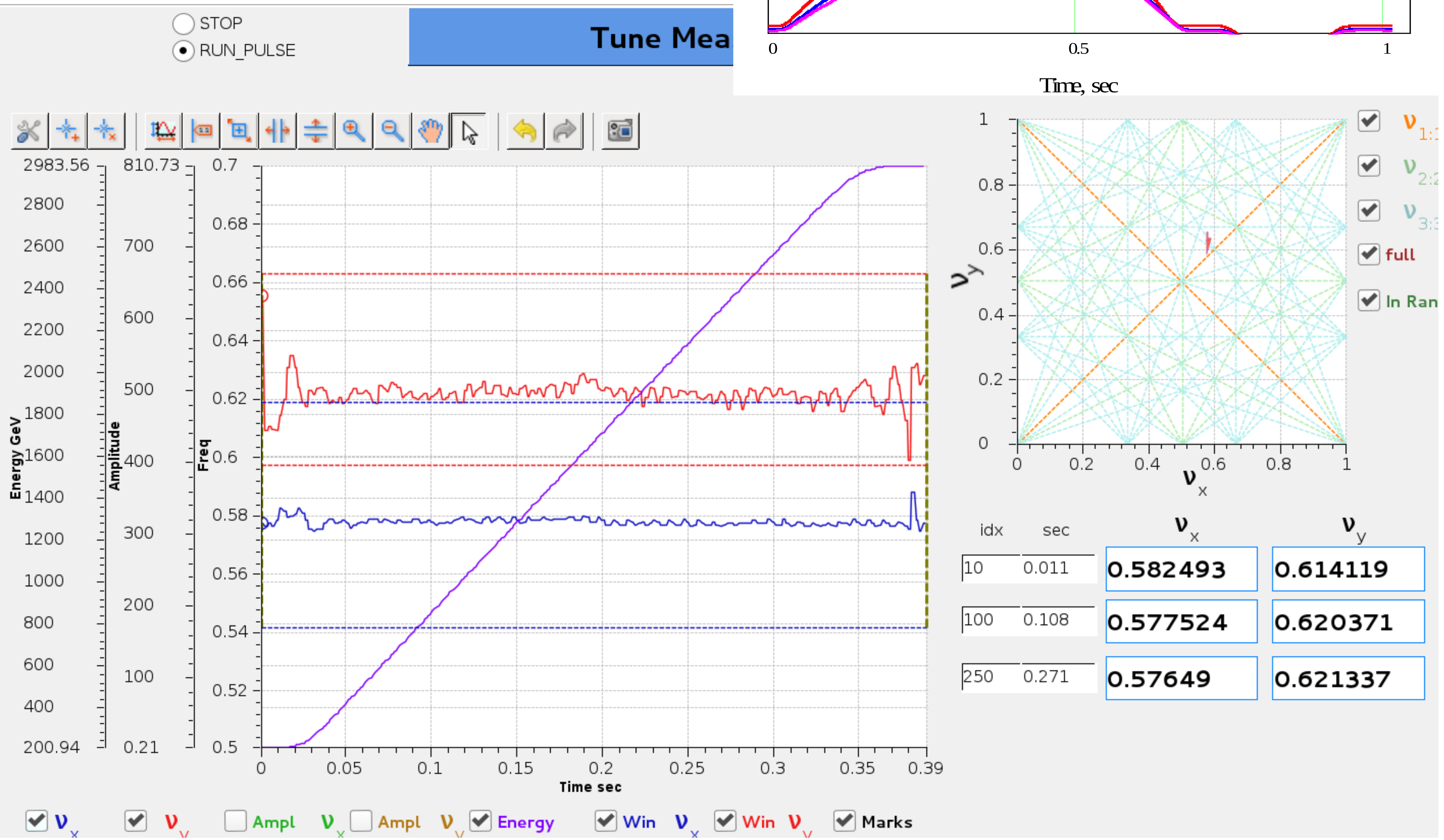


The tune measurement system

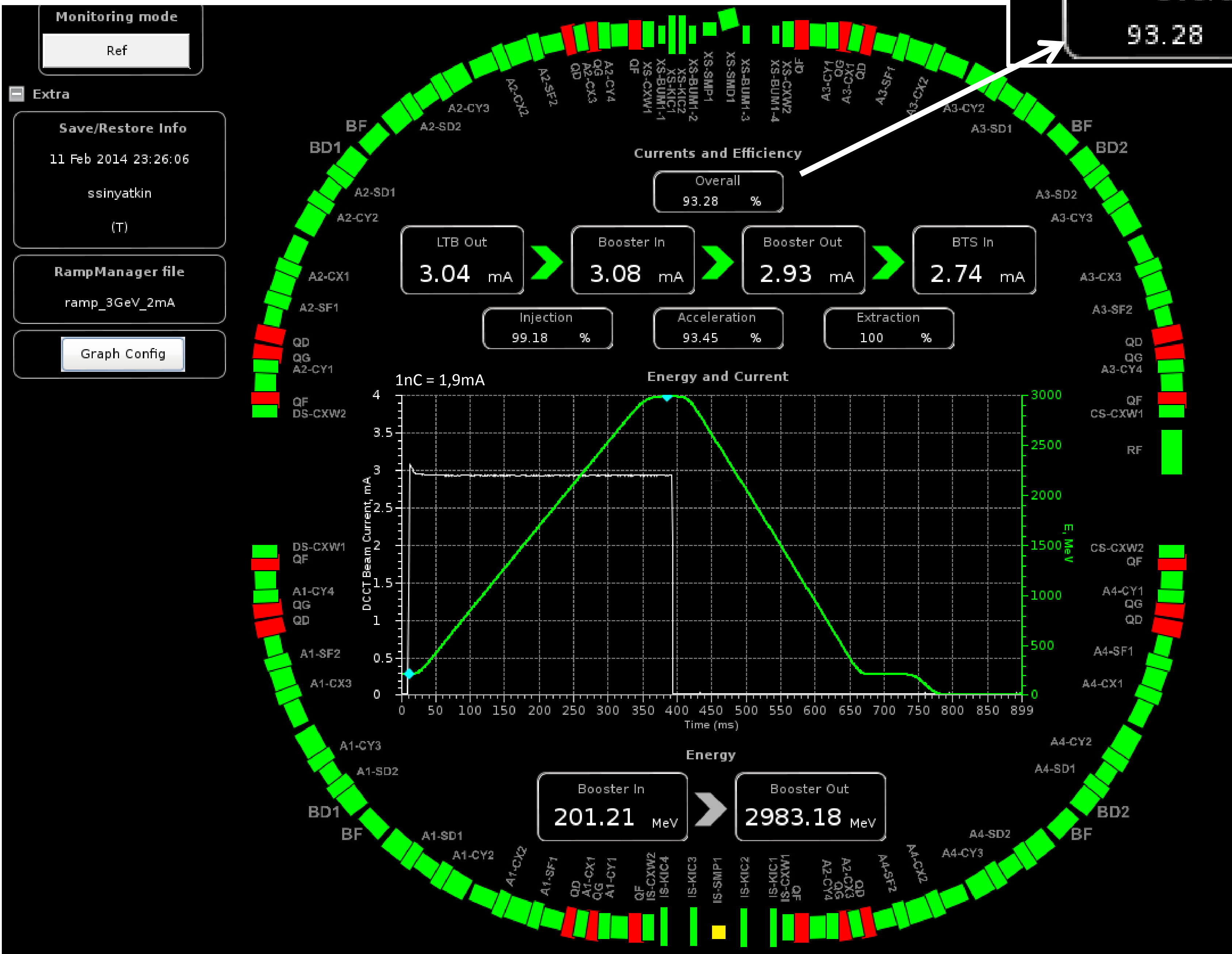


The tune measurement system

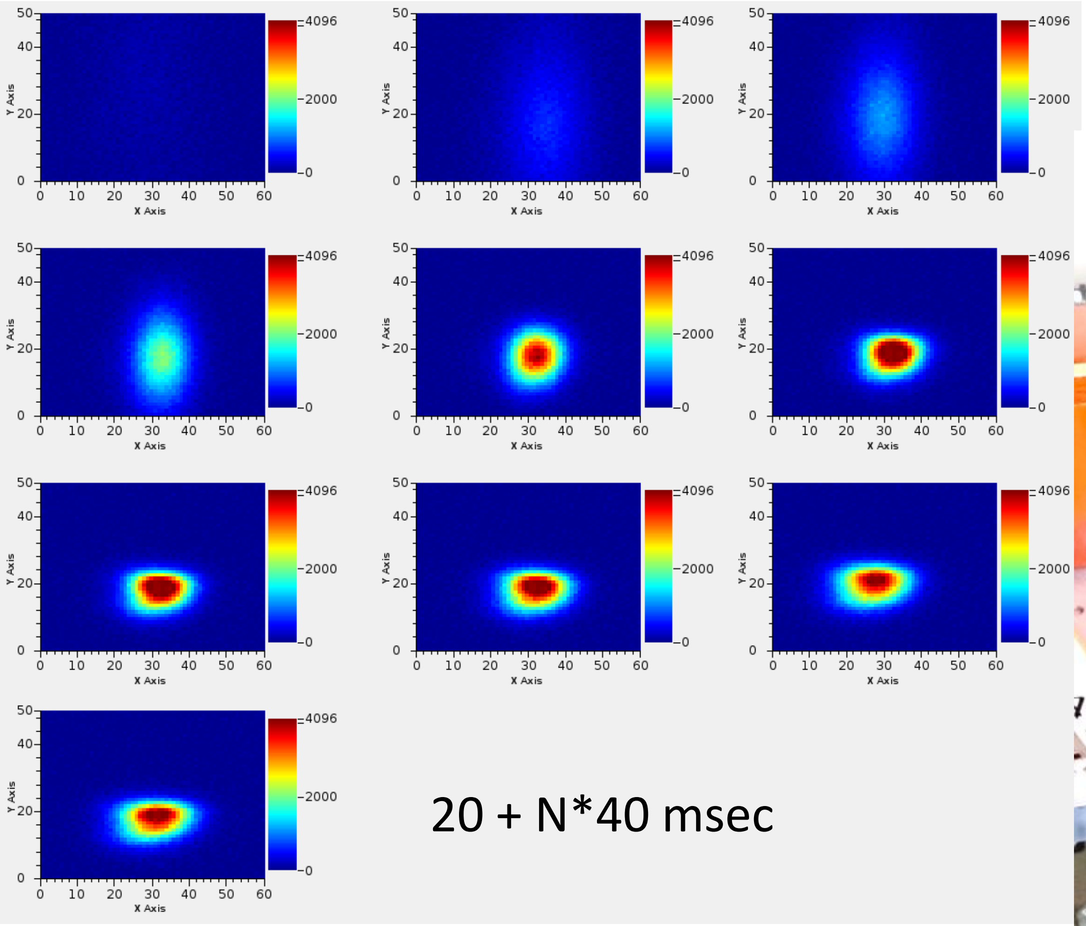




