# Ultra Low Emittance Ring challenges

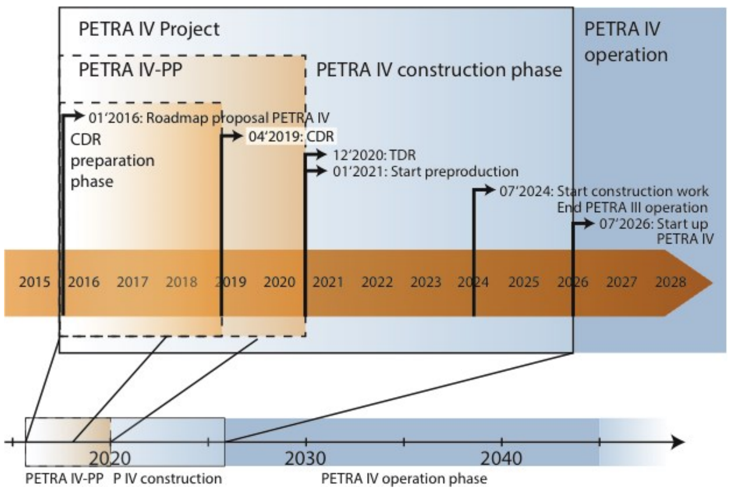
Ilya Agapov (DESY)
KfB-Perspektiven-Workshop Strahlungsquellen
27 April 2018

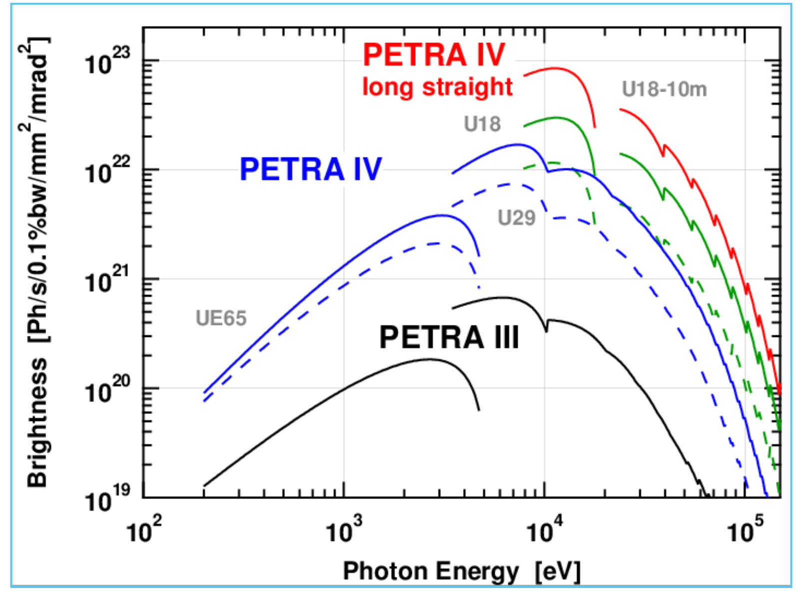
HELMHOLTZ
ASSOCIATION

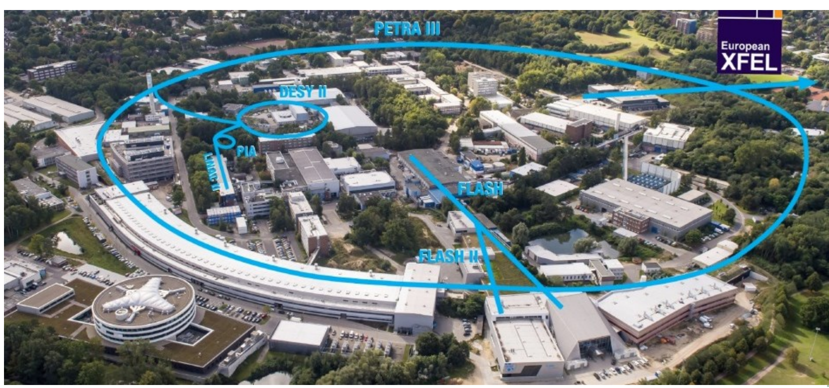
# Motivation and focus of the talk: PETRA IV

