## PETRA III Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circumference (m)</td>
<td>2304</td>
</tr>
<tr>
<td>Energy (GeV)</td>
<td>6</td>
</tr>
<tr>
<td>$\varepsilon_y$ (nm rad)</td>
<td>1</td>
</tr>
<tr>
<td>$\varepsilon_y$ (pm rad)</td>
<td>10</td>
</tr>
<tr>
<td>Current (mA)</td>
<td>100 (200)</td>
</tr>
<tr>
<td># bunches</td>
<td>40 / 960</td>
</tr>
<tr>
<td>Straight sections (*)</td>
<td>9</td>
</tr>
<tr>
<td>Undulators</td>
<td>14</td>
</tr>
<tr>
<td>Undulator length (m)</td>
<td>2, 5, 10 (20)</td>
</tr>
</tbody>
</table>

(*) limited budget
New experimental Hall

Arches refurbished but FOFO lattice kept
8 complete DBA cells
Cell length 23 m
High beta: $\beta_x = 20$ m $\beta_y = 4$ m
Low beta : $\beta_x = 1.4$ m $\beta_y = 4$ m

No sextupoles in new octant
Because of small Dx!!

Straights can house either
5m long IDs
or
2 2m long IDs (canted undulators)
angle between canted IDs: 5mrad

Number of 2m IDs: 10
Number of 5m IDs: 3
Number of 10m ID: 1
Total : 14
Damping Wiggler Sections

Collaboration with BINP

Damping wigglers

- Number 20
- \( L_{\text{wiggler}} = 4 \text{ m} \)
- \( B = 1.5 \text{ T} \)
- \( \lambda = 0.2 \text{ m} \)
- \( h = 0.025 \text{ m} \)
- \( \text{Prad@200 mA} = 2 \times 440 \text{ kW} \)
- critical energy 36 keV

\( \varepsilon_x : 4.5 \rightarrow 1 \text{ nmrad} \)

Machine can be operated w/o wigglers

Short absorbers \( l = 0.8 \text{ m} \)

\( P \approx 25 \text{ kW} \)
Complete Optics

Machine Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qx</td>
<td>37.1</td>
</tr>
<tr>
<td>Qy</td>
<td>33.26</td>
</tr>
<tr>
<td>ξx / ξy</td>
<td>-41 / -40</td>
</tr>
<tr>
<td>α</td>
<td>1.2 × 10⁻³</td>
</tr>
<tr>
<td>Qs</td>
<td>0.05</td>
</tr>
<tr>
<td>σs</td>
<td>13 mm</td>
</tr>
<tr>
<td>σE</td>
<td>1.3 × 10⁻³</td>
</tr>
</tbody>
</table>
Stored beam

Beam was stored on April 13 (one bunch with 20 µA i.e. about $10^9$ e+)
RF – phase right and orbit empirically corrected in the new octant
Summary of Commissioning Results with all wigglers installed
Optics correction

Result after 2 Iterations  \((\Delta k/k)_{\text{max}} \approx 2\%\)

Horizontal \(\Delta \beta_x / \beta_{xrms} \approx 3\%\)

Vertical \(\Delta \beta_y / \beta_{yrms} \approx 2\%\)

Details see THPD085
Dispersion

Spurious vertical dispersion in Damping wiggler sections ≈ 1mm

Details see THPD086
Emittance Measurement

Emittance measured with dedicated beam line
Details see MOPD089

Calculated horizontal width: $\sigma_x \approx 44 \, \mu m$

Calculated emittance $\epsilon_x \approx 0.9 \, \text{nm rad}$

Summary

Measured emittances (nmrad)
$0.9 \leq \epsilon_x \leq 1.1$
$\epsilon_y \leq 0.02$

Expected emittance (no ID's)
$\epsilon_x \approx 1.06 \, \text{nm rad}$
Off- and on-momentum Aperture
Acceptance

Calculated Acceptance:
Ax = 35.0 mm mrad
Ay = 2.2 mm mrad

Measured Acceptance:
Ax = 27.0 mm mrad
Ay = 1.2 mm mrad

Close to 100 % Injektion efficiency requires Ax = 20 mm mrad and Ay= 0.8 mm mrad
Detuning with Amplitude

\[ Q_y = Q_{yy} \cdot J_y + Q_{yx} \cdot J_x \]

Calculated detuning; basically dominated by Sextupoles (wigglers included!)