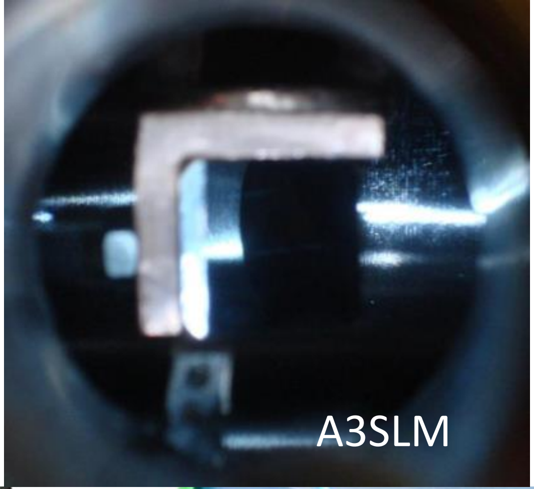
Booster Status Monitor

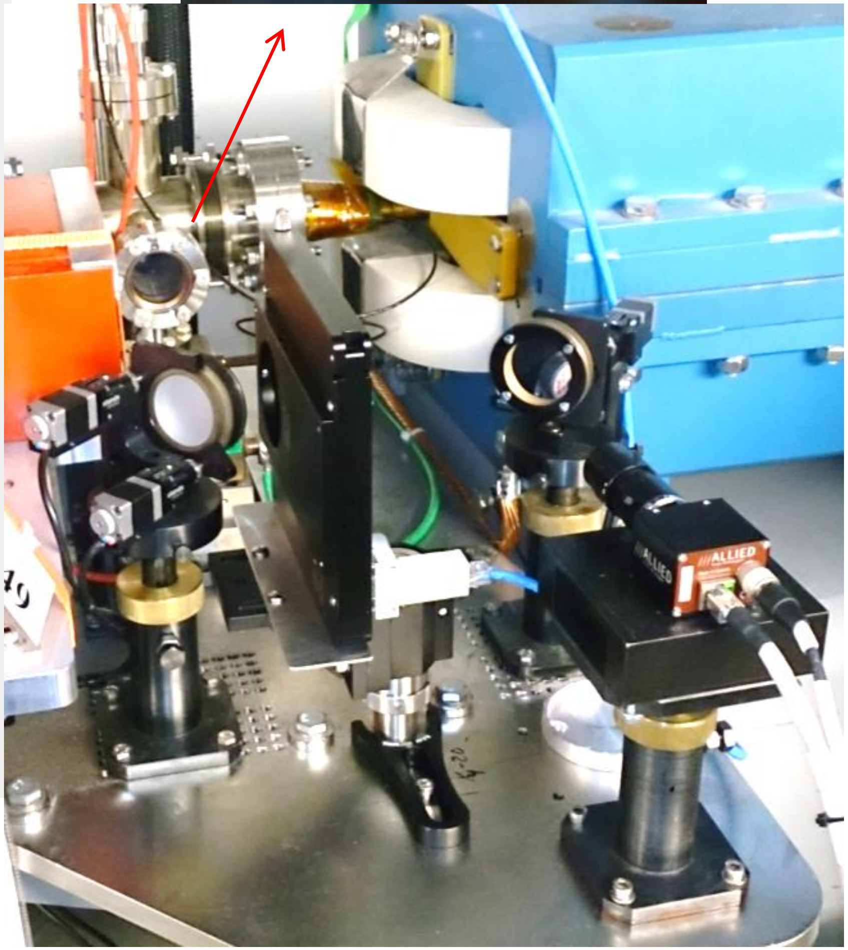


Two SR monitors

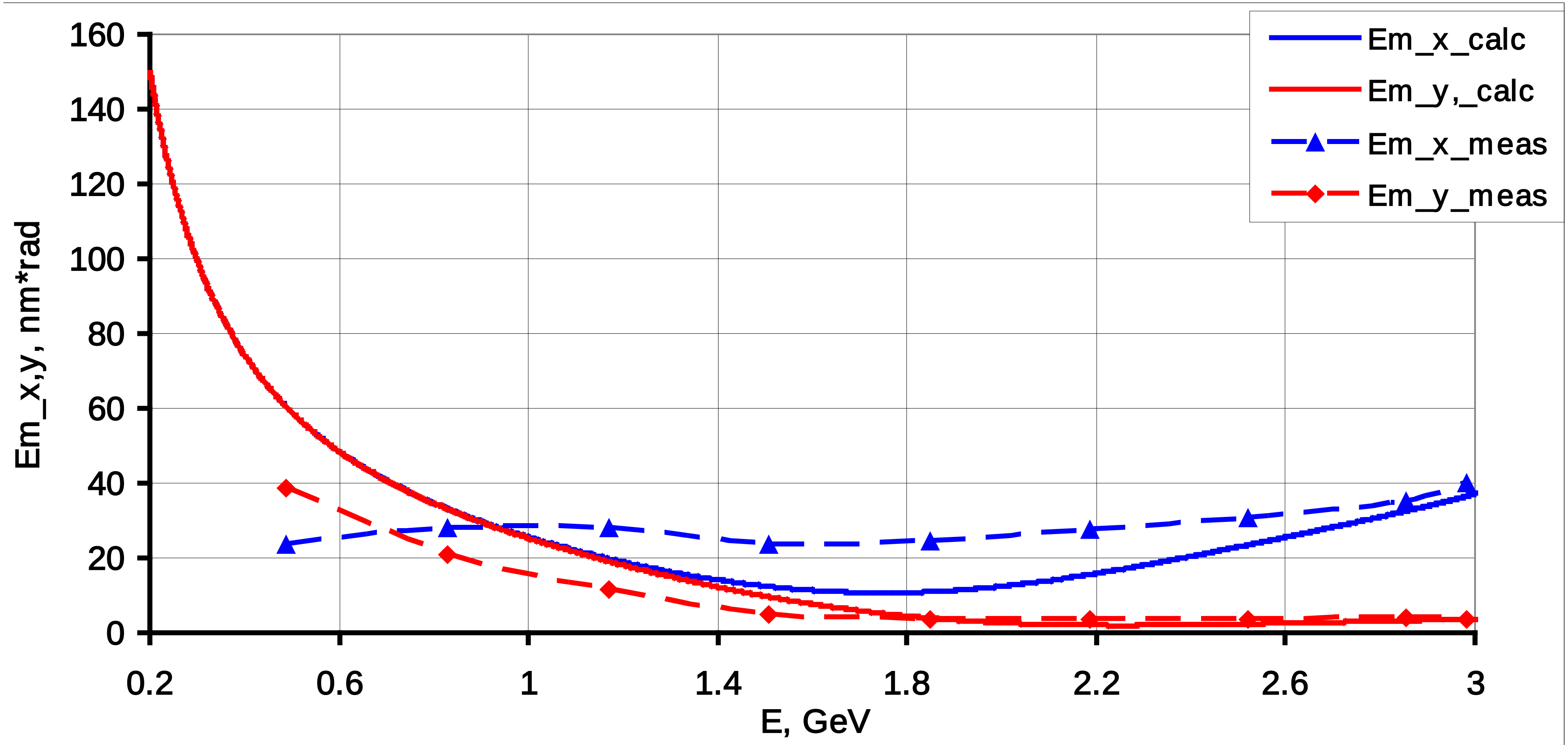


