Status of the Diamond Light Source

Marco Apollonio – Diamond Light Source Ltd, AP-group

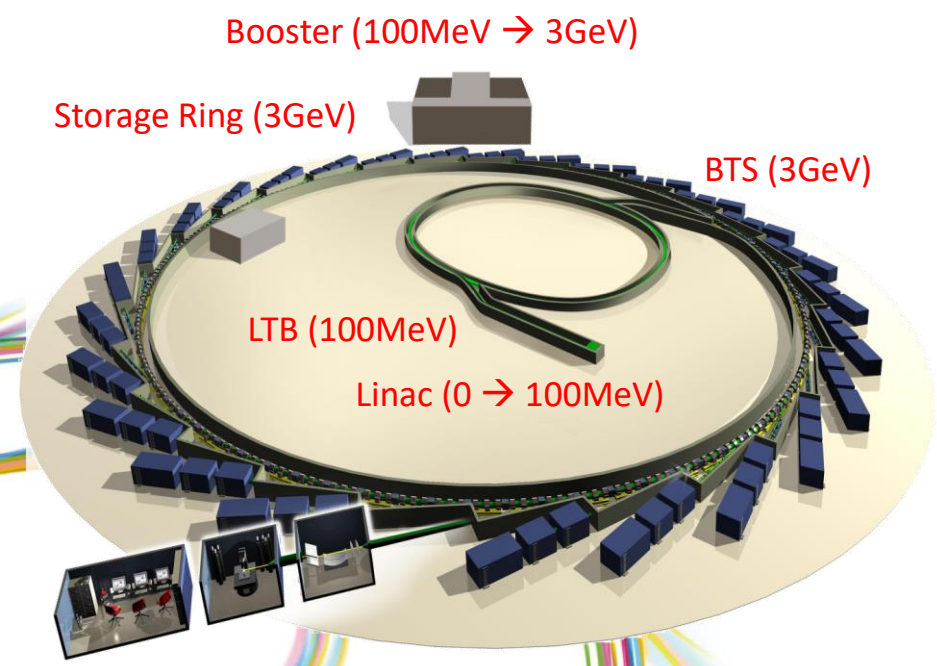
ESLS-XXVI Workshop

Krakow, Poland

26th-28th November 2018

- Introduction to **Diamond**
- **Operations** update
  - Statistics
- **RF** cavities:
  - two new **Normal Conducting Cavities**
  - one new **Booster Cavity**
- **Upgrades** of existing **IDs**
- **K**icker **T**est **R**ig / **N**on **L**inear **K**icker
- "missing sextupole" new lattice for **DIAD beamline**
  - **preparation / tests**
- **No-minibeta** tests
- **Conclusions**

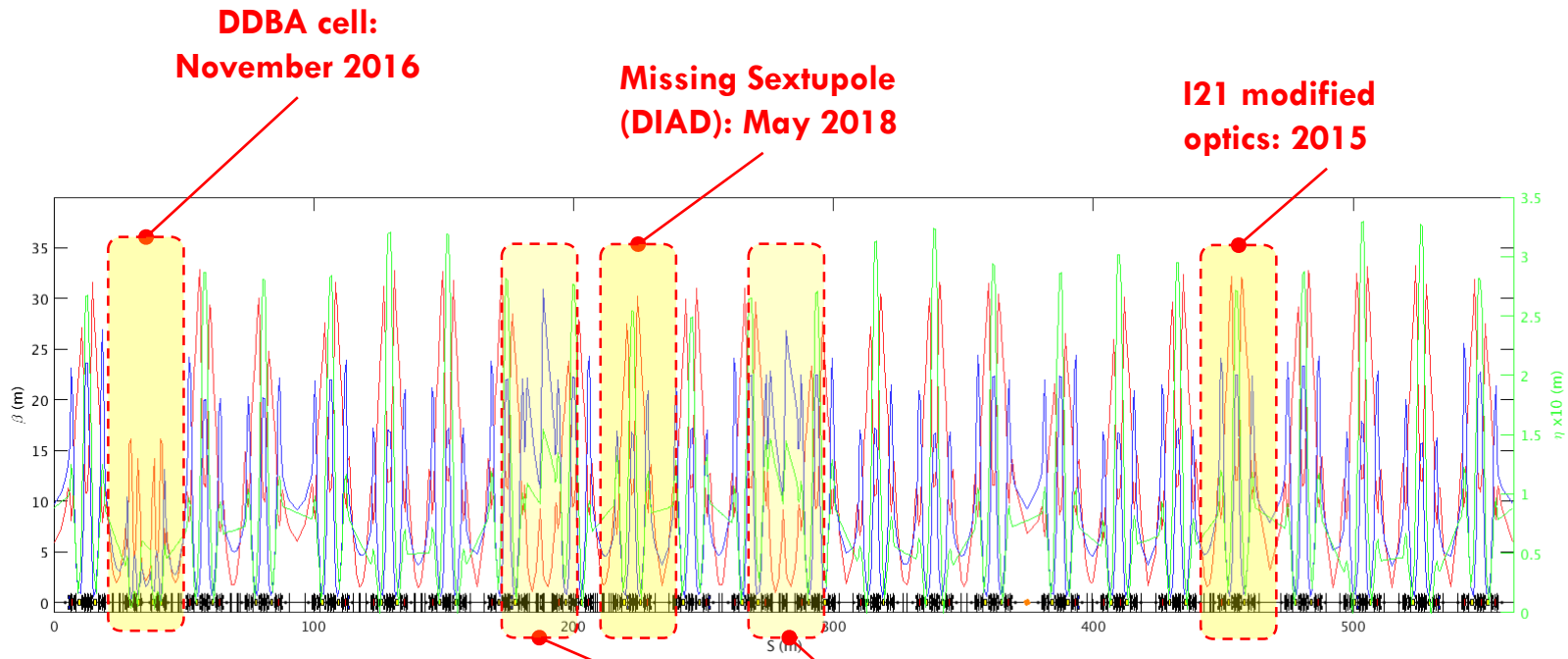
- UK's national **synchrotron radiation facility**
- Located at **Rutherford Appleton Laboratory**, Oxfordshire
- Construction began March 2003
- Commissioning 2005 - 2006
- Start of user operations Jan 2007



Lattice	DBA+
Structure	24 cell
Symmetry	6 (reduced by **mini-beta cells**, I21 optics, **DDBA cell**, **missing sextupole cell**)
Straights	18 × 5m / 6 × 8m / **1x3.4m**
Energy	3 GeV
Circumference	561.571 m
H / V Tunes	28.184 / 13.284
H / V Chromaticity	1.5 / 1.5
H / V Emittance	2.72 nm.rad / 8 pm.rad
Energy spread	0.096 %
Current	300 mA
Lifetime	>10h

Diamond lattice evolution

DLS
DIAD
2018



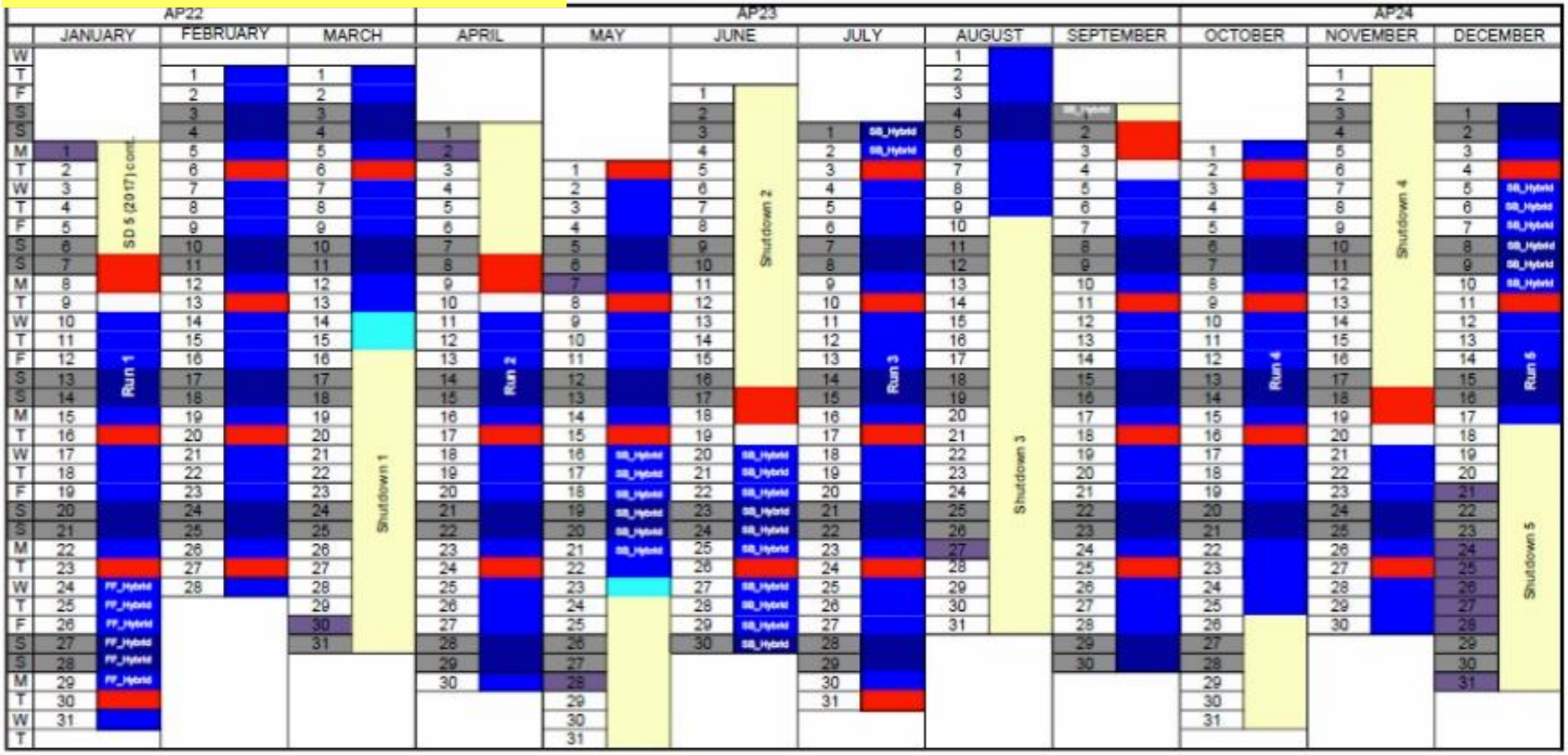
Mini-beta straights: 2011

			Total Beam Time	User Beam + Preparation	Special Beam	Machine Development	Shutdown	Total hours
Year 11	**April 2017 - March 2018**	**hours**	**6072**	**5112**	**48**	**912**	**2688**	**8760**
		%	**69.30%**	**58.40%**	**0.50%**	**10.40%**	**30.70%**	
AP23	**Apr - Sep 2018**	**hours**	**3087**	**2583**	**0**	**504**	**1305**	**4392**
		%	**70.30%**	**58.80%**	**0.00%**	**11.50%**	**29.70%**	