Details see WEPEA016, WEPEA017
Momentum acceptance

Touschek lifetime vs. Uhf

Calculated Touschek Lifetime (MAD)
\( \varepsilon_x = 0.9 \text{ nmrad} \)
\( \varepsilon_y = 13 \text{ pmrad} \)

Calculated acceptance
About 1.7 %

Estimated momentum acceptance about 1.6 %

Measured lifetime
\( I_b = 1 \text{ mA} \)

\( \tau (\text{h}) \)

Uhf (MV)

\( \varepsilon \)
Orbit Stability
Stability Requirements

\[ \varepsilon_x = 1 \text{ nm rad}; \quad \kappa = 0.01 \]

Stability requirements:
- horizontal: 3.0 µm
- vertical: 0.6 µm

\[ \sigma_x \approx 30 \mu \text{m} \quad \sigma_y \approx 6 \mu \text{m} \]

\[ \sigma_x \approx 140 \mu \text{m} \quad \sigma_y \approx 6 \mu \text{m} \]
Orbit Stabilization

> **Passive measures**
  - Foundation of the exp. hall
  - Careful design of girders
  - Air-conditioning of the new tunnel: ± 0.1°!
  - ...

> **Top-up**
  - Frequent filling of the machine to assure thermal equilibrium of components

> **Active measures**
  - Orbit-Feedback
Top-up Operation

Automatic procedure
Keeps current constant on a 0.1 % - 1.0 % level

For example:
70 bunch filling
(At present standard filling for users)
Orbit Feedback

> PI controller & suppression n * 50 Hz

> Standard BPM electronics
  but special output port with higher data rate

> central processing via star structure
  positive feedback effect from DC up to 600 Hz

> Air coils
  $\Theta_{\text{max}} \approx 35 \mu$rad
  # new part: 30 hor. & ver.
  # old part: 11 hor. & ver.
  mounted on stainless steel chambers
Horizontal Feedback (short term stability)

Quad-supports of old octants

\[ \sigma \] / 10

\[ \sigma(f) = \sqrt{\int_{f}^{f_{\text{max}}} S(f) df} \]

- 50 Hz!
- 100 Hz!
- 600 Hz!
Vertikal Feedback (short term stability)

![Graphs showing vertical PSD vs. f(Hz)]

- Integrated vertical PSD vs. f(Hz)
  - 50 Hz!
  - \( \sigma / 10 \)
  - 100 Hz!
  - 600 Hz!
Long term stability

Stability of position and angle at PU7 (high beta cell)

<table>
<thead>
<tr>
<th>Stability requirements</th>
<th>Hor.</th>
<th>Ver.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position (µm)</td>
<td>14</td>
<td>0.60</td>
</tr>
<tr>
<td>Angle (µrad)</td>
<td>6</td>
<td>0.24</td>
</tr>
</tbody>
</table>

36 h
Current limitations
Current limitations
single bunch (TMCI)

Design: 2.5 mA (100 mA in 40 bunches)

Measured coherent tune shift vs. current

\[
\frac{\Delta f_x}{\Delta I} \approx -0.15 \frac{\text{kHz}}{\text{mA}} \quad \frac{\Delta f_y}{\Delta I} \approx -1 \frac{\text{kHz}}{\text{mA}}
\]

Determine kick parameters:

\[
\frac{d}{d I} f = \frac{\langle \beta \rangle}{4\pi E/e} k_\perp
\]

Kick parameter (V/pC/m) horizontal  vertical
measured : 490   3420
calculated : 750   2600

Limit for 2.5 mA : 4800 V/pC/m

Single bunch intensities of up to 2.9 mA could be stored;
Deliberately limited at this current
In order not to damage BPM electronics
Current limitations
coupled bunch instabilities

Coupled bunch instabilities in PETRA II:

