

Status of PETRA IV and its Collective Effects

Sergey Antipov

Many thanks S. Klumpp, S. Pfeiffer
DESY-TEMF Meeting, TU Darmstadt

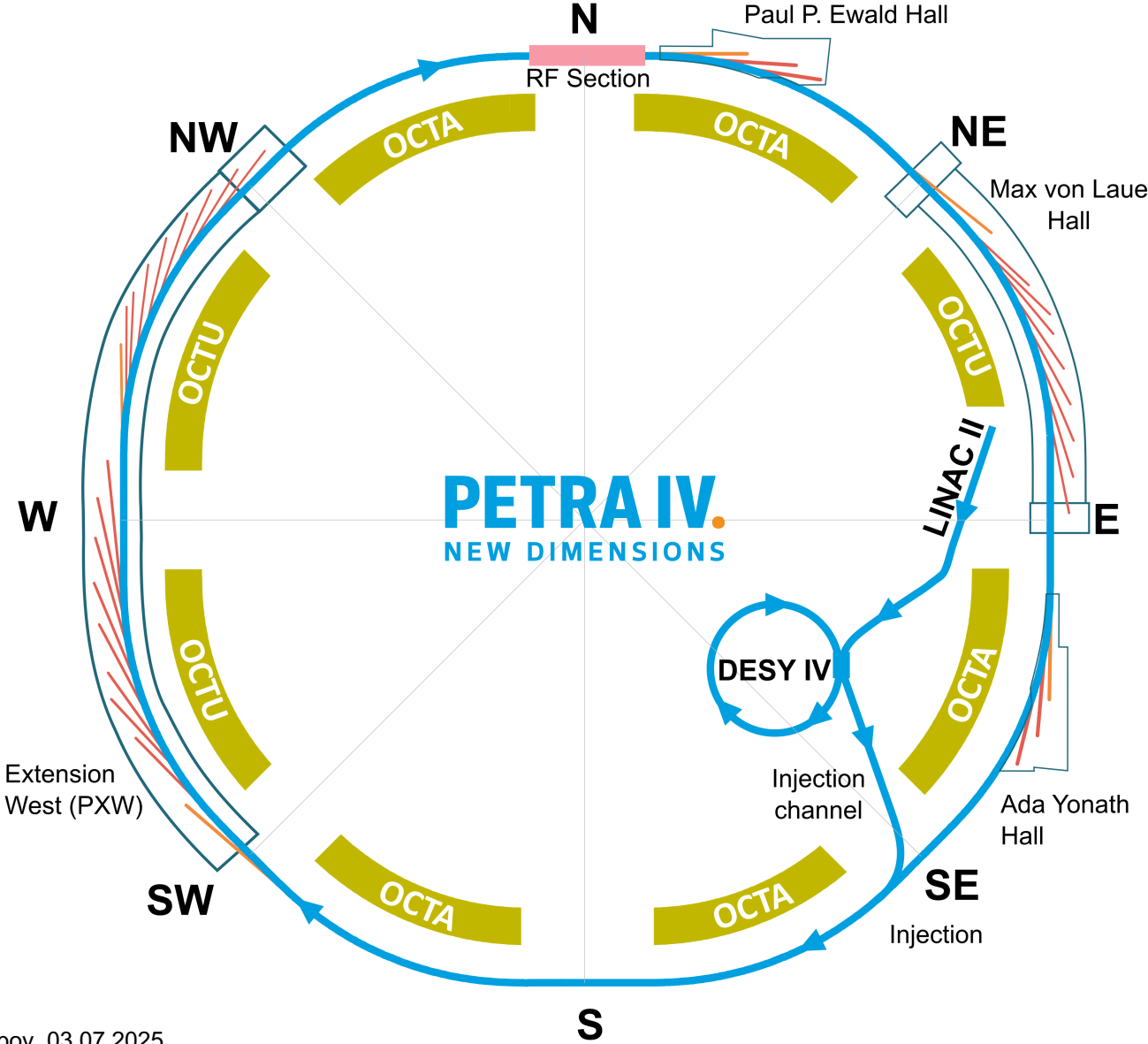
July 3, 2024

HELMHOLTZ



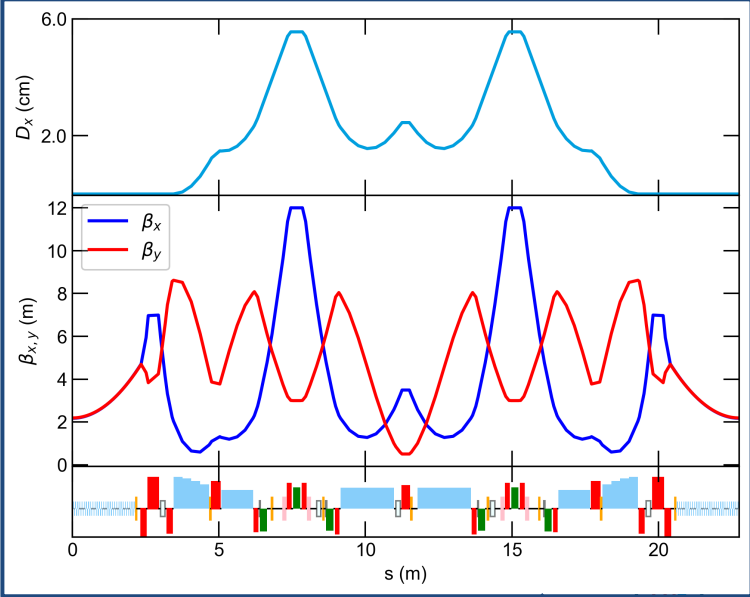
PETRA IV: Germany's future flagship light source