BEAM TIME STATISTICS

```
72h     low alpha
720h    hybrid mode [868+1]
4320h   900 bunches mode
```

courtesy C. Bailey



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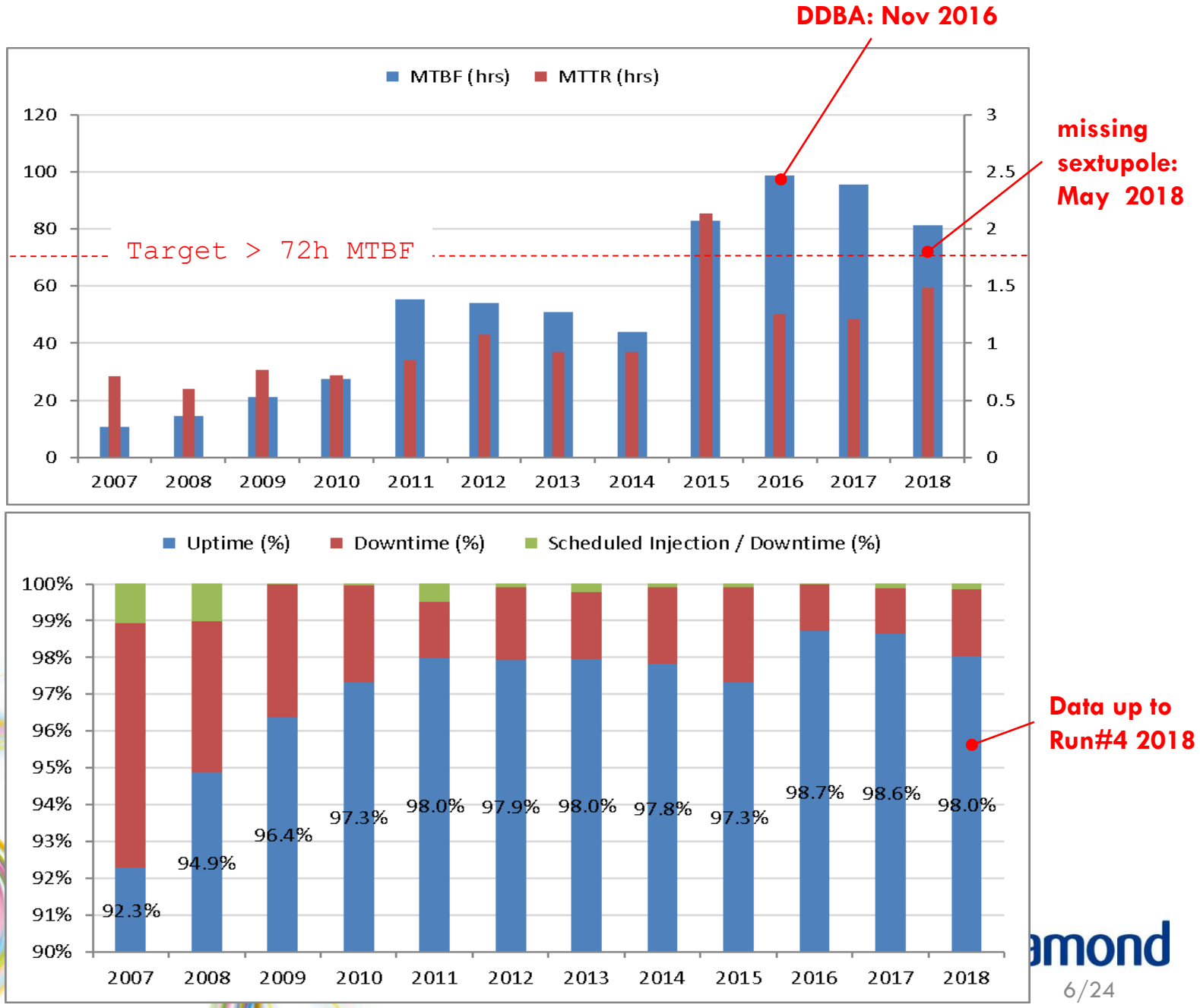

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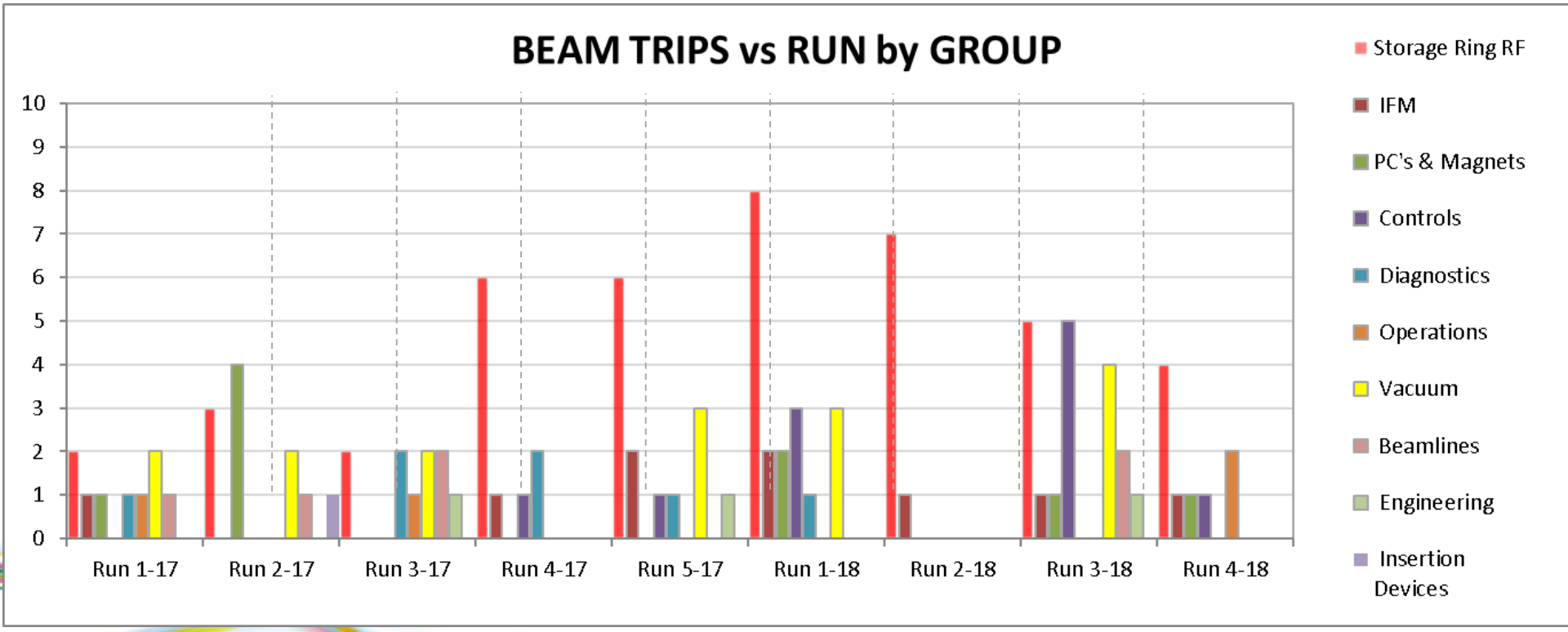
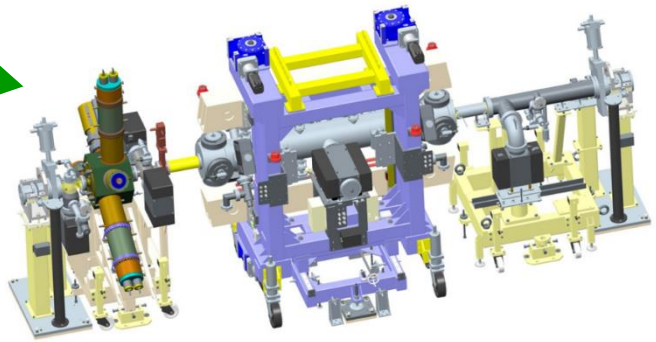


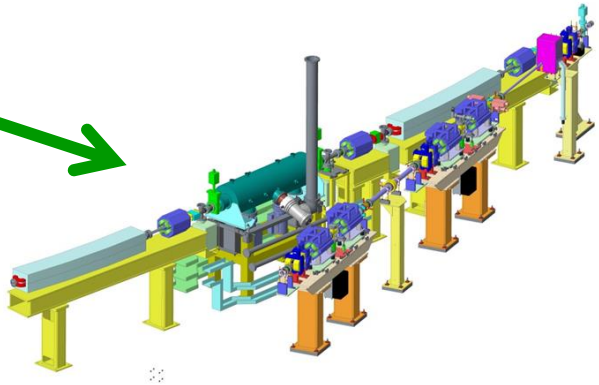
RF system upgrade

- **SR: two new Normal Conducting RF cavities**
  (Bessy HOM-damped design)
  - Back-up to existing SC cavities
  - Reduce Voltage (SC)/Power (NC) requirements
  - In situ since Jan 2018

courtesy C. Christou



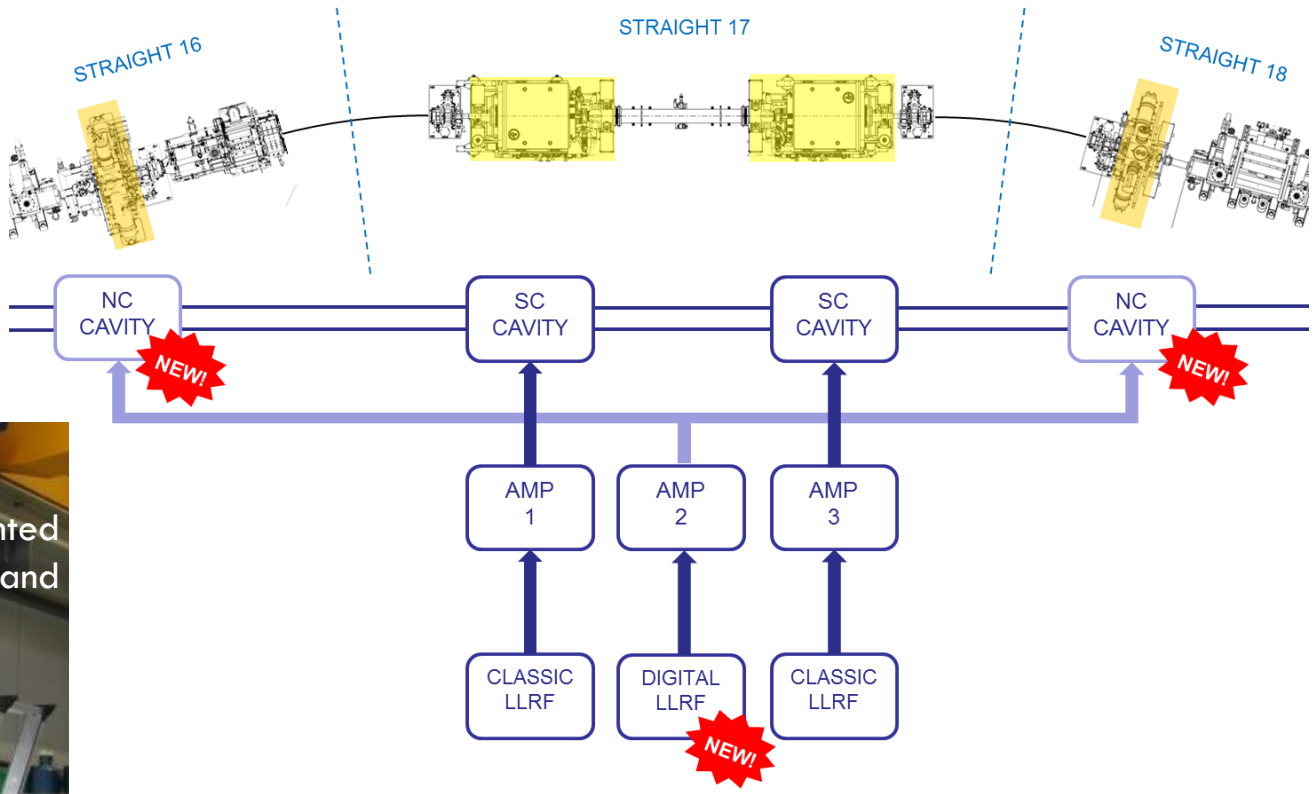
- **New cavity for booster** ring
  - In vacant straight after booster extraction
  - Used cavity bought from DESY in 2017
  - Baked in tunnel (summer 2018)
  - Installation (Nov. 2018)