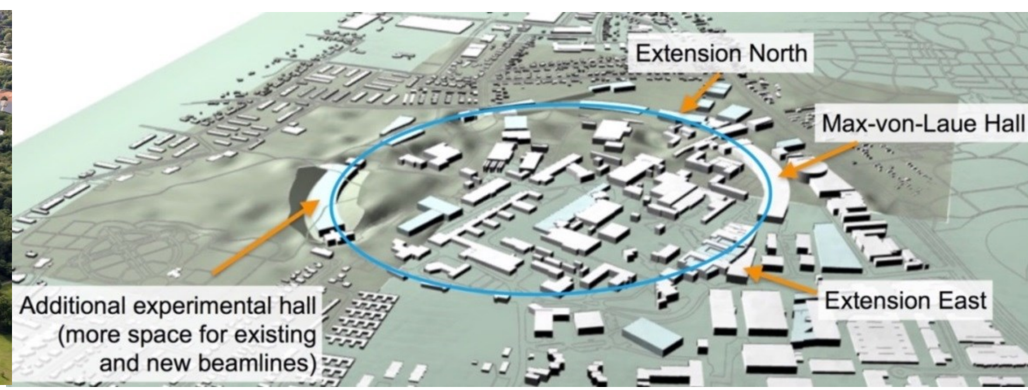
Proposed 10keV (10 pm) diffraction-limited SR source – upgrade of PETRA III

TDR end 2020. Start operation 2026



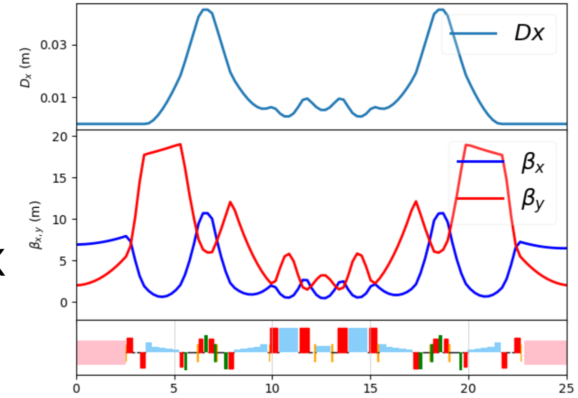



# Challenges

- Beam physics: nonlinear dynamics
- Beam physics: collective effects
- Coherent radiation generation (optional)
- Technical challenges: magnet design
- Technical challenges: fast kickers
- Technical challenges: mechanical stabilization
- Technical challenges: radiation power load
- Technical challenges: automation
- Technical challenges: diagnostics and feedbacks (see P. Kuske's talk yesterday)

# Beam physics: nonlinear dynamics

- DA small – usual situation for MBA rings but especcially prominent for USR due to large C/small dispersion/strong sextupoles

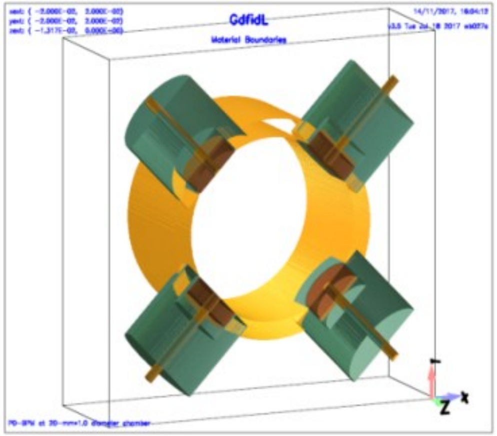



- Many recipes but no simple approach, rely on tracking
  - π, 3π phase advances between strong sextupoles
  - Achromats or 3rd and 4th order for rings like PETRA-IV or PEP-X
  - Possibly local chromaticity correction for large MA
- Perturbative methods (E.g. Lie algebra, resonance driving terms, detuning calculations) help, but beyond 3rd or 4th order theory virtually useless
- MOGA approaches help, but only at the polishing phase and only so far (say factor 2 in DA max)
- Relatively minor modifications to optics can require days/weeks of optimization (on a cluster) to readjust nonlinear characteristics. Is there a faster way to do so?
- Do we have new paradigms in nonlinear dynamics (probably no)? Can we link IOTA & Co. to the real world (probably no)?
- Bright new ideas needed to continue squeezing the optics further

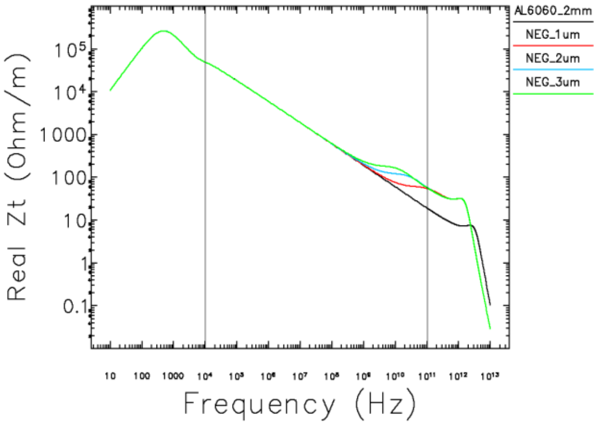
# Beam physics: collective effects

- At PETRA III 2.5 mA/bunch limitation due to impedance
- At PETRA IV – more impedance (~1 MΩ/m), and shorter bunches (due to reduced momentum compaction D/ρ). Current TMCI estimate at 1mA
- High single-bunch current needed for “timing experiments”. Presently we would need to reduce timing mode current to 40-80 mA vs 200 mA brightness
- Can we have fast and reliable simulations of TMCI, head tail, multi-bunch coupling, etc.?
- What are the ways to reduce impedance (smooth geometry, novel coatings)?