6 GeV, 2.3 km, 20 pm-rad

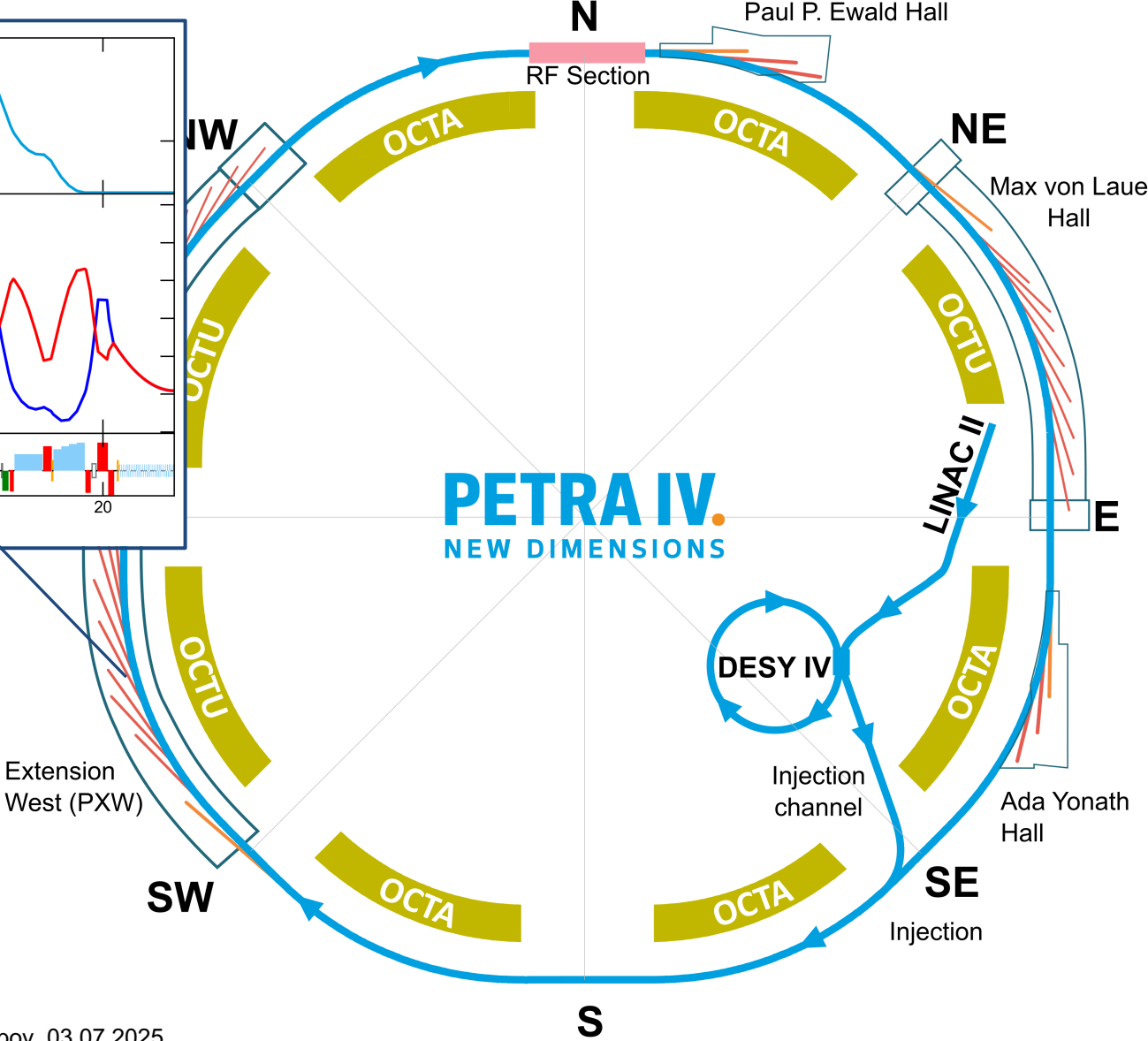


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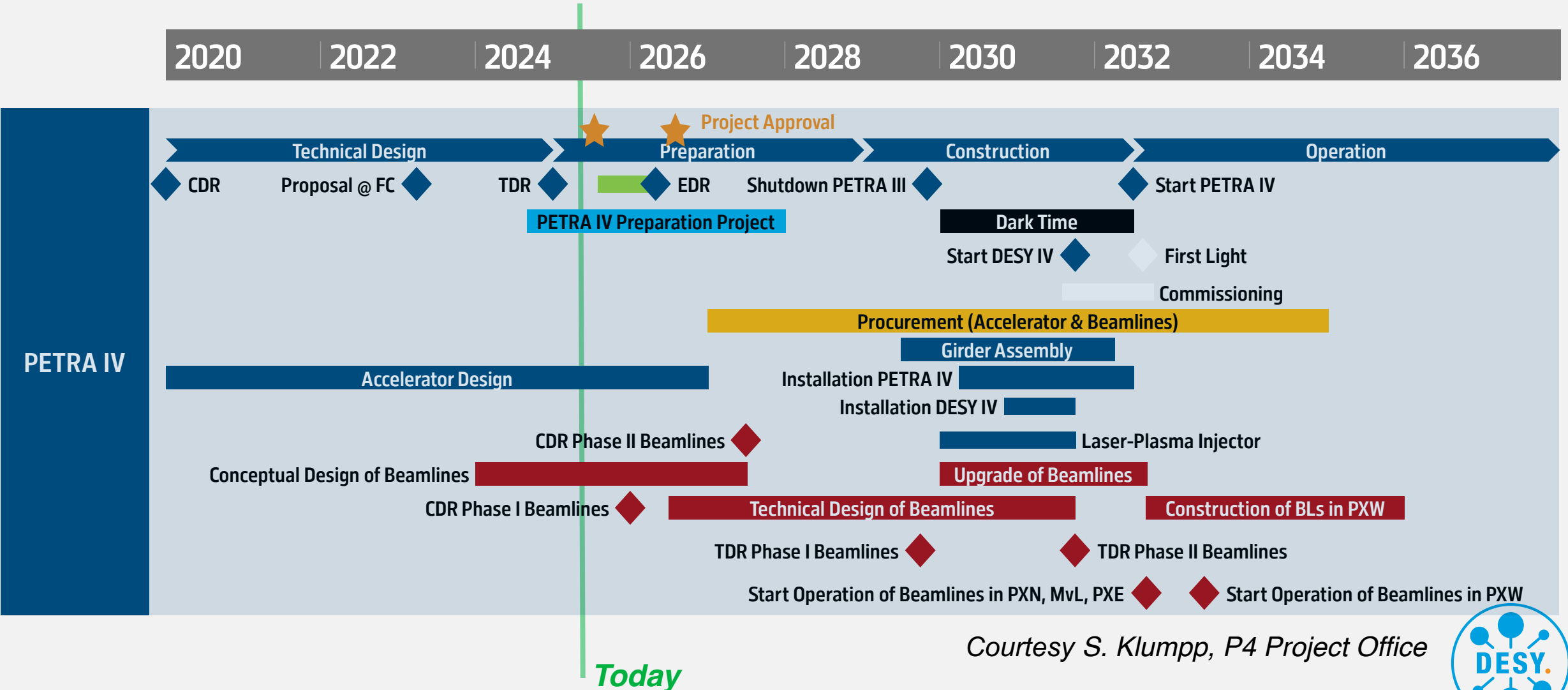