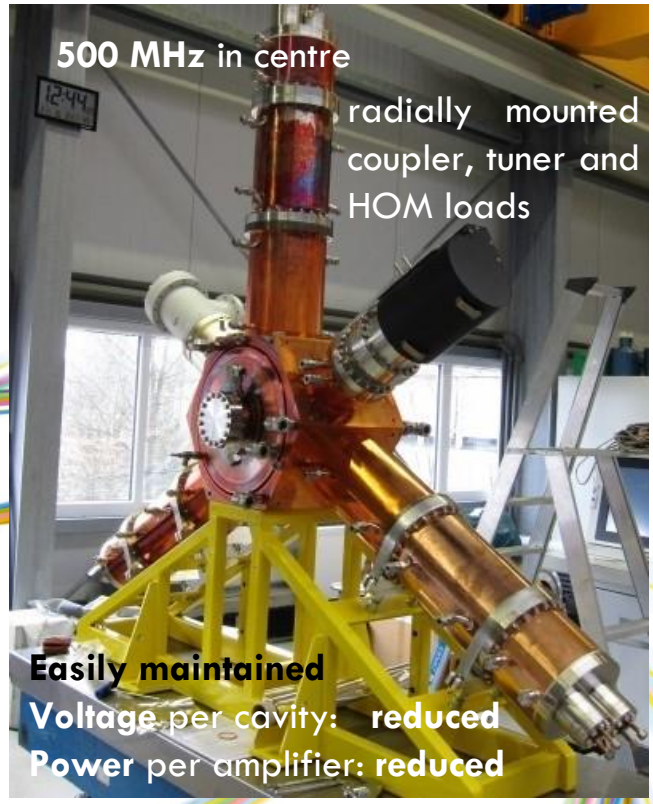


- High Power **SS amplifiers** (Ampegon)
  - for new RF test facility (2018) and BC (>2019)
  - Similar to SLS booster amplifier

- **New Digital LLRF**
  - Required for new **normal conducting** cavities
  - To be deployed on all systems
  - Collaboration with ALBA
  - Similar to systems in MAXIV/Solaris

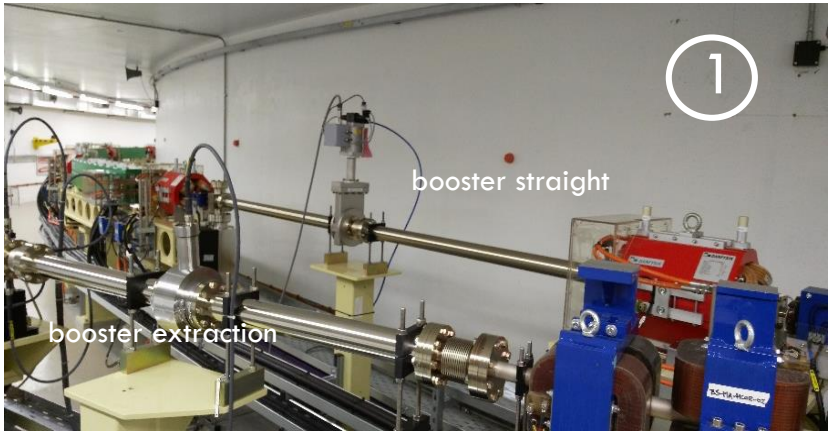
New storage ring RF configuration

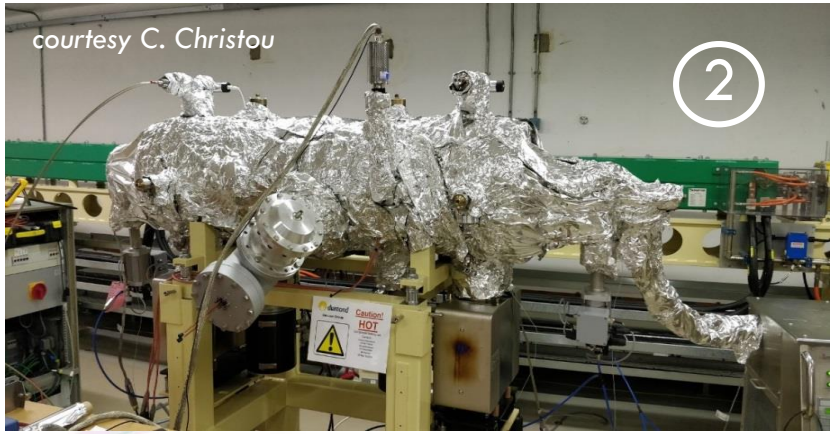




Small longitudinal footprint!
Can be **installed in regular straight**
SC cavity environment undisturbed
Further NC cavities can be installed

courtesy C. Christou





BOOSTER new RF cavity

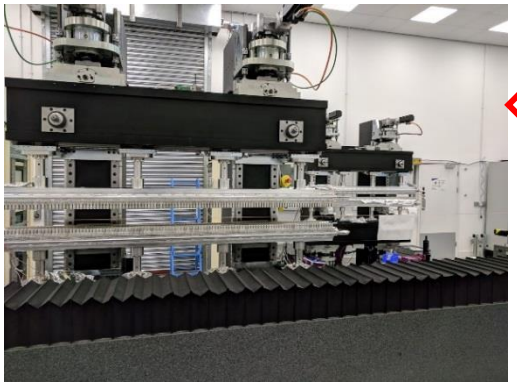
Diamond booster: single 5-cell copper cavity
Cavity & amplifier both single points of failure

1) second cavity in **vacant length of booster ring**
   - 5 cell Petra cavity from DESY

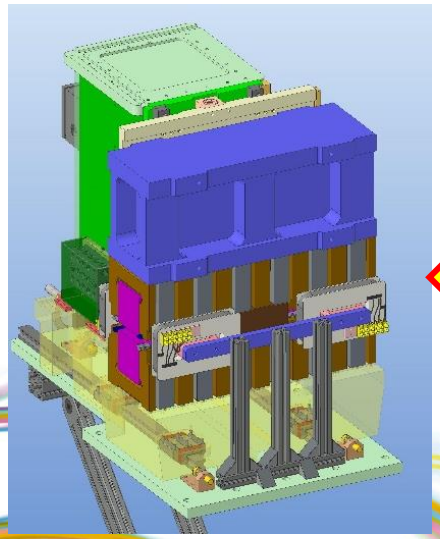
2) **baked in tunnel** in summer 2018

3) **Installation progressing** in November 2018

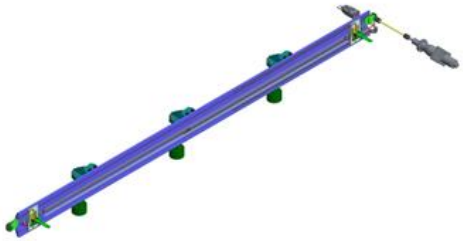
Powered by solid state amplifier, controlled by digital LLRF



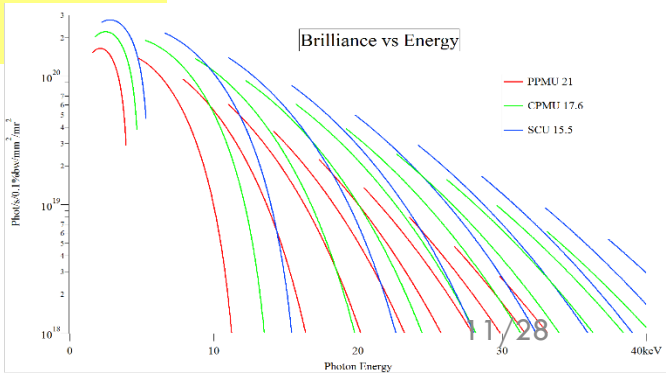
- **Two CPMU17.6** shimmed
  - 1st didn't meet phase error specs
  - 2nd within phase error but underwent mechanical issues when fitting beam foils. New magnet holders developed
- **installation** expected in **2019**
- Further **CPMU17.6 and CPMU16.5** under procurement
  - **Installation 2020/21**
- **SCU15.5** under development with **BINP** (Russia) Installation **2020**



- On-Girder **10-pole Wiggler** for **DIAD BL**
  - Installed May **2018**
- **In-vacuum measurement** system
  - Measure CPMUs cold
  - Commissioned



courtesy E. Rial / S. Milward



*Both technologies of **CPMU** and **SCU** are under development and will replace some of the existing IDs due to significant brightness gain over **PPMU's** at higher photon energies*

Progressive **degradation** in **kickers'** coating

courtesy A. Johnson

- timing/amplitude differences between the 4 kickers used in the off-axis injection system
- Entails a **large initial oscillation** degrading injection performance
- Original vessels (Danfysik) substituted with new set (new coating) in April 2016
  - Two new vessels showing **arcing issues**
  - System **reverted to original**
- New coated vessels (polyteknik) under test in the newly set-up **Kicker Test Rig (July 2018)**
- Alternative ideas under study: **N**on **L**inear **K**icker (**NLK**)

Non Linear Kicker

courtesy R. Fielder

rationale: use a pulse magnet (PM) to suppress oscillations in the stored beam by means of a non-linear field with By=0 on axis

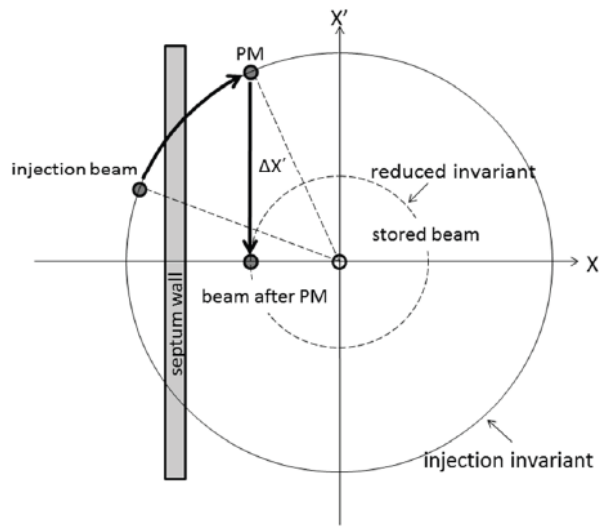


Figure 1: Schematic of injection using PM where PM is located in same straight as septum magnet.