20 + N*40 msec





Emittance Measurement

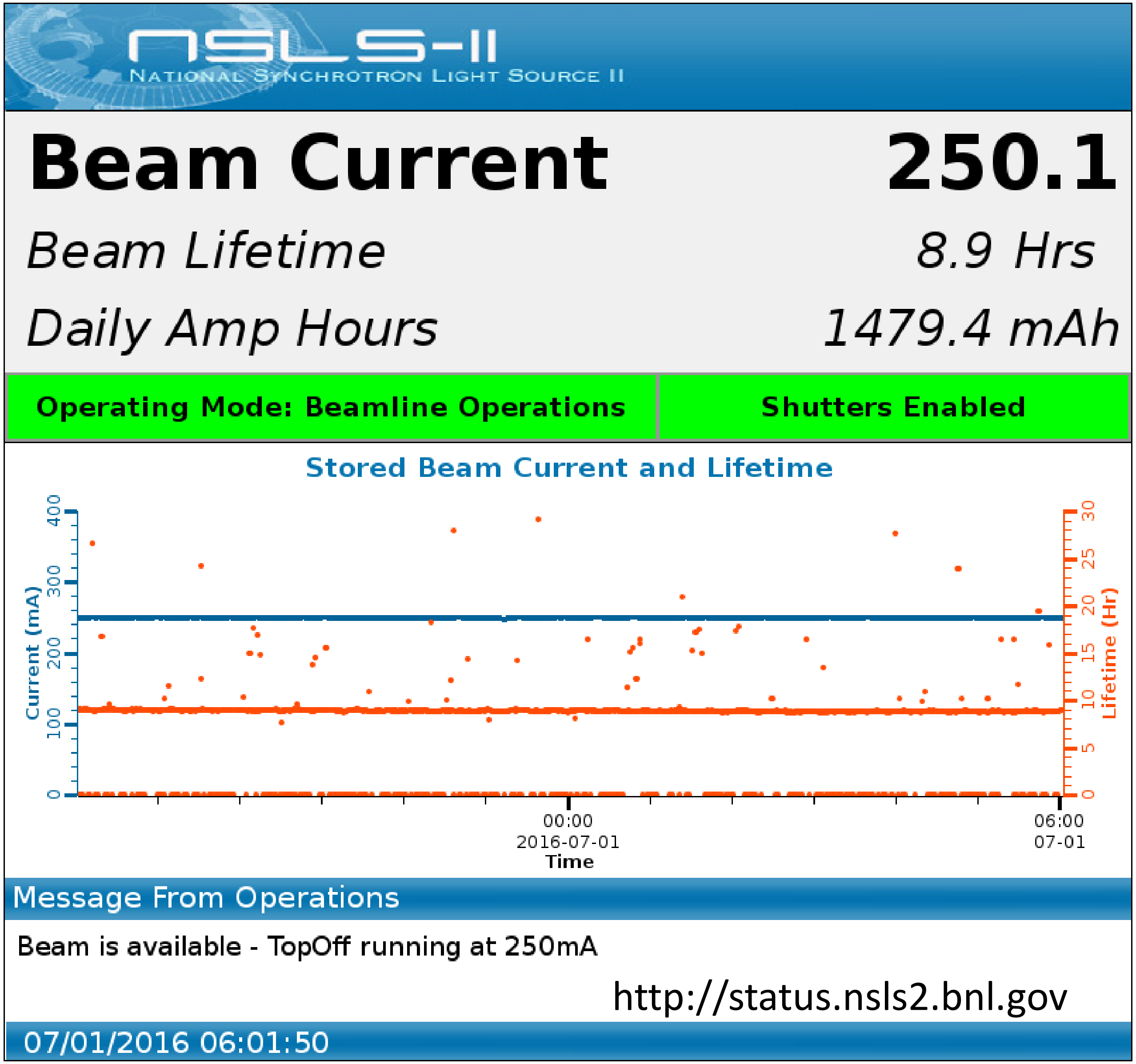


E = 3 GeV :

Em_x = 40 nm*rad => Later 35 nm*rad

Em_y = 3.7 nm*rad

“The injector complex is very robust. After a break or shutdown, full performance is reestablished after only a few hours. Operation is fairy reliable and re-tuning is required only rarely”, Ferdinand Willeke, IPAC2015, “COMMISSIONING OF NSLS-II”.



Work under kicker modulators

Thank you!

The way from control room towards NSLS-II during commissioning

Extraction Straight