H6BA cell



Our Timeline

Expecting positive news in less than 2 weeks



Courtesy S. Klumpp, P4 Project Office



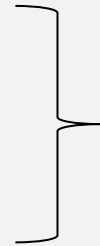
TEMF help to PETRA IV project

Shorter chamber would make it fit both for PETRA III and PETRA IV

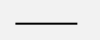
Impedance modeling

Fast orbit corrector R&D

Single-mode harmonic cavity design



Direct help and impact for the PETRA IV project



More academic interest, likely outside of the PETRA IV scope



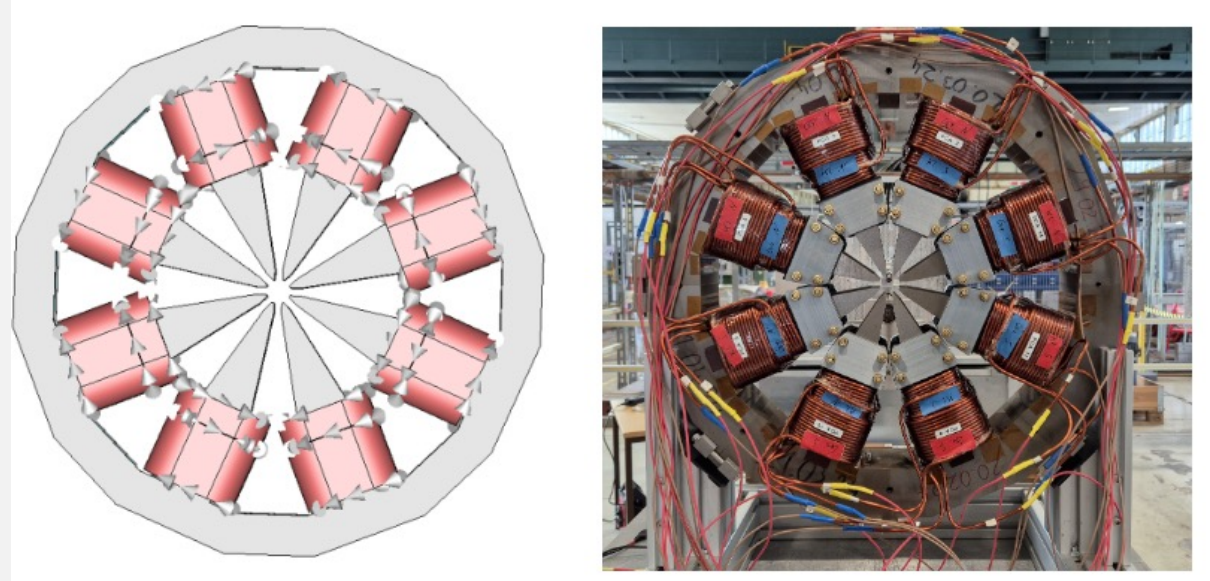
Fast corrector R&D is making progress

Validating simulations with measurement on a prototype

Validation of the simulations

1. with the measurements of the first prototype of the fast corrector
2. with the two types of vacuum chambers that could be used in PETRA IV

→ Summary by Jan-Magnus Christmann



Remaining point

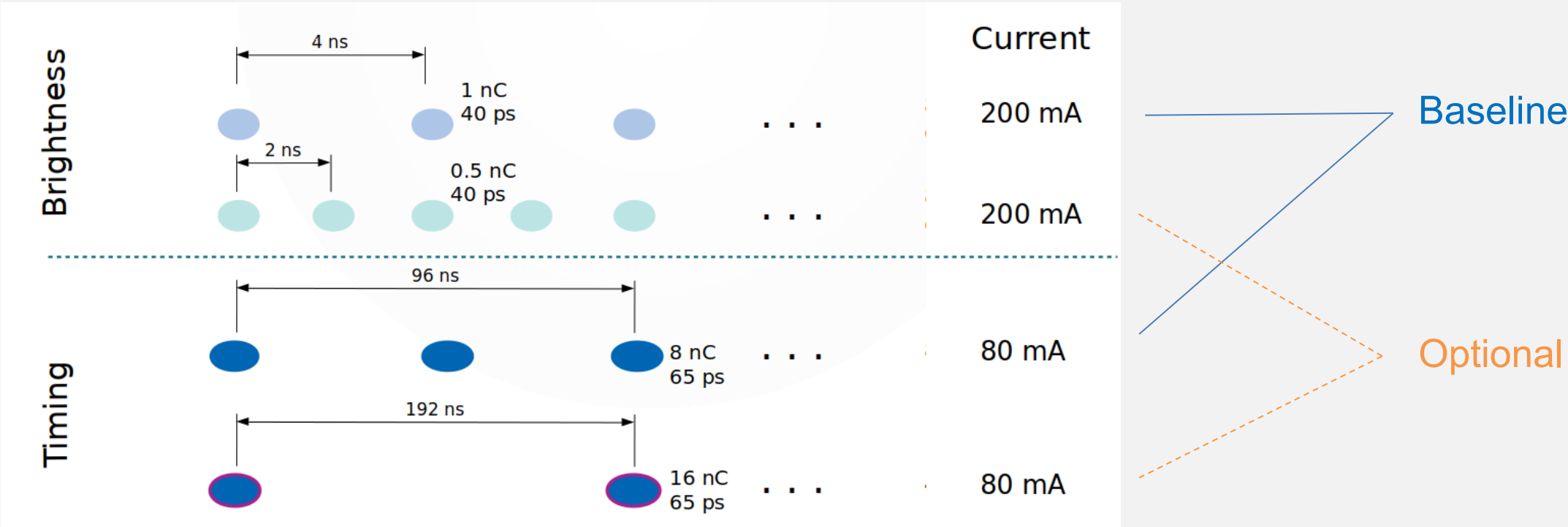
Understand the 10 times faster response of the fast corrector:

- Measurement problem?
- AC fields too small?