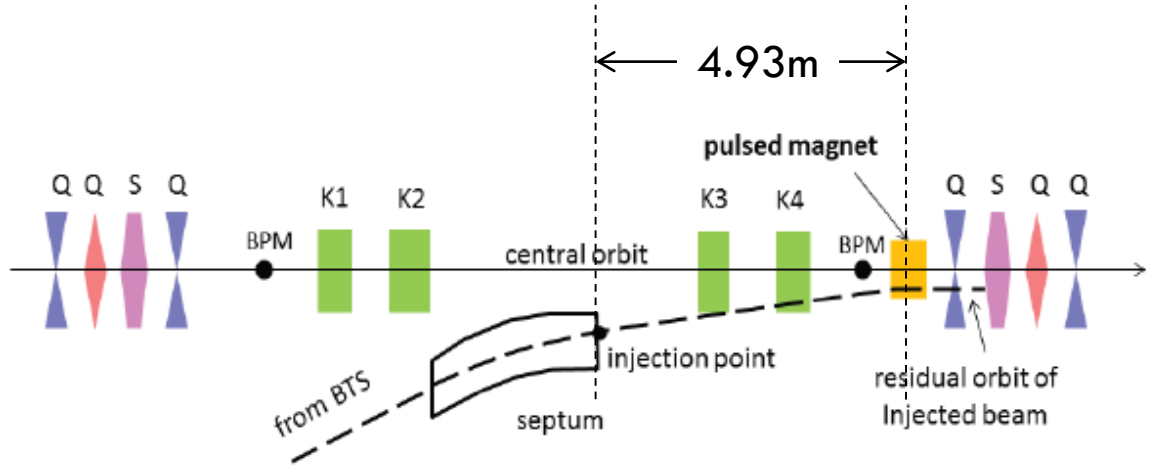
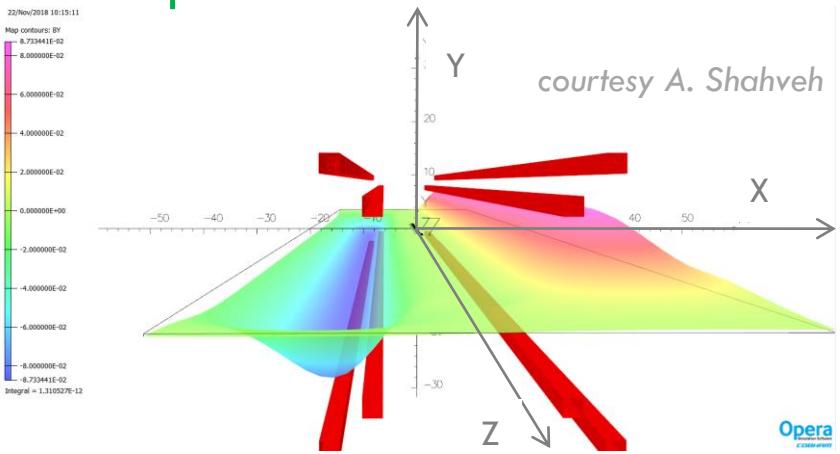


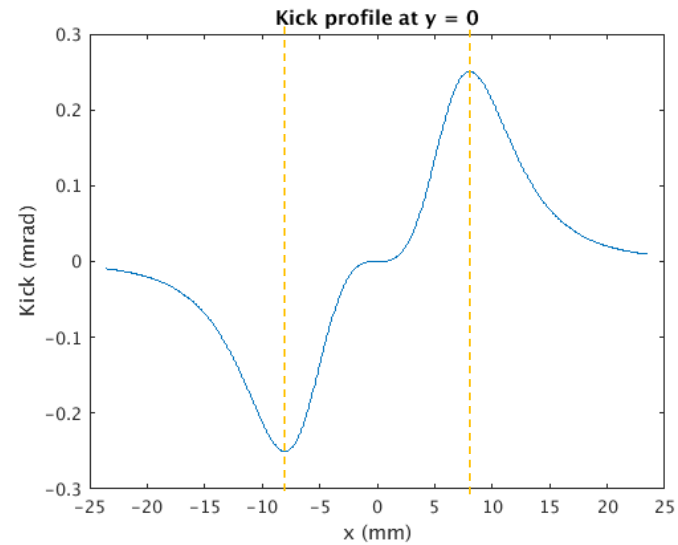
Figure 2: Schematic of the proposed injection scheme using PM which is to be located after kicker K4 of the four kicker bump injection.

Non Linear Kicker

NLK Opera Model – 8mm kicker



Best results for peak kick =2.5mrad
@ 8mm from stored beam

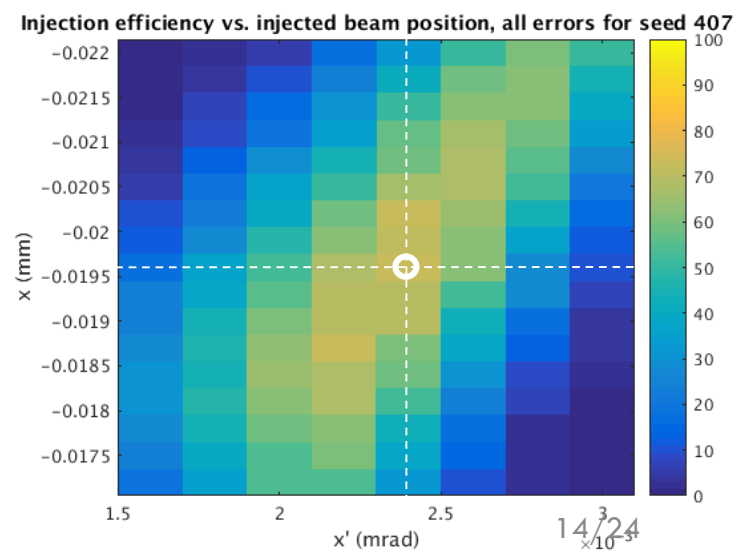


kick-map imported into ***elegant*** simulation
To verify best (X,X') for Injection Efficiency

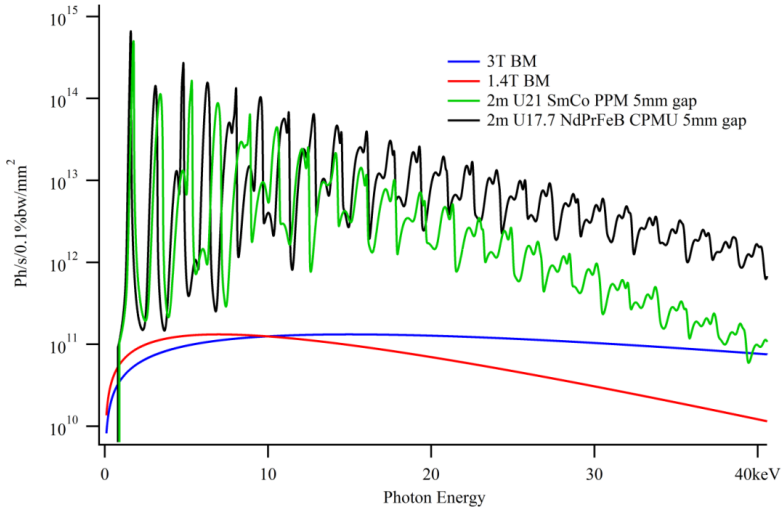
best point: (-19.6mm,2.4mrad) @ septum
IE ~ 73%

courtesy R. Fielder

σ error	Tilt (mrad)	Field error	Shift (mm)
Dipole	0.1	5e-4	0.02
Quad	0.2	2e-4	0.02
Sext	0.2	2e-3	0.02



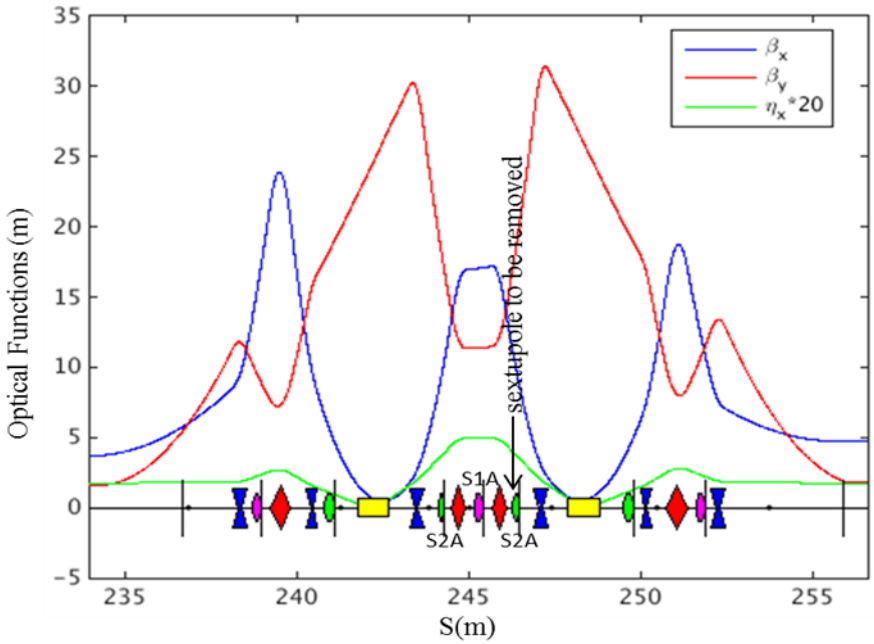
Dual Imaging and Diffraction Beamline



- 7-38 keV, 1 μm resolution
- Several options investigated:
  - Standard dipole source
  - 3T super-bend
  - **2nd DDBA cell?**
- Simulations for the **second DDBA** showed further and significant **degradation** of **dynamic aperture** and especially **lifetime**
- Decision taken **not to proceed** (for now)
- alternative proposal: remove one chromatic sextupole and insert a **short mini-wiggler (0.7 m)** in its place
- Simulations show this can work, **local chromaticity** correction deferred to the **nearby sextupole**
- A project was launched in autumn 2016 for **installation in 2018**

DIAD (missing sextupole) lattice

courtesy I. Martin



- **Missing sextupole** compensated by **doubling strength** of partner
- Permanent magnet **wiggler 0.7 m placed in gap**
- V/H **steerer**, **skew** quadrupole and **BPM** also removed
- Lattice tested with **minimal impact** on **lifetime** and **injection efficiency**

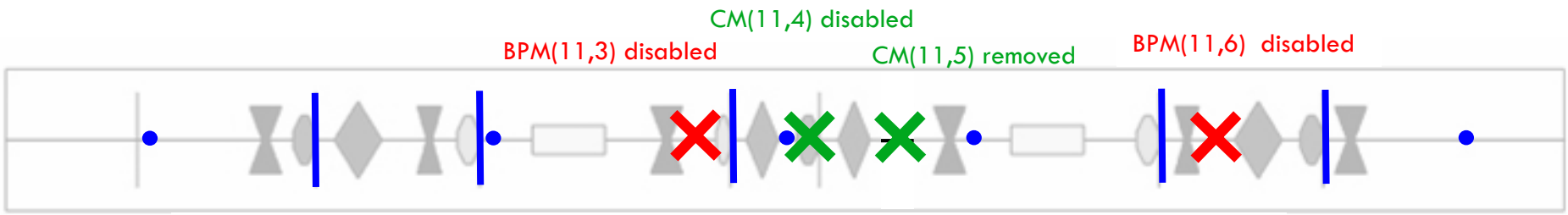
- Installed: **first half of 2018**

DIAD (missing sextupole) lattice

courtesy I. Martin

Removing sextupole (5) has two main implications:

- Need for **stronger nearby sextupole** (3)
- **Loss of CM(5)**, embedded in the original sextupole ➔ new local CM/BPM scheme needed