BPMs



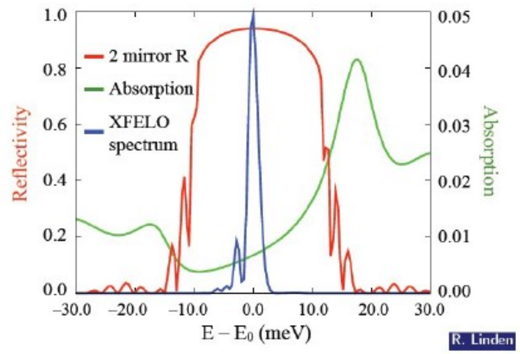

Resistive wall/NEG

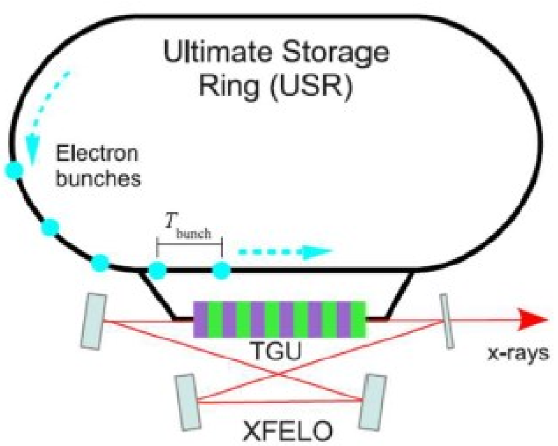


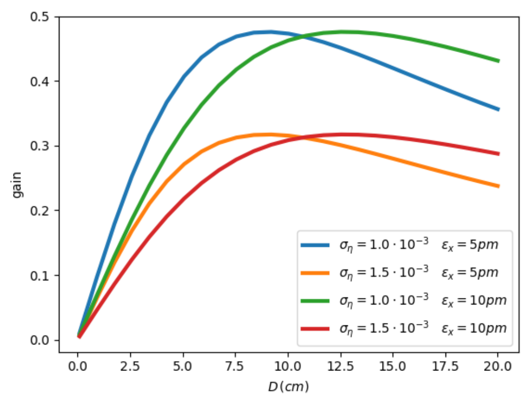
# Coherent schemes

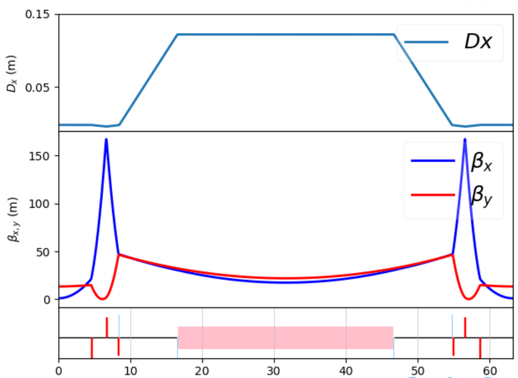
- SSMB, seeding etc, -- not yet feasible at 6 GeV. Feasible for lower-energy rings, see talks of A. Jankowiak, S Khan from yesterday
- Low alpha: at PETRA IV $\alpha \approx 1.5\ 10^{-5}$, 2ps bunches come 'for free' with 500MHz + 1.5GHz 3rd harmonic RF. IBS and impedance will limit possible intensity there
- High gain FEL – no (should work in soft x-ray but not compatible with operation)
- Now considering a bypass XFELO option with TGU
- $10^{26}$ brightness at 14.4 keV (Mössbauer spectroscopy)
- XFELO workshop at DESY Sept. 2019

(including science, CW XFEL)