Reminder: PETRA IV offers a variety of operation modes

Collective effects shall not degrade the performance



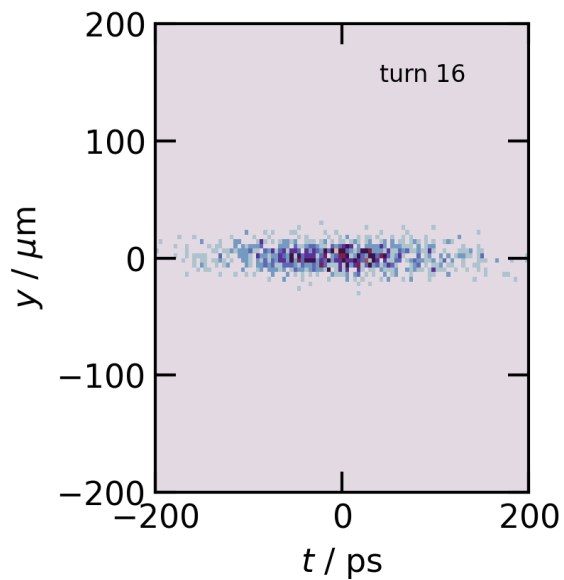
Potential Hybrid filling patterns have interest for Timing community and are presently being discussed



Instability at high intensities

Leads to blow-up of the transverse beam size in ~1000 turns

Before



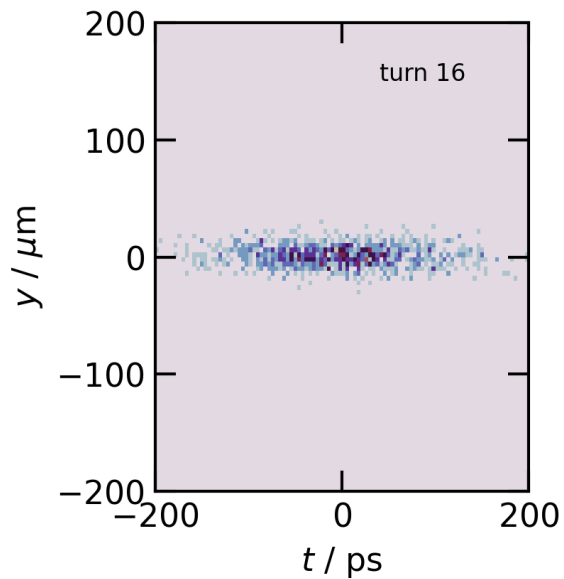
High-charge Timing mode

- 14 nC in the stored bunch
- No aperture sharing (starts from noise)
- Chromaticity 5

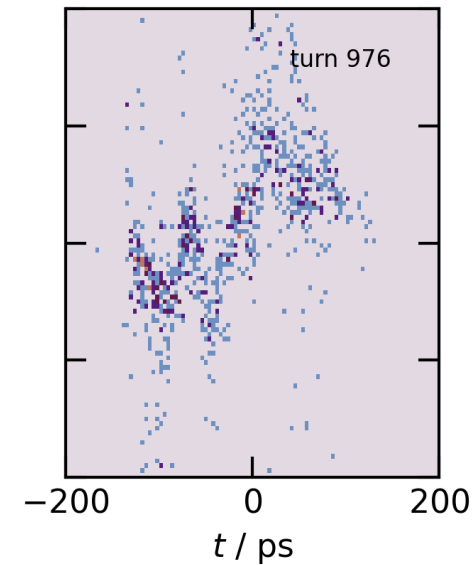
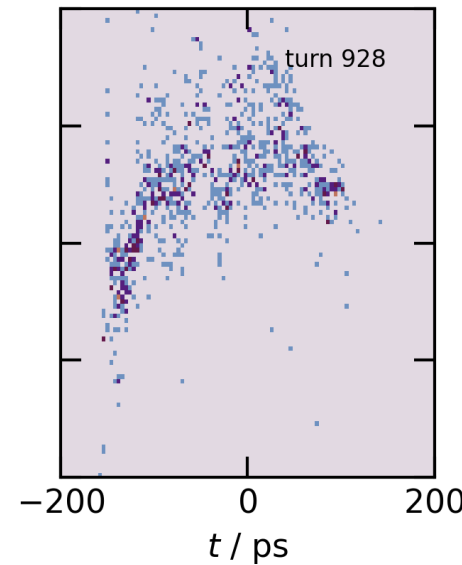
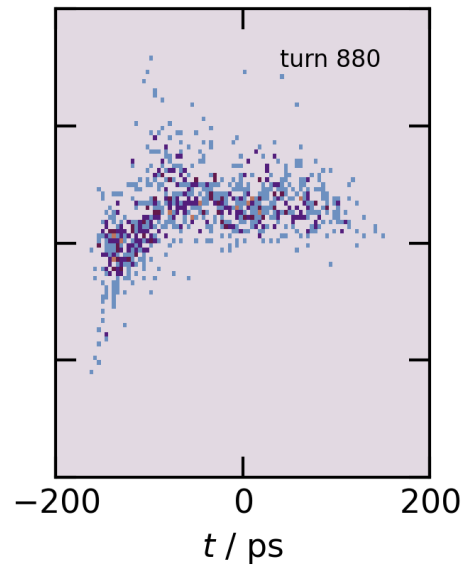
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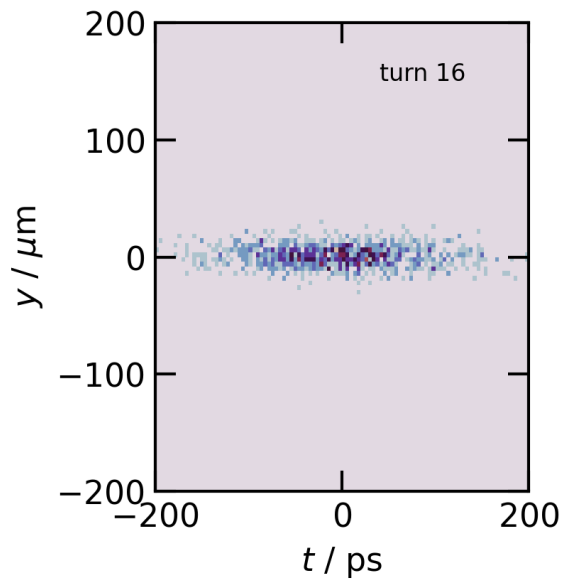
During



