A cold neutron beam facility for particle physics at the ESS

G. Konrad, SMI & TU Wien, Austria
on behalf of the ANNI collaboration
**Proton accelerator**

Proton kinetic energy: 2 GeV  
Average macro-pulse current: 62.5 mA

**Tungsten target**

Neutron production rate: $10^{18}$ n/s  
Beam footprint on target: $6 \times 18 \text{ cm}^2$
Advantages of the

• Available without loss of statistics:
  → Spatial localization of neutron pulse
  → Time localization of neutron pulse
  → Separation by neutron wavelength
  → Application of time-dependent neutron optics

• First pulsed source with higher time-averaged flux than the ILL
  ➔ We want an instrument there
Fundamental & Particle physics

- **Neutron beta decay** with $10^{-4}$ accuracy
  - Broad-band probe for BSM physics, at mass scales of 1 – 100 TeV
- **Absolute measurements** in **hadronic weak interaction**
  - Systematic experimental study of QCD in non-perturbative regime
- **New approaches to electromagnetic properties** of the neutron
  - Beam methods for EDM and charge as probes for matter formation in the Universe and unification of forces

More science very welcome
Design considerations

Maximum statistics at minimum systematics for versatile user instrumentation

→ Fully exploit pulse structure
→ Assure low background
→ Optimize for beam quality
→ Include polarization
→ Include versatile chopper system
→ Provide flexibility
→ Include ep/n separator

→ Access full high-intensity part of spectrum without frame overlap
→ Limit dilution of neutron pulse

→ Short instrument
14 Hz ESS, 8 Å → maximum length: 34 m
Instrument layout

Moderator  Guide  Beam preparation  Experimental area  Extension area

34 m  12 m  20 m

August 24, 2017  ANNI @ ESS, SPS-ÖPG2017, Genève  G. Konrad, SMI & TU Wien
Guide design

- Go out of sight twice within short distance
- Optimize for flux and polarization
  - S-shaped geometry
  - Curvature in vertical plane (flat moderator!)
  - Benders for maximum flux
  - Polarizing option for second bender
  - Natural way to implement X-SM geometry, beam remains horizontal

*Details optimized by McStas simulations for reference experiments*
Polarization options

1. Moderate polarization (98%) at highest intensity
   Bender 2 replaced by Polarizing bender

2. Highest polarization (>99.9%)
   Polarizing bender + bender in beam preparation area in X-SM geometry

3. Polarization with analytic wavelength dependence
   $^3$He spin filter in beam preparation area
Chopper modes

1. Full intensity: Choppers off
2. Max. intensity w/o frame overlap: FOCs
3. Time localization: 
PDC2 large opening + FOCs
4. **Monochromatic**: PDCs small opening @ 70 Hz + PSC + FOCs
5. Spatial localization: PDCs small opening @ 70 Hz *or* pulse multiplication + FOCs

*Example:*
Resolution at 8.9 Å: 0.55 Å (FWHM)
ep/n separator as integral option

- Available to all users
- Fully optimized for ESS
- Two detectors for improved systematics (stability monitoring, backscattering)
- Profits from experience with PERC

*Example:*
Maximize statistics and information on systematics by pulse multiplication ($f_{\text{ESS}} = 14$ Hz)
## Expected performance

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capture flux full spectrum</td>
<td>$5.4 \cdot 10^{10} \text{ n/(cm}^2\text{s)}$ at guide exit</td>
</tr>
<tr>
<td></td>
<td>$1.8 \cdot 10^{10} \text{ n/(cm}^2\text{s)}$ at start of experimental area</td>
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<tr>
<td>Capture flux 2—8 Å (FOCs)</td>
<td>$4.0 \cdot 10^{10} \text{ n/(cm}^2\text{s)}$ at guide exit</td>
</tr>
<tr>
<td></td>
<td>$1.4 \cdot 10^{10} \text{ n/(cm}^2\text{s)}$ at start of experimental area</td>
</tr>
<tr>
<td>Particle flux @ 8.9 Å</td>
<td>$5.8 \cdot 10^{8} \text{ / (cm}^2\text{sÅ)}$ at start of experimental area (with additional guide in beam definition area)</td>
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<tr>
<td>Divergence distribution FWHM</td>
<td>42 mrad horizontal</td>
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<tr>
<td></td>
<td>22 mrad vertical</td>
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<tr>
<td>Instantaneous bandwidth</td>
<td>0.43 Å</td>
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<tr>
<td>Experiment</td>
<td>Facility</td>
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<td>---------------</td>
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<tr>
<td>NPDGamma</td>
<td>FnPB (SNS)</td>
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<tr>
<td>PERC</td>
<td>MEPHISTO (FRM II)</td>
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<td>PERKEO III</td>
<td>PF1B (ILL)</td>
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<td>aSPECT</td>
<td>PF1B (ILL)</td>
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<tr>
<td>BeamEDM</td>
<td>PF1B (ILL)</td>
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World leading from 1 MW ESS power
Status and Outlook

• Instrument proposal submitted in 2015, strongly recommended by STAP, but low priority in SAC
• ESS: 16 instruments selected (all scattering), to be build from construction budget

• Strategy meeting: Fundamental physics should be part of ESS
• ESS: 6 more public instruments to be selected in 2019 & 2021 (tbd), to be build from initial operational budget

→ Proposed timeline

<table>
<thead>
<tr>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
<th>2025</th>
<th>2026</th>
<th>2027</th>
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<tbody>
<tr>
<td>Proposal round</td>
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<td>Construction</td>
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<td>Hot commissioning</td>
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<td>User program</td>
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ANNI Partners

ANNI Collaboration
• H. Abele, TU Wien, Austria
• G. Konrad, TU Wien & SMI Wien, Austria
• B. Märkisch, TU München, Germany
• F. Piegsa, Universität Bern, Switzerland
• U. Schmidt, Universität Heidelberg, Germany
• T. Soldner, ILL Grenoble, France
• C. Theroine, ESS Lund, Sweden & TU München, Germany

+ 2 Letters of Intent
• K. Bodek, University Kraków, Poland: BRAND
• C. Crawford, University of Kentucky, US: NPDGamma

New partners very welcome
Summary

• Pulsed beams extremely useful for particle physics
  → Separation by wavelength
  → Time and spatial localization of pulse
  → Cleaner systematics

• ESS has ideal time structure & brightness

• Full beamline design and simulated performances
  → ANNI will outperform all existing cold beam lines for particle physics,
    by 1 – 2 orders of magnitude

• Need joint effort from community for realization
Thank you for your attention!