<table>
<thead>
<tr>
<th></th>
<th>longitudinal</th>
<th>horizontal</th>
<th>vertical</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_{\text{thres}}$ (mA)</td>
<td>7</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>$1/\tau$ (Hz)</td>
<td>35</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>$Z_{\text{eff}}$</td>
<td>3.6 MΩ</td>
<td>45 MΩ/ m</td>
<td>54 MΩ/ m</td>
</tr>
</tbody>
</table>

PETRA III: 12 seven cell cavities which large par. shunt impedance

→ powerful broadband (BW≥ 60MHz) feedback neccessary
Current limitations

coupled bunch

Design: 100 mA
achieved
70 bunches : 96 mA
240 bunches: 98 mA
960 bunches: 89 mA

Transverse broadband FB is working well

Longitudinal FB: at least 5 out of 8 broadband amplifiers damaged October ‘09!
Probably amplifiers were destroyed during switch on!

Successful tests with four repaired amplifiers in 2010
Vertical blow up  (Operation with e+!)

50 mA in 70 bunches

63 mA in 70 bunches
Vertical blow up (Operation with e+!)

70 bunches ($\Delta t_B=96\text{ns}$)
- $I = 55 \text{ mA}$
- $f_y = 39 \text{ kHz}$

Remedy for 70 bunches:
- $\xi \rightarrow +5$
- Increase Gain of vertical feedback by a factor of 4

210 bunches ($\Delta t_B=32\text{ns}$)
- $I = 74 \text{ mA}$
- $f_y = 39 \text{ kHz}$

640 bunches ($\Delta t_B=8\text{ns}$)
- $I = 64 \text{ mA}$
- $f_x = 15 \text{ kHz}$
- $f_y = 39 \text{ kHz}$

$e^{-}$ cloud?
ID’s
Undulator Installation

Undulator PU 10

Undulator PU 4
APPLE II

Undulator PU 8 & 9

10 of 14 Undulators have been installed
<table>
<thead>
<tr>
<th></th>
<th>U29_5m</th>
<th>U29</th>
<th>U32</th>
<th>U23</th>
<th>UE65 *</th>
<th>U19</th>
<th>U32_10m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum magnetic gap [mm]</td>
<td>9.5</td>
<td>9.5</td>
<td>9.5</td>
<td>9.5</td>
<td>11.0</td>
<td>7.0</td>
<td>12.5</td>
</tr>
<tr>
<td>Period length (\lambda_U) [mm]</td>
<td>29</td>
<td>29</td>
<td>31.4</td>
<td>23</td>
<td>65.6</td>
<td>19</td>
<td>31.4</td>
</tr>
<tr>
<td>Length (L) [m]</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Periods</td>
<td>169</td>
<td>66</td>
<td>60</td>
<td>84</td>
<td>72</td>
<td>204</td>
<td>2x 156</td>
</tr>
<tr>
<td>Peak field (B_0) [T]</td>
<td>0.81</td>
<td>0.81</td>
<td>0.91</td>
<td>0.61</td>
<td>1.03</td>
<td>0.7</td>
<td>0.68</td>
</tr>
<tr>
<td>Deflection parameter (K_{max})</td>
<td>2.2</td>
<td>2.2</td>
<td>2.7</td>
<td>1.3</td>
<td>6.3</td>
<td>1.24</td>
<td>2.0</td>
</tr>
<tr>
<td>1st Harmonic (E_1) [keV]</td>
<td>3.5</td>
<td>3.5</td>
<td>2.4</td>
<td>8.0</td>
<td>0.3</td>
<td>10.2</td>
<td>3.6</td>
</tr>
<tr>
<td>Total power (P_{tot}) [kW]</td>
<td>7.5</td>
<td>3.0</td>
<td>3.8</td>
<td>1.7</td>
<td>11.8</td>
<td>4.5</td>
<td>10.7</td>
</tr>
<tr>
<td>On-axis power density [kW/mrad^2]</td>
<td>190</td>
<td>76</td>
<td>80</td>
<td>71</td>
<td>0.17</td>
<td>200</td>
<td>300</td>
</tr>
<tr>
<td>Power in 1x1mm^2 at 40m [W]</td>
<td>119</td>
<td>47</td>
<td>49</td>
<td>44</td>
<td>0.1</td>
<td>122</td>
<td>185</td>
</tr>
<tr>
<td>High-(\beta) source (10keV)</td>
<td>size : 140 x 5.6 (\mu)m^2</td>
<td>divergence : 7.9 x 4.1 (\mu)rad^2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-(\beta) source (10keV)</td>
<td>size : 36 x 6.1 (\mu)m^2</td>
<td>divergence : 28 x 4.0 (\mu)rad^2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Beam-line Status 2009