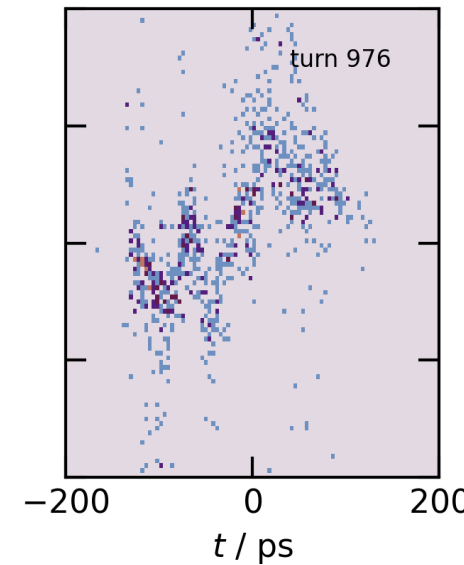
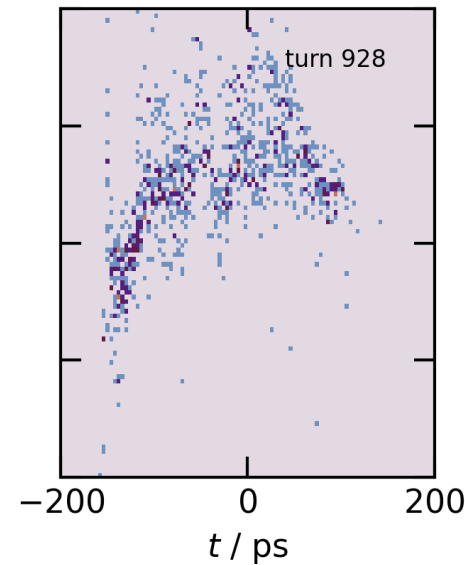
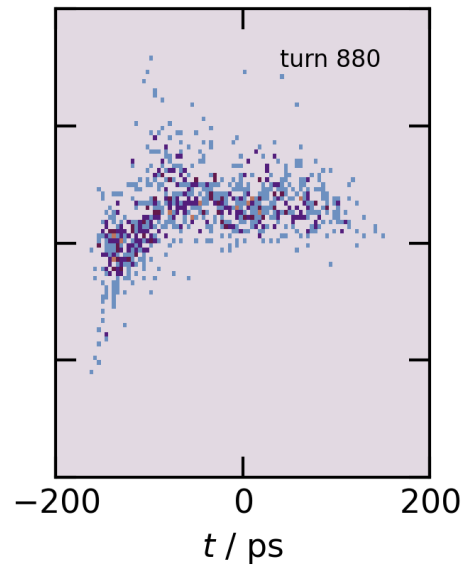
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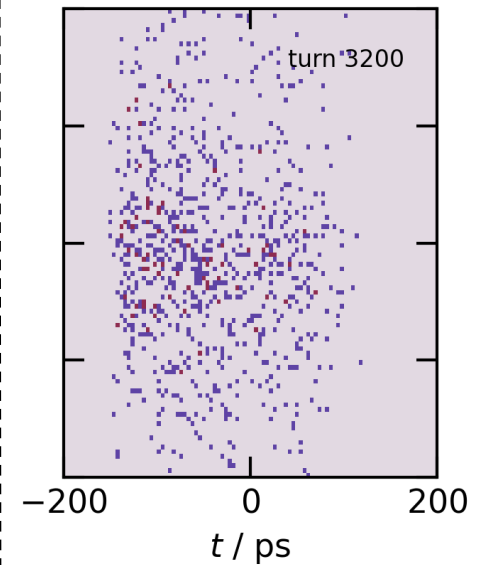
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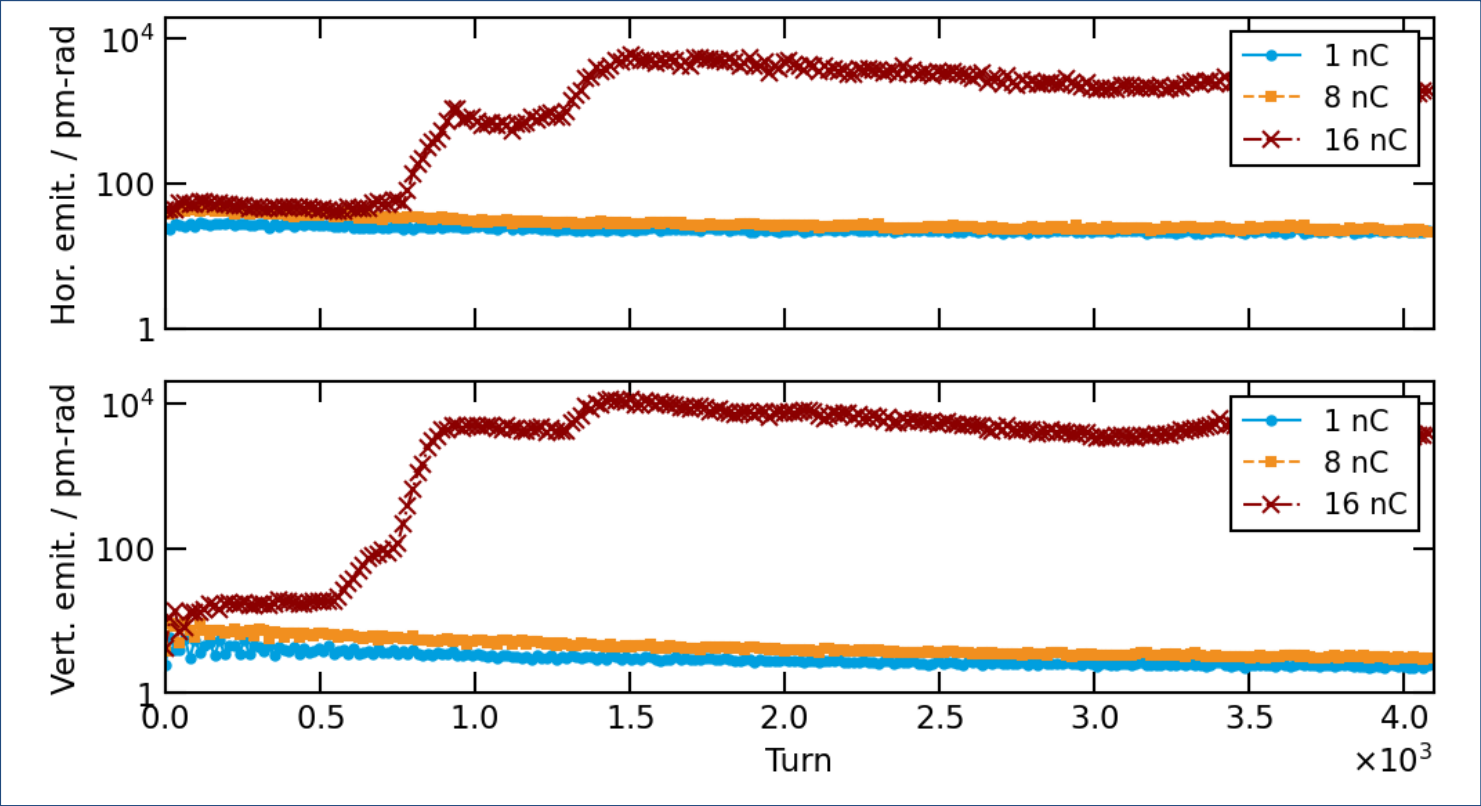