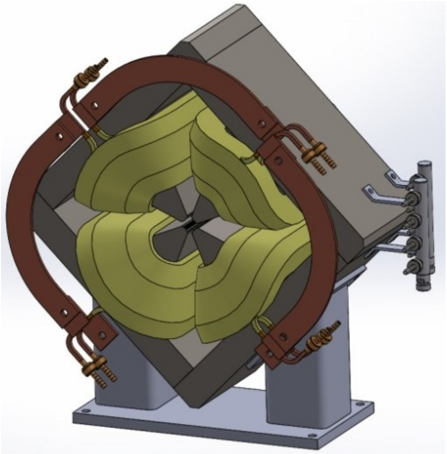






DESY

# Technology: high-gradient magnet design



- Fields in excess of 100 T/m difficult.
- PETRA IV baseline has < 100 T/m, but going up would help make the design compact
- New materials?
- Permanent magnets (not yet)?
- Reduced weight → better stabilization, eigenfrequencies
- For 6 GeV USR-type machines 10 pm optics is probably the limit due to IBS. But we can have say a 10 GeV extra strong-focusing machine with a <10pm emittance to fight IBS/Touschek → need stronger magnets

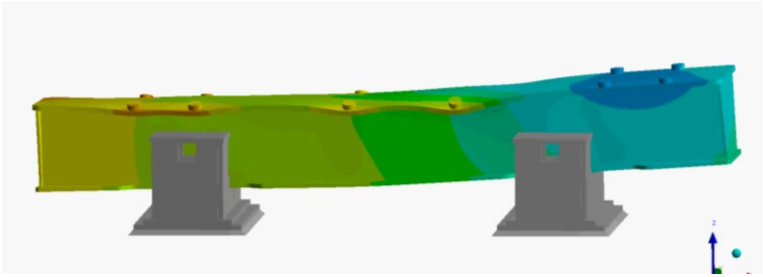
| Parameters | Units | **QHG20** |
|---|---|---|
| **Air gap** | mm | **20** |
| **Field gradient, G** | T/m | **149,7** |
| Field quality at R= 0.6a | | $3{,}7\text{x}10^{-4}$ |
| Core length | mm | 200 |
| Number of turns per coil | | 56 |
| Number of coils | | 4 |
| Nominal current | A | 200 |

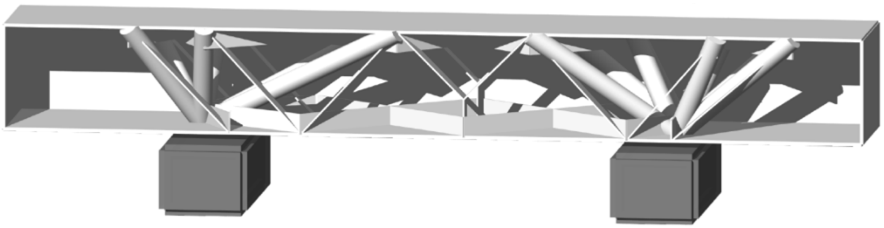
# Technology: fast kickers

- We are pursuing a large DA lattice so that off-axis injection will be possible
- It is however possible that given all the imperfections and jitters only on-axis injection will be possible and we will need to do swap-out
- In that case could live with <4 ns rise time + longer flat top (swap trains) for 2000 bunches
- If <4 ns rise time not possible could (probably) live with gaps in the fill pattern
- Ideally we would like <2 ns rise time + flat top kickers.  Then single bunches could be manipulated in any fill pattern with 500 MHz RF

# Technology: mechanical stabilization

- USR optics has high sensitivity and mechanical stability has increased importance
- Generally can be solved by active measures (feedback), however this is to be avoided when possible with passive stabilization
- Tolerance specs for PETRA IV in progress, present target 30 μm alignment on girder
- Tunnel temperature stabilization important
- R&D into lightweight girders for PETRA IV (collaboration with AWI)





# Technology: power load

- Current 6 GeV machines run at 100-200 mA.
- The limitation is due to the power load on front-end components
- In an upgrade from 10pm down to 0 pm we could win maybe a factor of 2 in brightness (~10 keV, typical 5 m ID)
- Given 1mA/bunch instability limit and a 500 MHz RF we could have 4A in PETRA leading to another factor 20 in brightness. In the distant future, why not?

# Technology: vacuum

- For PETRA IV the beam pipe radius will not be a severe limitation from the vacuum perspective (according to simulations).
- Currently r=10mm due to beam stay clear and impedance
- Uncertainly in impedance of NEG-coated chamber. Measurements underway.
- Self-activation studies underway to try avoiding in-situ activation
- Otherwise the vacuum system not a major challenge

# Technology: automation

- Stability and availability of SR sources is good
- However the next generation (PETRA IV) will have a sensitivity of the optics
- 1 µm rms machine drifts will already have significant impact on the tune
- Commissioning/first turn/accumulation only possible with automatic steering tools
- Power supply ripple/ orbit and optics manipulations will have an increased chance of producing beam loss
- More intelligent controls and feedbacks  will be required
- Better integration between experimental and machine controls (photon BPMs for accelerator alignment, bunch-by-bunch data from machine to experiments)

# The end