First beam on diffractometer
September 27

Start of beamline commissioning
July 17

First friendly users
October 5

<table>
<thead>
<tr>
<th>Beam line</th>
<th>Beam hours ’09</th>
</tr>
</thead>
<tbody>
<tr>
<td>P08</td>
<td>1000</td>
</tr>
<tr>
<td>P09</td>
<td>1200</td>
</tr>
<tr>
<td>P10</td>
<td>200</td>
</tr>
</tbody>
</table>
Impact of IDs on tune /optics

PU 10

Undulator gap

$\Delta Q_y \approx 0.0015$

Optics correction for planar Undulators not foreseen!

In case of the Apple II and IVU we have to see …
## Beam-line status  March 2010

<table>
<thead>
<tr>
<th>Number</th>
<th>ID Type</th>
<th>Energy range (keV)</th>
<th>Status 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>First half</td>
<td>Second half</td>
</tr>
<tr>
<td>P01</td>
<td>10 m U32 (pres. 2m)</td>
<td>5 – 40</td>
<td>commissioning</td>
</tr>
<tr>
<td>P02</td>
<td>2 m U23</td>
<td>20 – 100</td>
<td>commissioning</td>
</tr>
<tr>
<td>P03</td>
<td>2 m U29</td>
<td>8 – 25</td>
<td>commissioning</td>
</tr>
<tr>
<td>P04</td>
<td>5 m UE65 (APPLE)</td>
<td>0.2 – 3.0</td>
<td>commissioning</td>
</tr>
<tr>
<td>P05</td>
<td>2 m U29</td>
<td>8 – 50</td>
<td>commissioning</td>
</tr>
<tr>
<td>P06</td>
<td>2 m U32</td>
<td>2.4 – 50</td>
<td>commissioning</td>
</tr>
<tr>
<td>P07</td>
<td>4 m U19 (IV) (pres. 2m)</td>
<td>50 – 300</td>
<td>commissioning</td>
</tr>
<tr>
<td>P08</td>
<td>2 m U29</td>
<td>5.4 – 30</td>
<td>Friendly users</td>
</tr>
<tr>
<td>P09</td>
<td>2 m U32</td>
<td>2.4 – 50</td>
<td>Friendly users</td>
</tr>
<tr>
<td>P10</td>
<td>5 m U29</td>
<td>4 – 25</td>
<td>Friendly users</td>
</tr>
<tr>
<td>P11</td>
<td>2 m U32</td>
<td>8 – 35</td>
<td>commissioning</td>
</tr>
<tr>
<td>P12</td>
<td>2 m U29</td>
<td>4 – 20</td>
<td>commissioning</td>
</tr>
<tr>
<td>P13</td>
<td>2 m U29</td>
<td>5 – 35</td>
<td>commissioning</td>
</tr>
<tr>
<td>P14</td>
<td>2 m U29</td>
<td>5 – 35</td>
<td>commissioning</td>
</tr>
</tbody>
</table>

### Notes:
- **High $\beta_x$**
- **Low $\beta_x$**
**Summary**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Design</th>
<th>Achieved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (GeV)</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>$\varepsilon_x$ (nm rad)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>$\varepsilon_y$ (pm rad)</td>
<td>10</td>
<td>&lt; 20</td>
</tr>
<tr>
<td>Current (mA)</td>
<td>100</td>
<td>98</td>
</tr>
<tr>
<td># undulators</td>
<td>14</td>
<td>10</td>
</tr>
</tbody>
</table>

Regular user operation (4.5 d / week) with up to 60 mA works fine

**Orbit stability:**
- short term stability okay
- long term stability looks promising but more work required

**Current:**
- more work required to raise current
  and in particular to understand the vertical blow-up
Thank you for your attention