After



Emittance might blow up to nm scale for high charge modes

Blow-up happens on time scales of ~1000 turns



Unexpected player: space charge

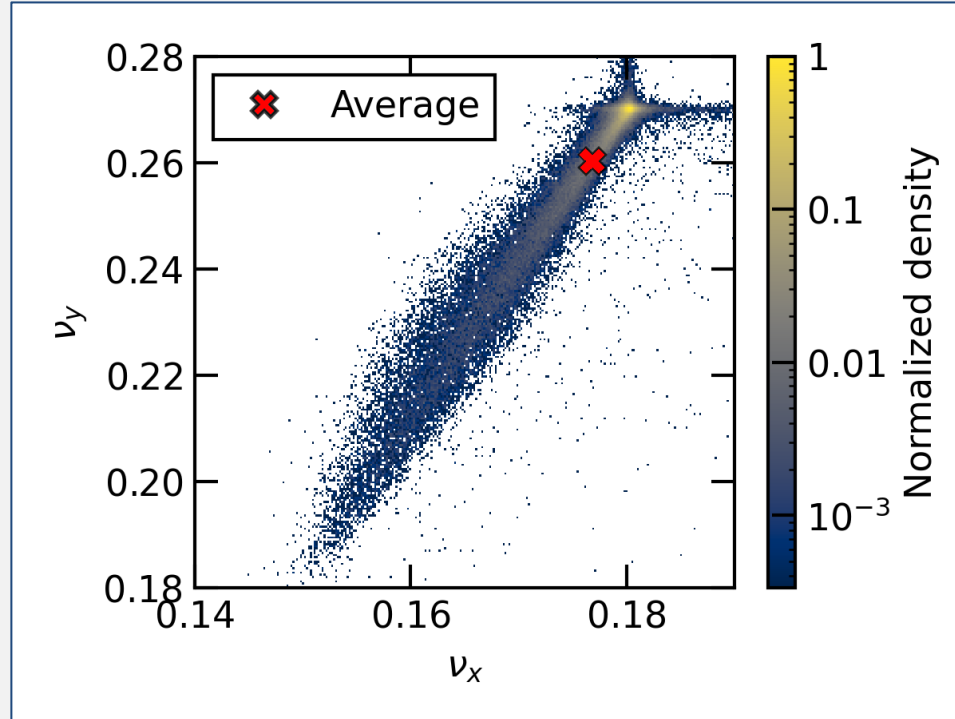
Normally neglected in light sources it becomes important as one approaches diffraction limit

$$\Delta\nu_{x,y}^{SC} = -\frac{Nr_e C}{(2\pi)^{3/2}\gamma^3\sigma_z} \left\langle \frac{\beta_{x,y}}{\sigma_{x,y}(\sigma_x + \sigma_y)} \right\rangle$$

10^{12}

Unexpected player: space charge

Normally neglected in light sources it becomes important as one approaches diffraction limit



Tune spread of a 10 nC bunch in PETRA IV

- nominal working point of (0.18, 0.27)
- Numerical simulation in XSuite

S. Antipov et al., PRAB 28, 024401 (2025)

Impedance model: RW dominates

Mainly due to tight undulator gaps

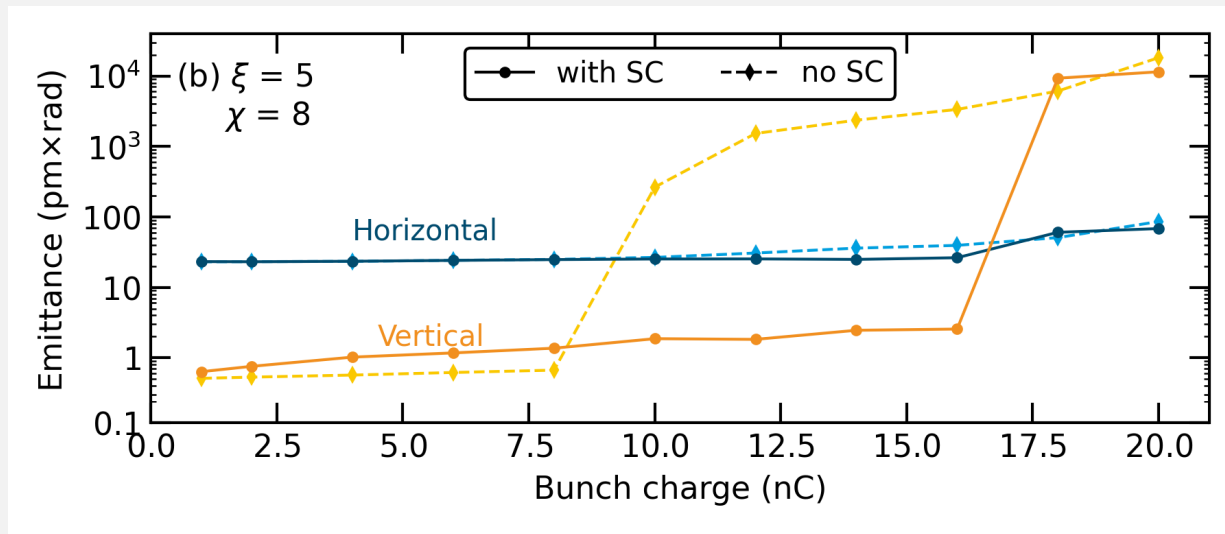
All key hardware included

RW simulated with I2DW

- NEG coating included, based on measured resistivity

Geometric simulated up to 100 GHz

- Including hardware as it is being designed
- Some still as broadband contributions