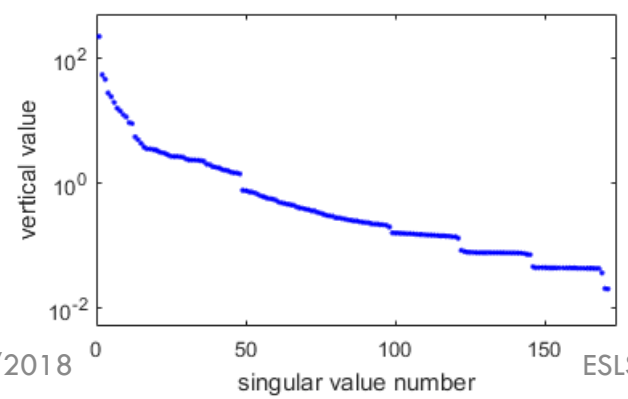
Run with 5 BPMs / 5 CMs in the cell

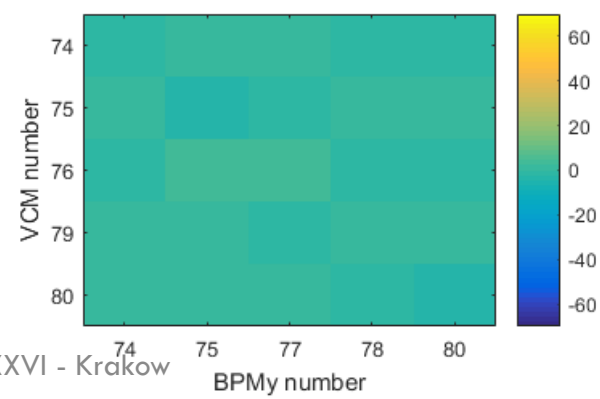
BPM[11,3] disabled

BPM[11,6] disabled to prevent the orbit response matrix becoming ill-conditioned

CM[11,4] at long-term settled values from VMX optics [prior to DIAD instalment]
and no longer in the feedback