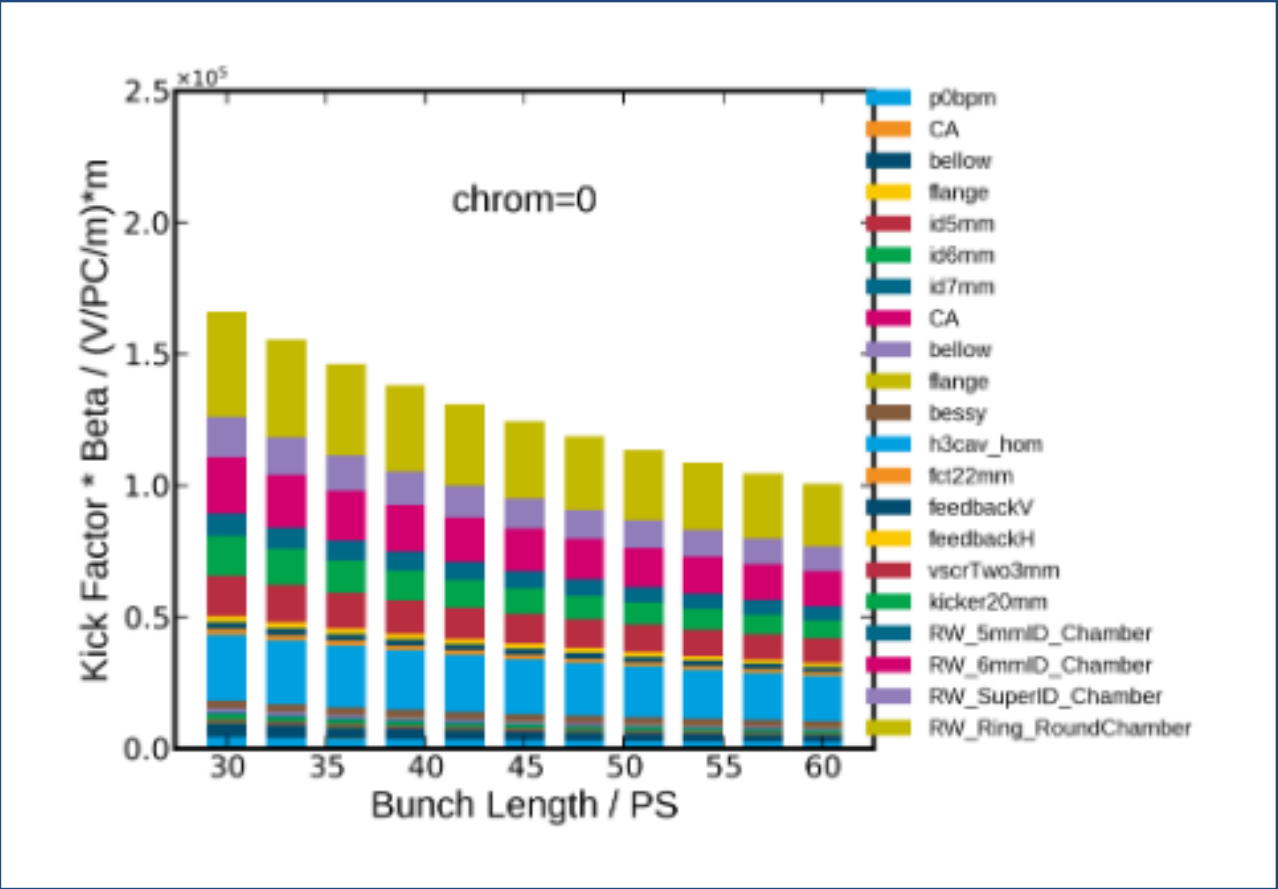


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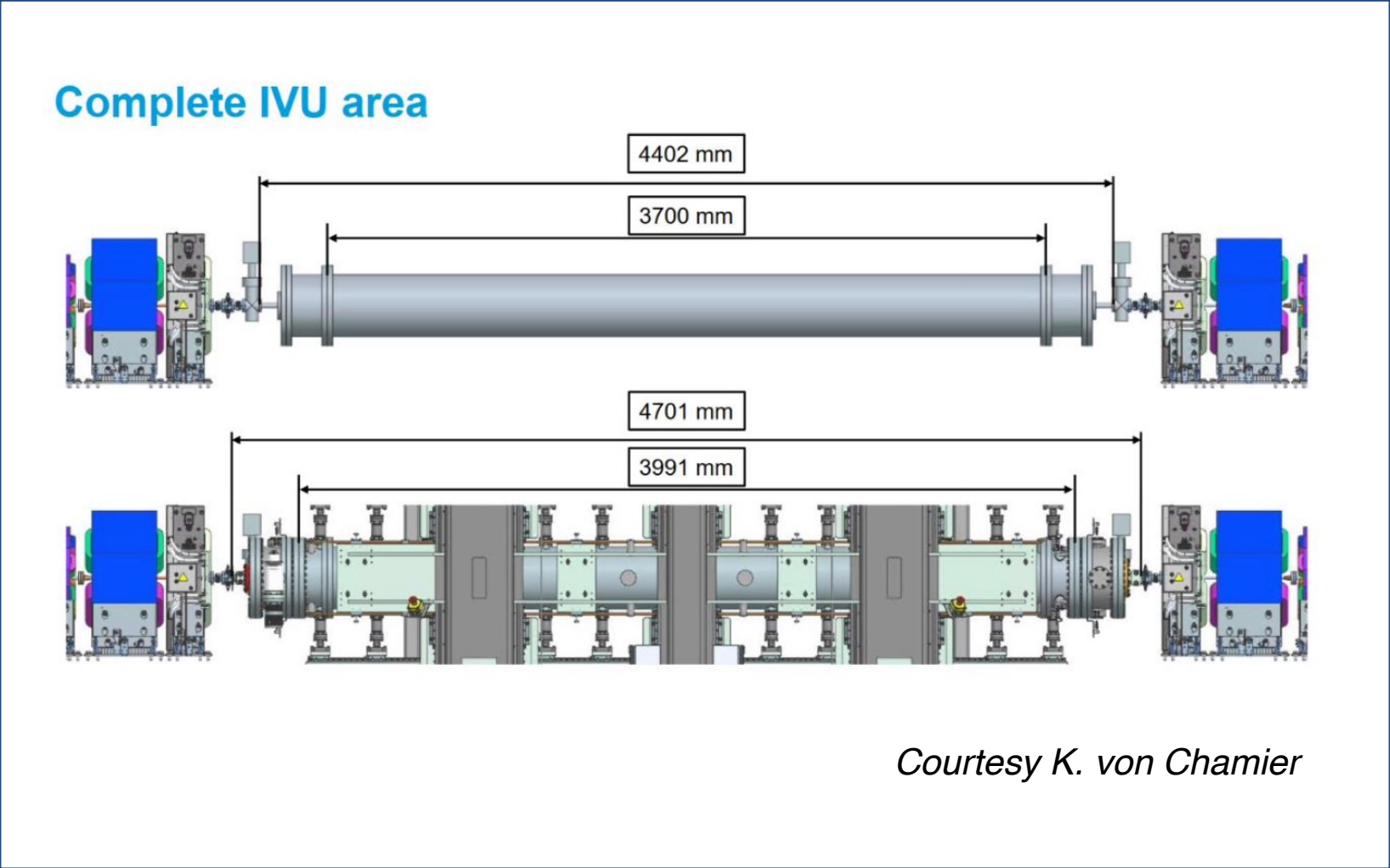
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Courtesy Chao Li



Impedance simulation request to study shorter flexible tapers

Shorter chamber would make it fit both for PETRA III and PETRA IV

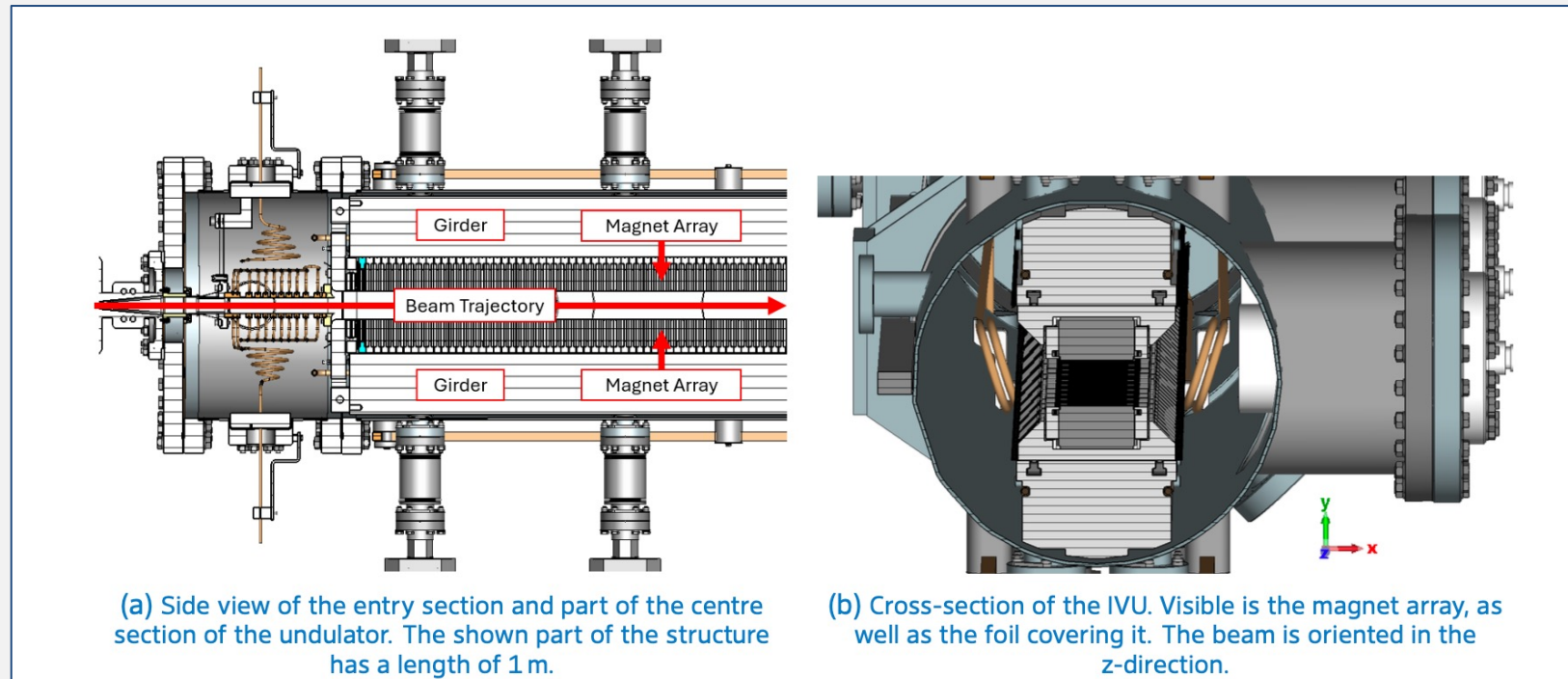


Present structure studied by DESY-TEMF collaboration

Complete IVU assembly studied

Three solvers:

- Wakefield and eigenmode solvers from CST Studio Suite
- In-house finite element impedance solver in the frequency domain

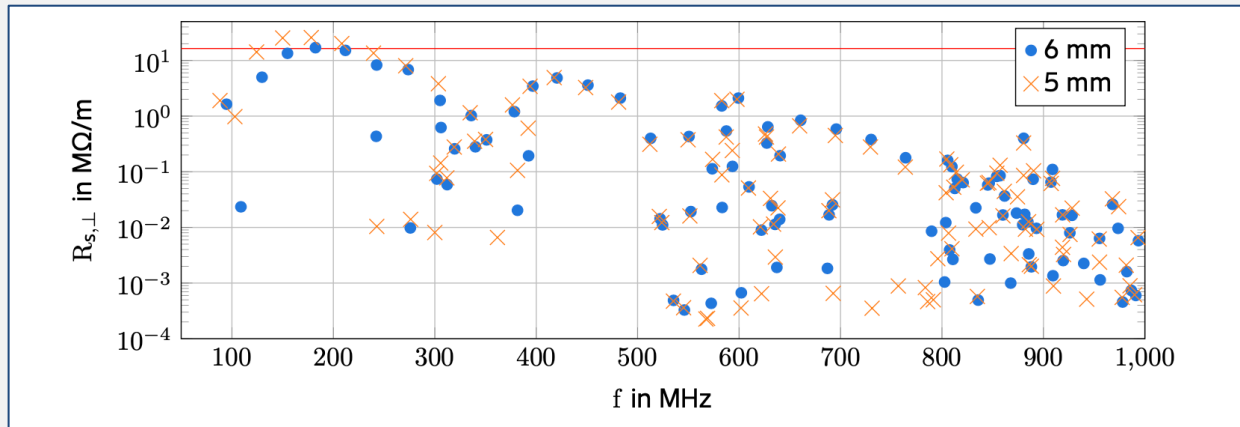


HOMs can be a problem

Found uncompliant HOMs in the present design

Impedance reduction action is recommended

- Suppress HOMs located below 300 MHz
- TEMF produced a report with recommendations: *p4-WP201-0019*



F. Quetcher et al., P4 Rep. p4-WP201-0019 (2025)

The analysis will have to be repeated for the shorter structure

- Discussed and preliminarily agreed up with TEMF
- Simulation pipeline already developed
- Heating of the foil also to be investigated (an issue at MAX-IV)
- Deformation of the flexible taper may enhance the heat load (*P. Chou et al., IPAC'25*)

TEMF is helping DESY to build its future flagship light source

Two most important thrusts are

- R&D of combined-function fast corrector magnets
- Impedance modelling of challenging accelerator components

It is useful to write down the results as technical notes

- Become a part of project knowledge base
- Templates available, DESY team can assist in preparation