BPM[11,6] no longer in the feedback

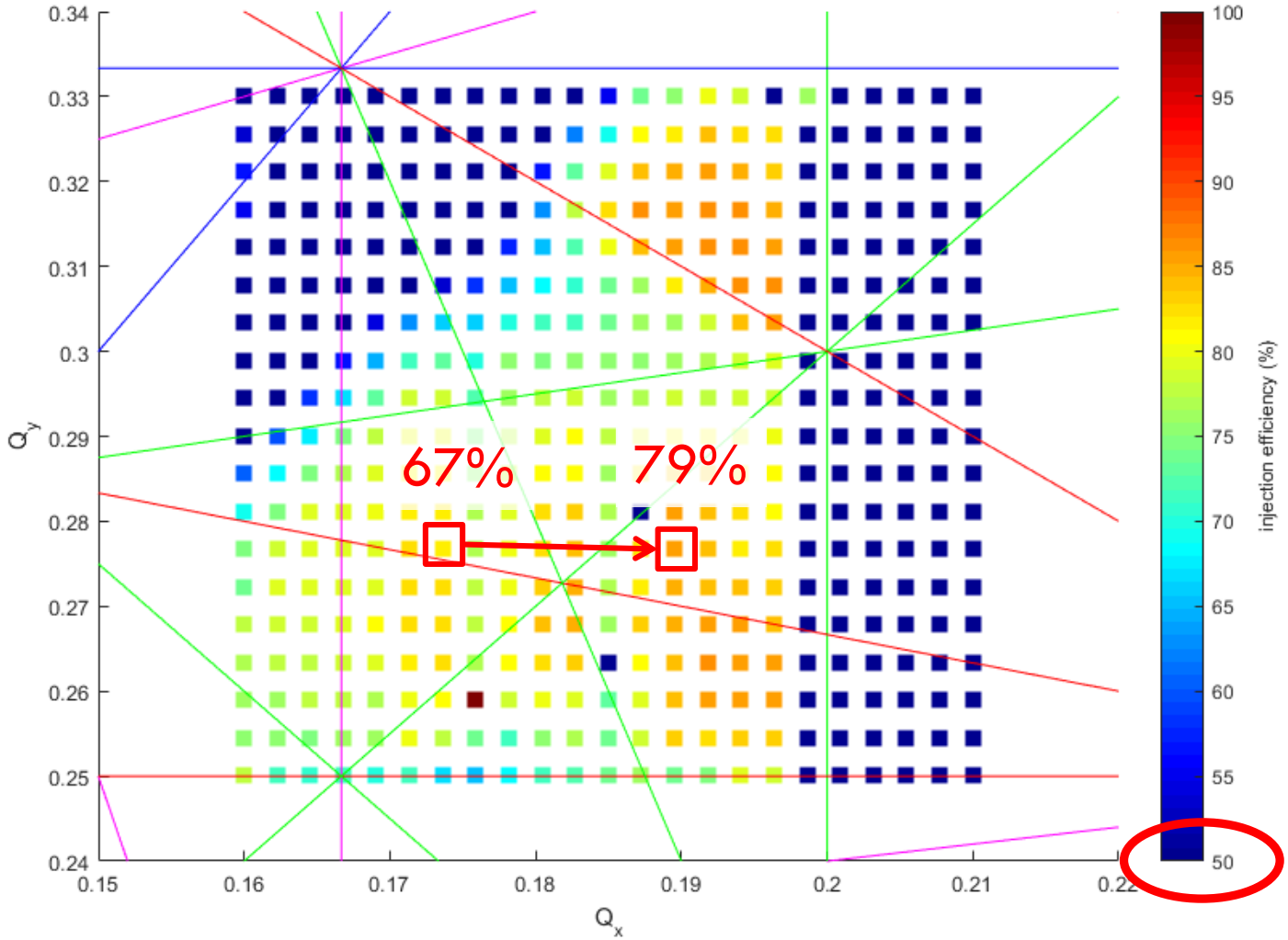




DIAD Commissioning: tune scan for IE

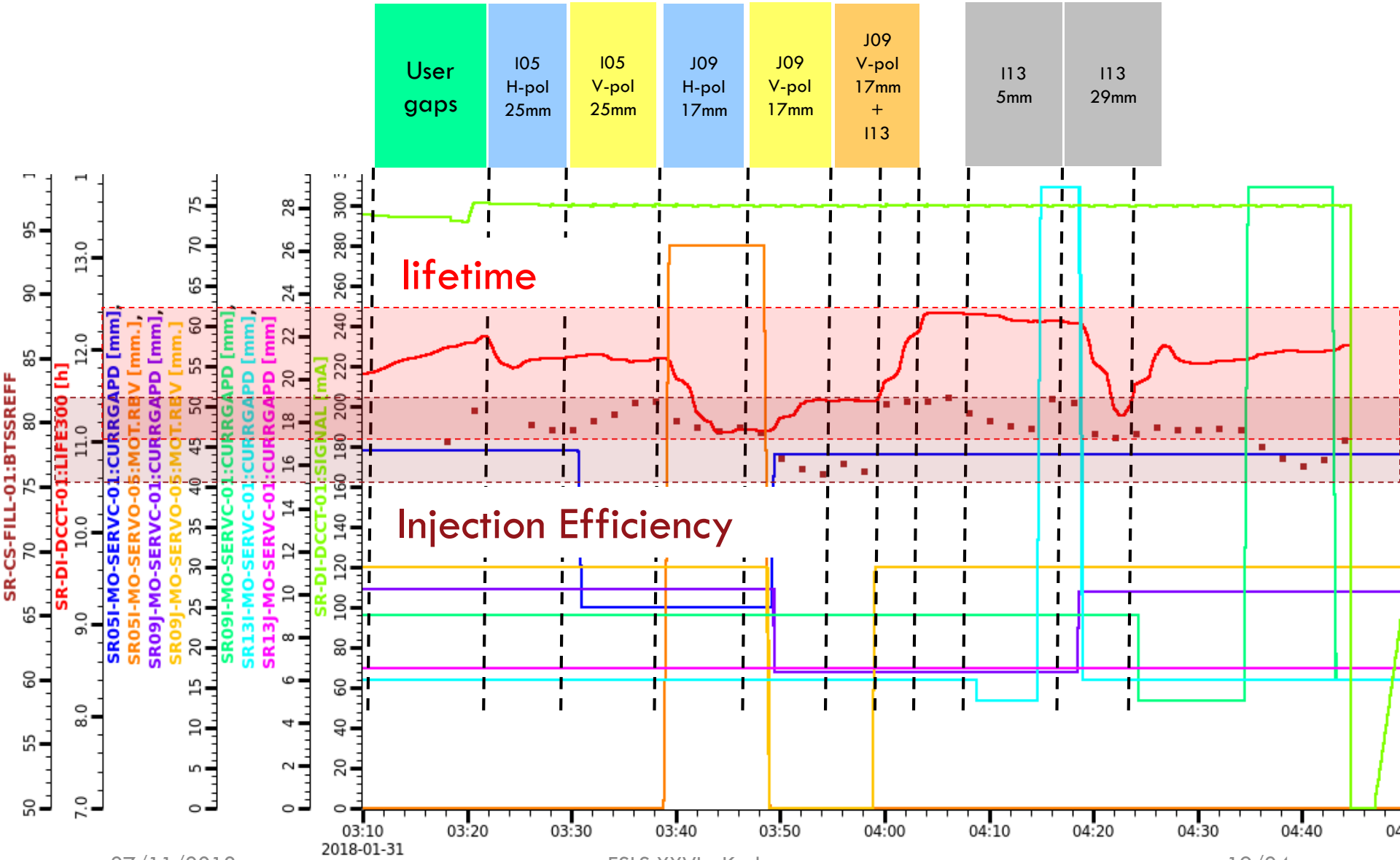
courtesy I. Martin

BS → SR injection efficiency



IDs at 'user gaps', wigglers at field, X = [1.6,2.0], 900 bunches

DIAD Commissioning: effect of beamlines during operations



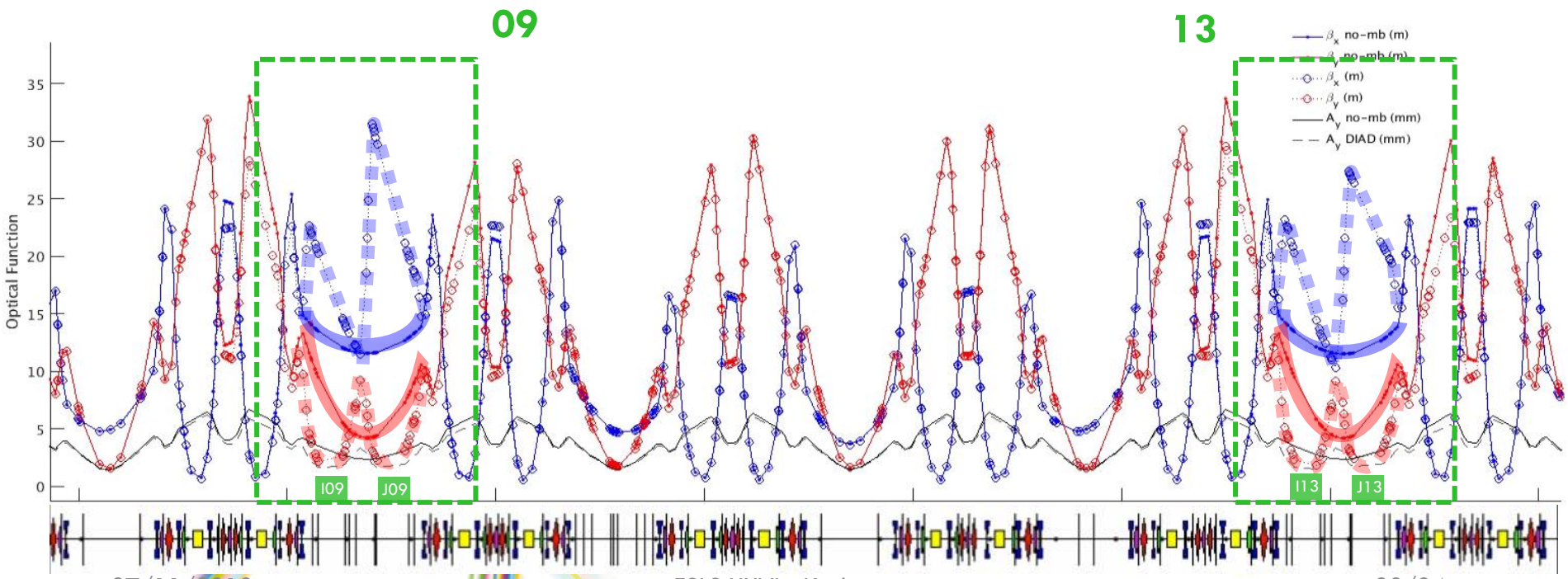
no-minibeta lattice for DII

present lattice: **two mini-beta sections** for beamlines **I09 / I13**

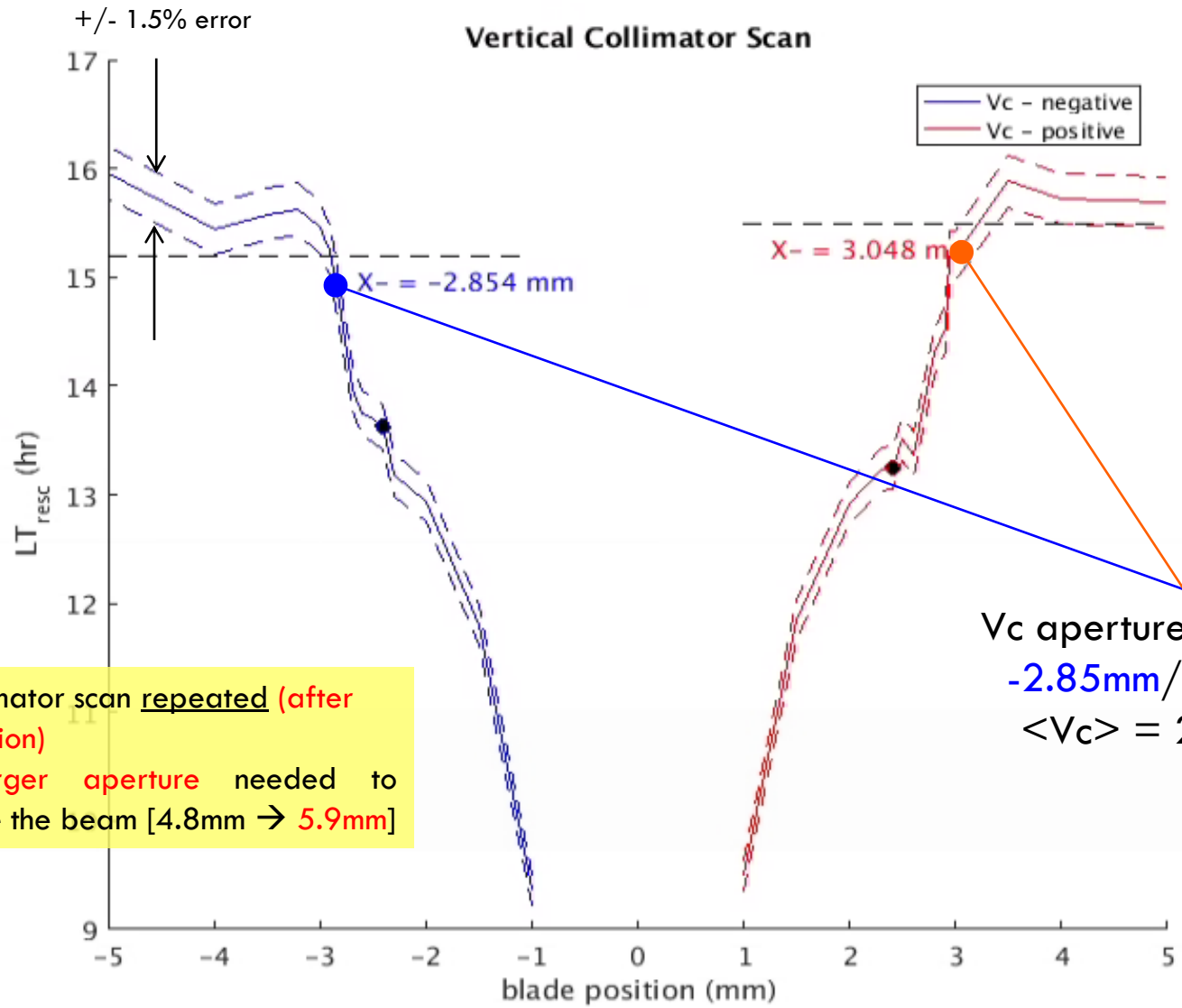
very **difficult to port to DII** [low LT / IE] → abandoned for a **standard waist**

In order to verify the ability at closing ID's with this new scheme a **no-minibeta** version of the **present lattice** was produced by **re-matching straight 09/13** without mid-straight doublets (quad. off)

Optimisation procedure (**MOGA**) and **tune scans** used to find a good w.p. (IE/LT)



no-minibeta lattice: limiting aperture



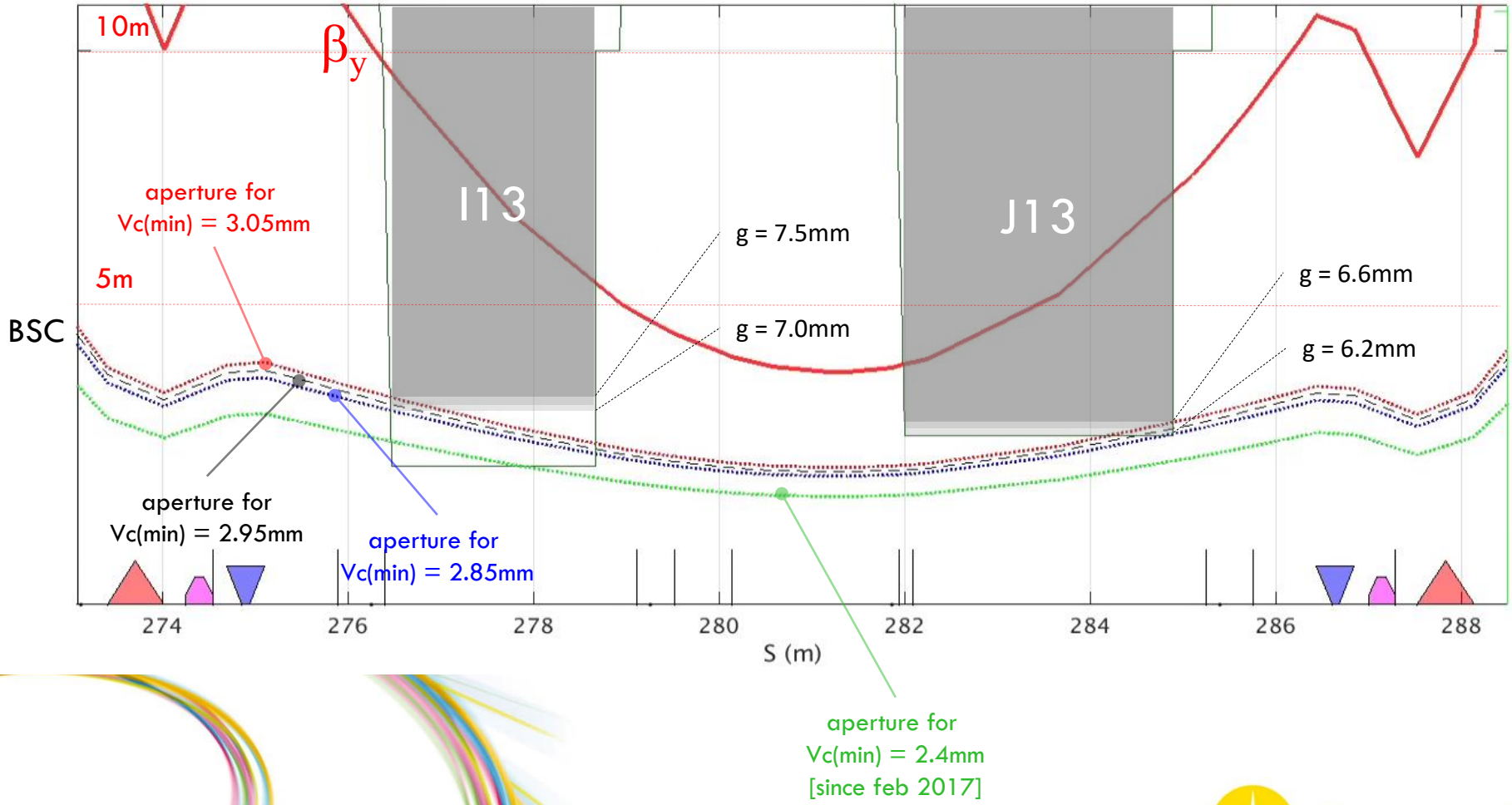
Vc aperture **after DIAD**
-2.85mm/+3.05 mm
<Vc> = 2.951 mm

Vertical Collimator scan repeated (after DIAD installation)
Suggests larger aperture needed to accommodate the beam [4.8mm → 5.9mm]

no-minibeta lattice: BSC @ IDs

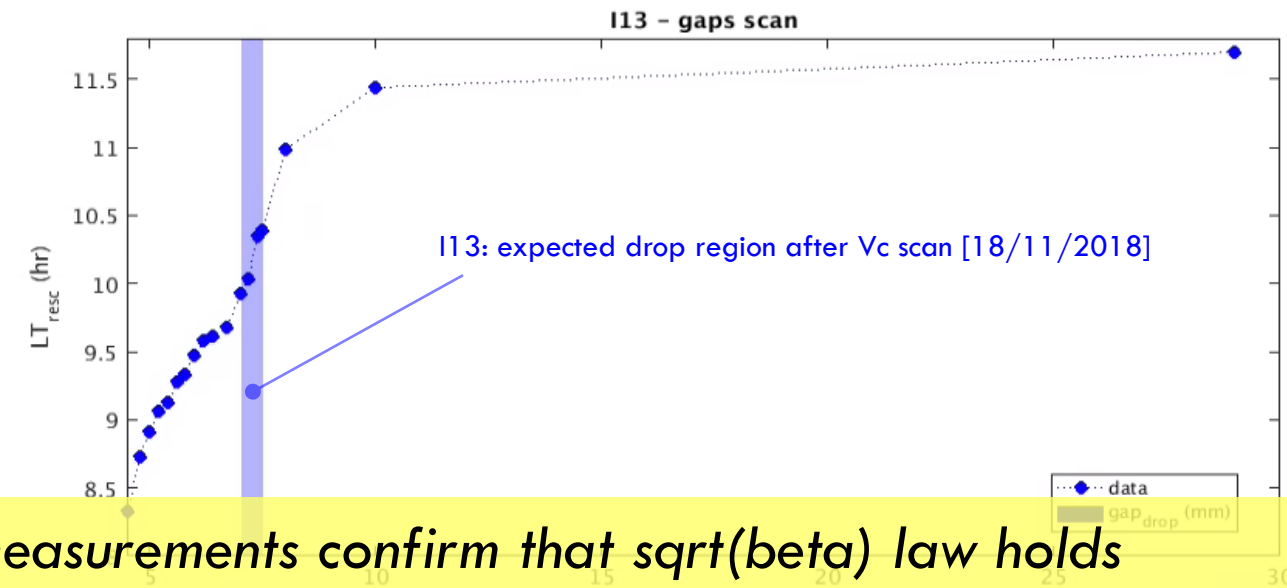
predictions of ID min. gaps from V-scraper outcomes based on sqrt(beta) scaling law

$$S_y = \sqrt{S_y^C} \times \sqrt{\frac{\beta_y}{\beta_y^C}}$$

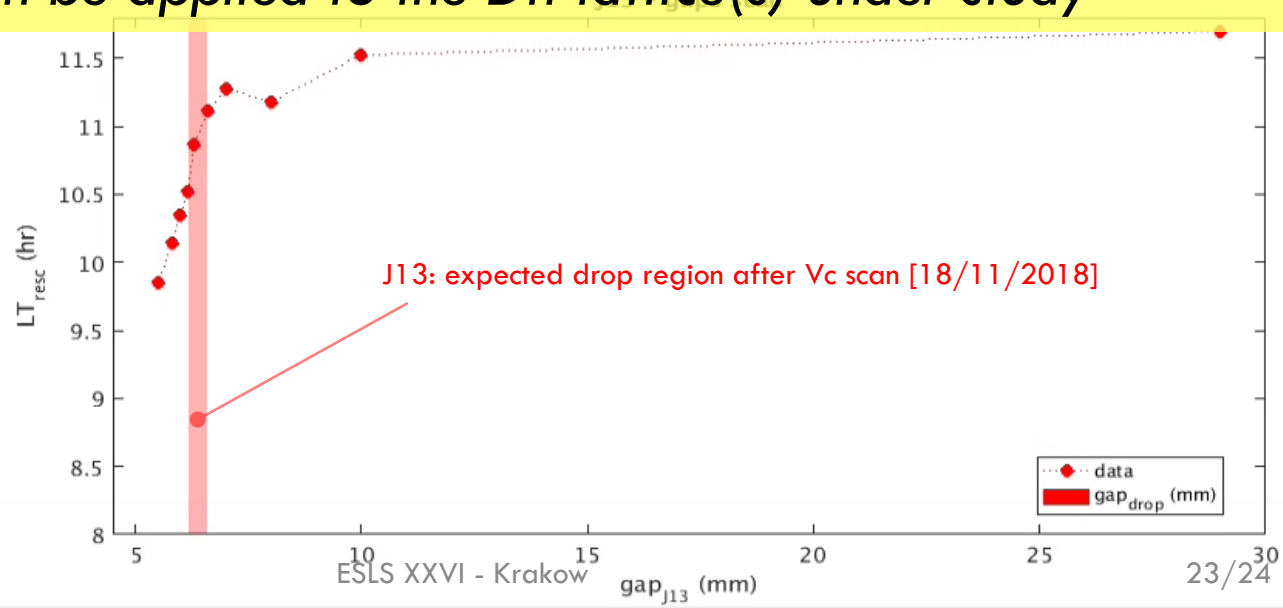


no-minibeta lattice: lifetime vs ID-gap

I_b ~ 140mA
N_b = 840
ε_y = 8pm



These measurements confirm that sqrt(beta) law holds and can be applied to the DII lattice(s) under study

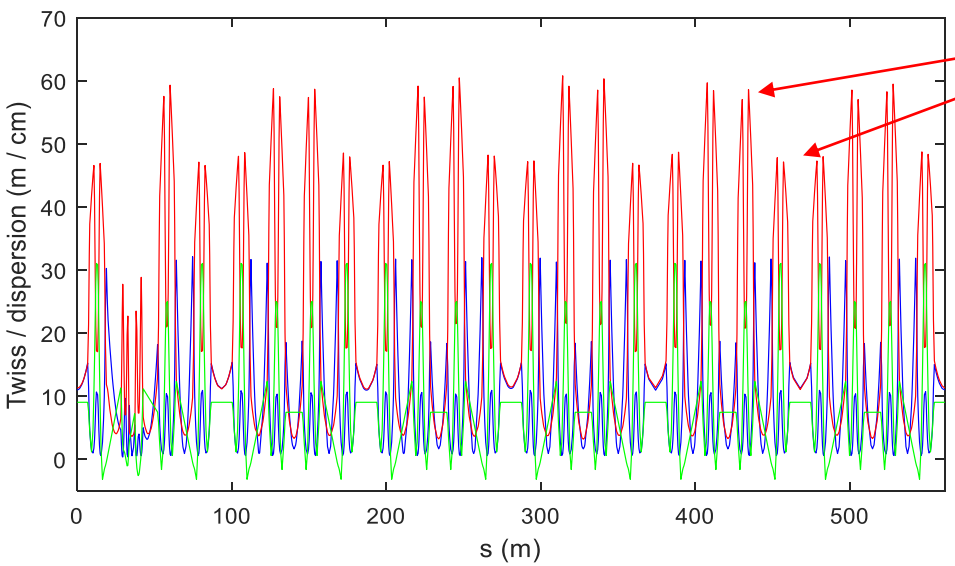


CONCLUSIONS

- Fairly **good operations**
- **RF-system**
  - **Two new NC Installed** in the SR
  - **booster** cavity
- **DIAD BL installation**
  - **successful** operation
- **NLK** under study
- **No-minibeta** studies for DII

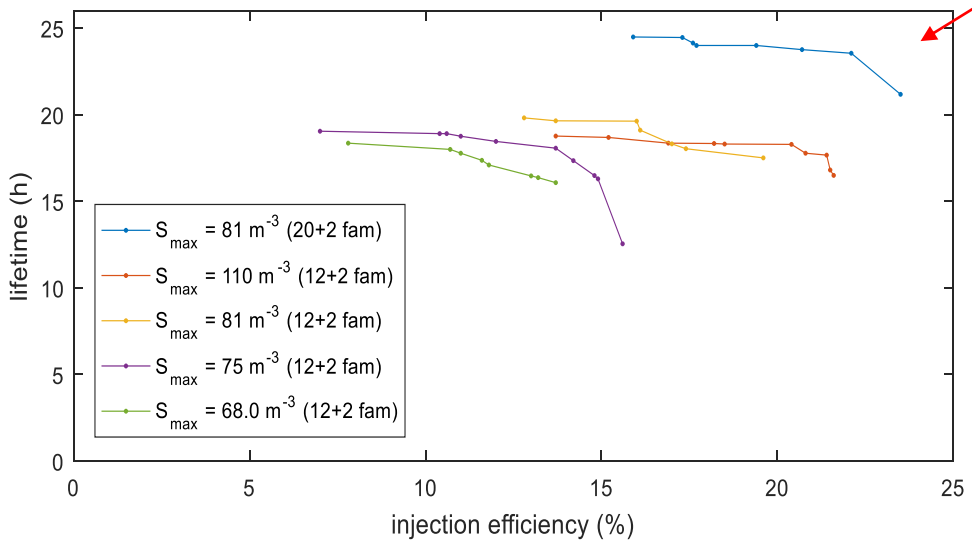
Thanks for your attention …

DIAD Commissioning: low-α operations



courtesy I. Martin

For **low alpha** optics, beta functions alternate between high/low beta functions in the arcs

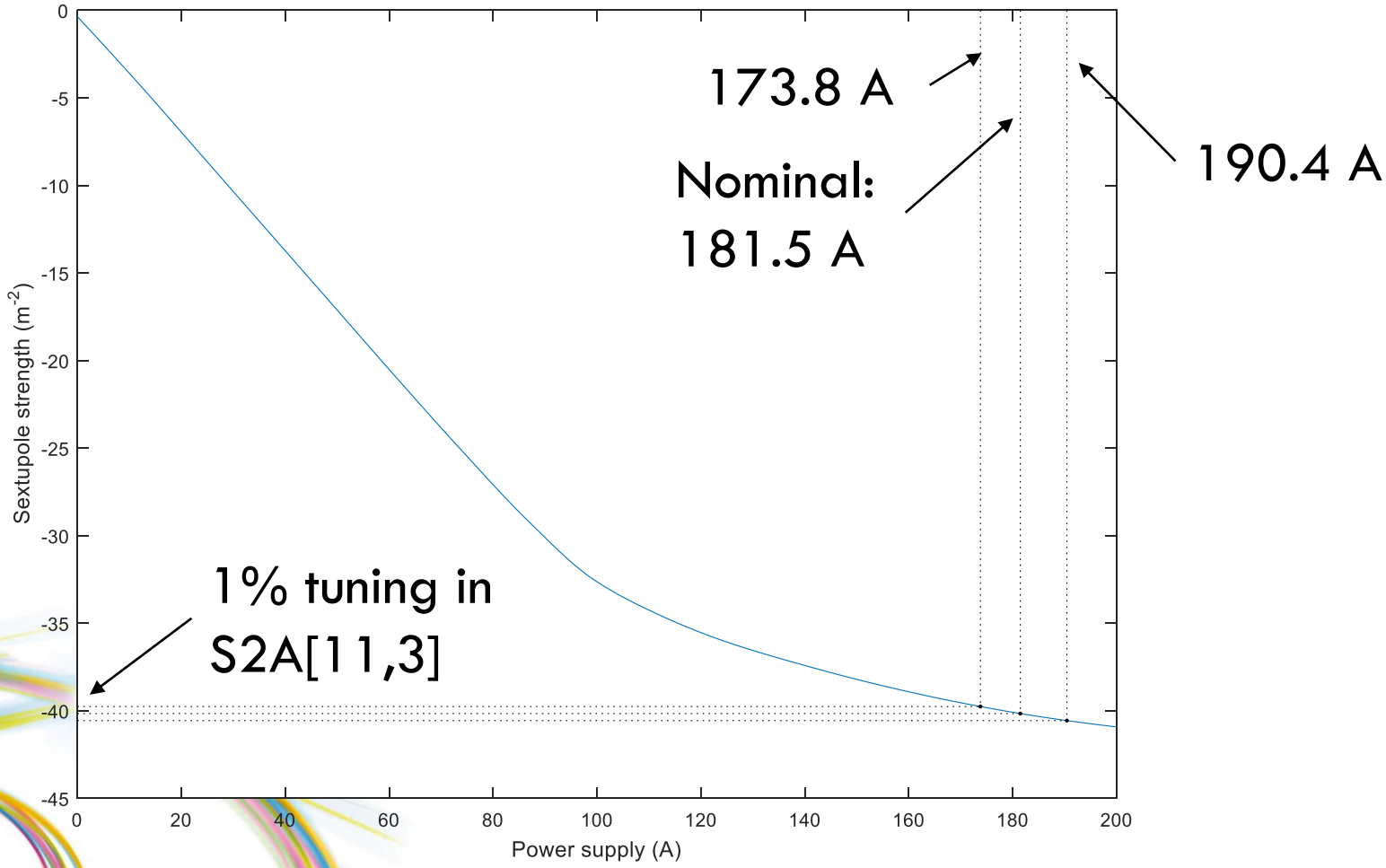


MOGA optimisation
significant gain in lifetime found by **breaking some sextupole families into 2:**

- S1A
- S2A
- S1B
- S2B
- DDBA sextupoles

Note: S1C, S2C, S1D, S2D stay as single families

DIAD Commissioning: S2A[11,5] removed ➔ S2A[11,3] doubled to compensate



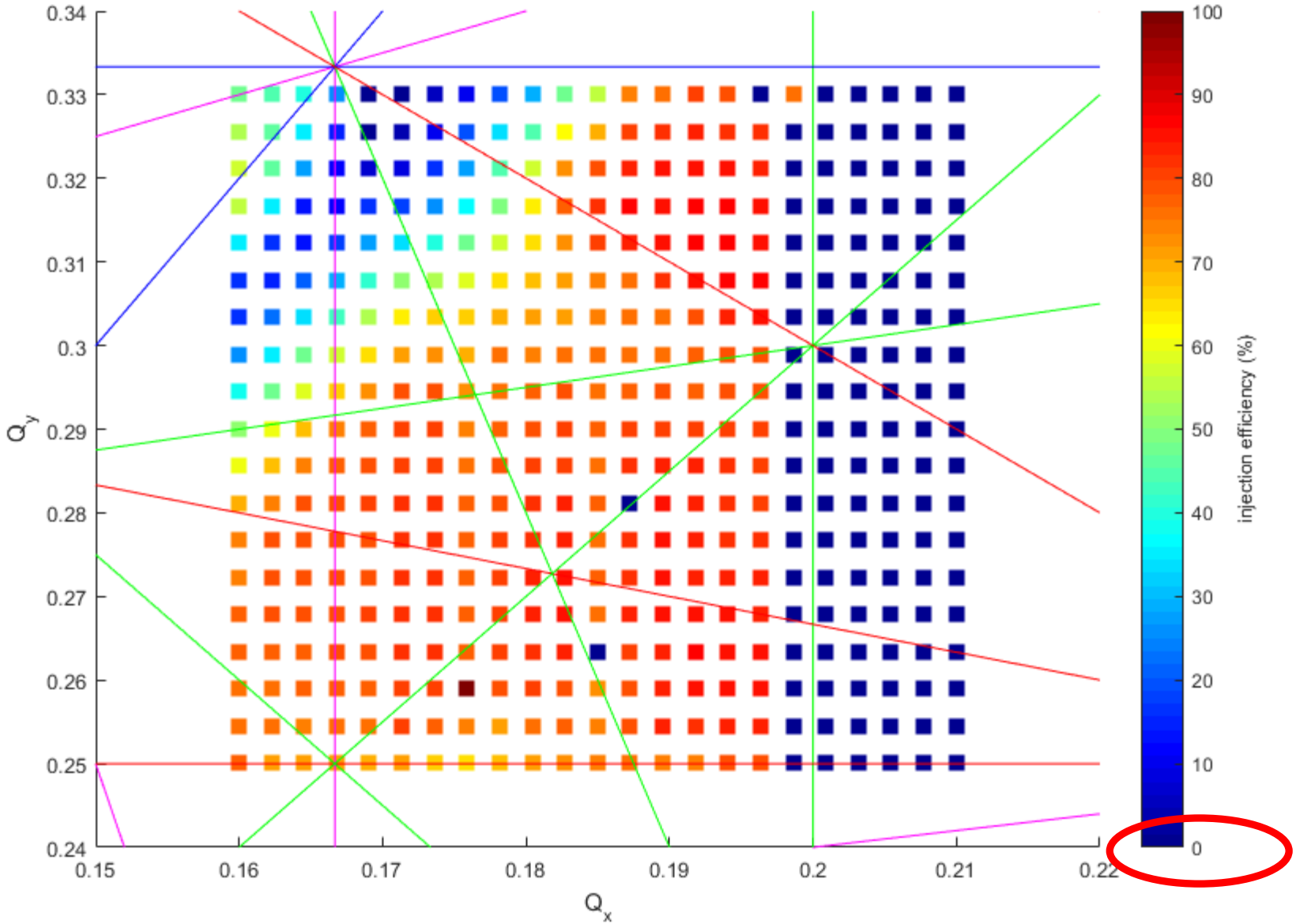
Wouldn't it be nice if we had somewhere..

Courtesy C. Bloomer

ViSR … a visitor attraction

- Available when the machine is on.
- Close to the spare girder, perfect for tours!
- Come and "see the light".

Tune scan, using 2s EBPM BS=>SR injection efficiency



IDs at 'user gaps', wigglers at field, X = [1.6,2.0], 900 bunches

no-minibeta lattice: limiting aperture

Vc aperture **after DIAD** -2.85mm/+3.05 mm

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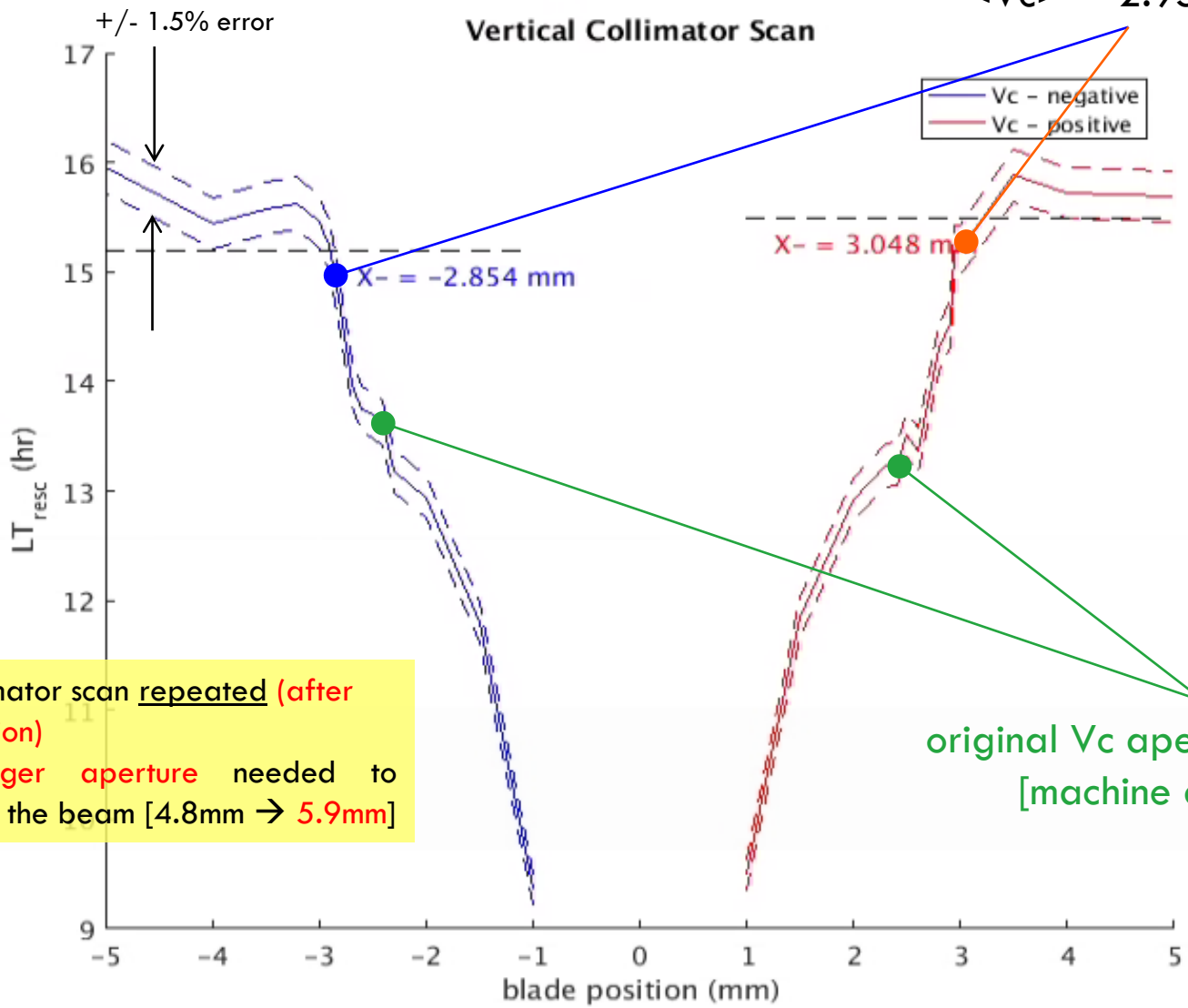


Vertical Collimator scan repeated (after DIAD installation)
Suggests larger aperture needed to accommodate the beam [4.8mm → 5.9mm]

original Vc aperture +/- 2.4mm [machine acceptance]

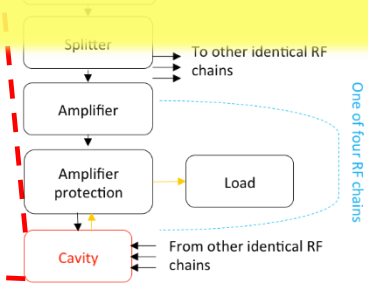
Longitudinal multi bunch feedback (LMBF)

- concern that addition of two **new NC-RF** cavities may cause **longitudinal instabilities**

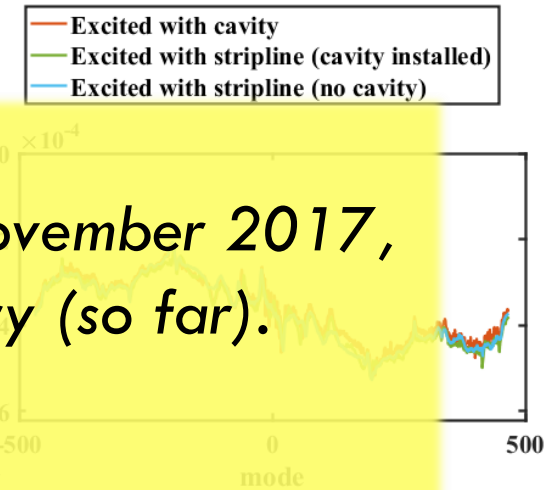
- i.o.t. mitigate these instabilities a **longitudinal feedback system** has been **designed, installed** and **tested**

courtesy A. Morgan

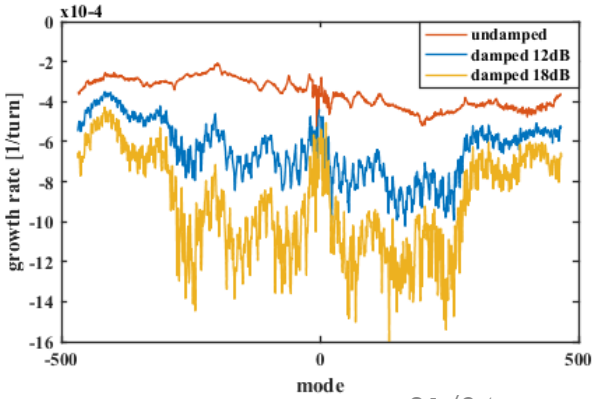
NC-RF cavities** have been tested since November 2017, showing LMBF is not strictly necessary (so far). It can though be used for **longitudinal dynamics tests



Cavity:
- no problem **when unpowered**
- expected behaviour **when powered**



When **FB loop closed** the system **suppresses growth rates** for all modes (machine currently intrinsically stable).



Normal Conducting Cavities

Resonant cavity at **500 MHz** in centre

Radially mounted components

Coupler, tuner and HOM loads

Less powerful than superconducting RF but simpler

Easily maintained

Voltage per cavity will be **reduced**

Power per amplifier will be **reduced**

Latest iteration of cavity installed at **BESSY**, **Alba** and **ESRF** (scaled for frequency)

Flanged joint at base of HOM damper waveguide removed to address trapped mode

Pickup coated at ESRF

Much smaller longitudinal footprint than SC cavity

Can be **installed in regular straight**

SC cavity environment undisturbed

Further NC cavities can be installed