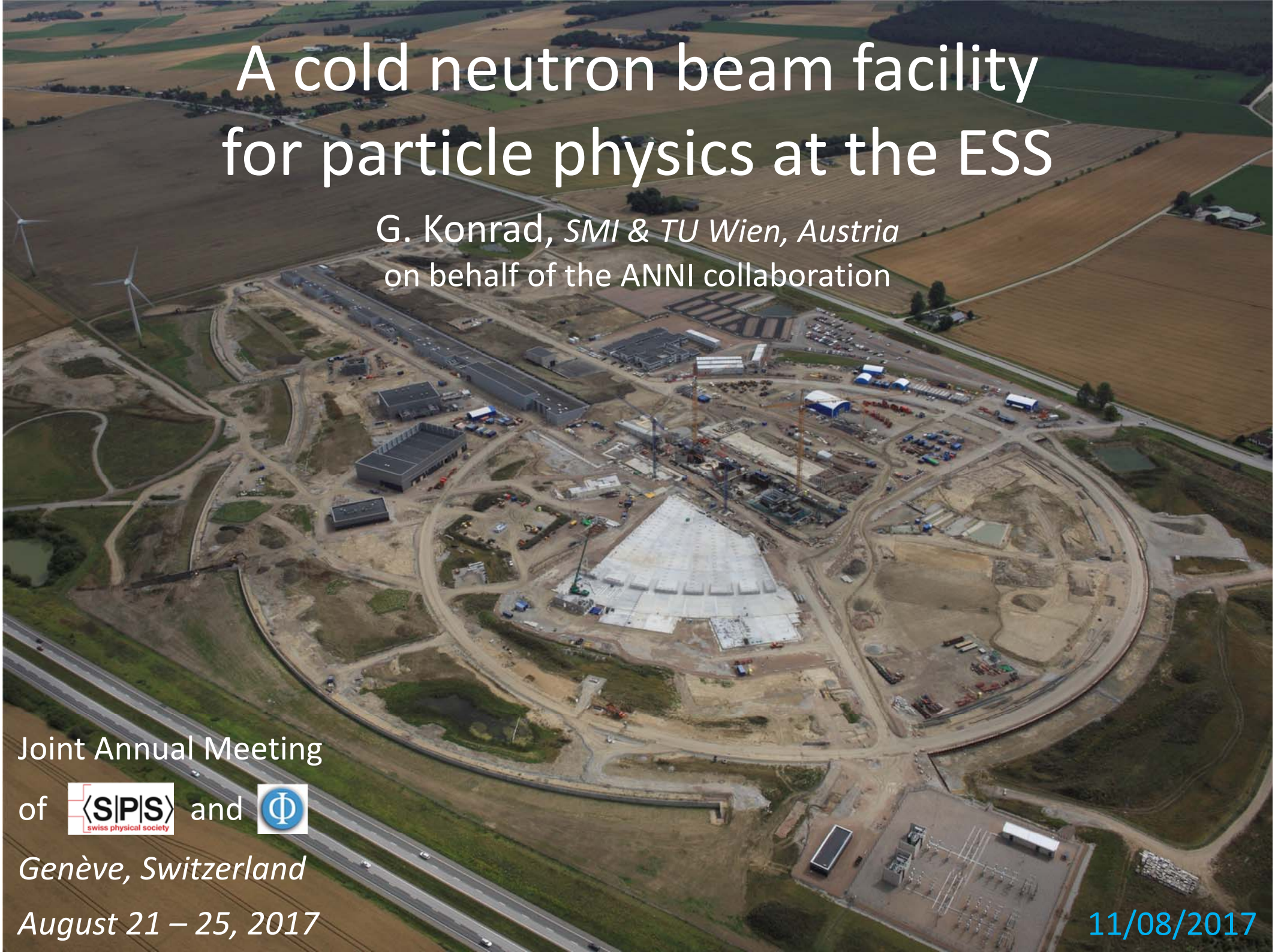
A cold neutron beam facility for particle physics at the ESS

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



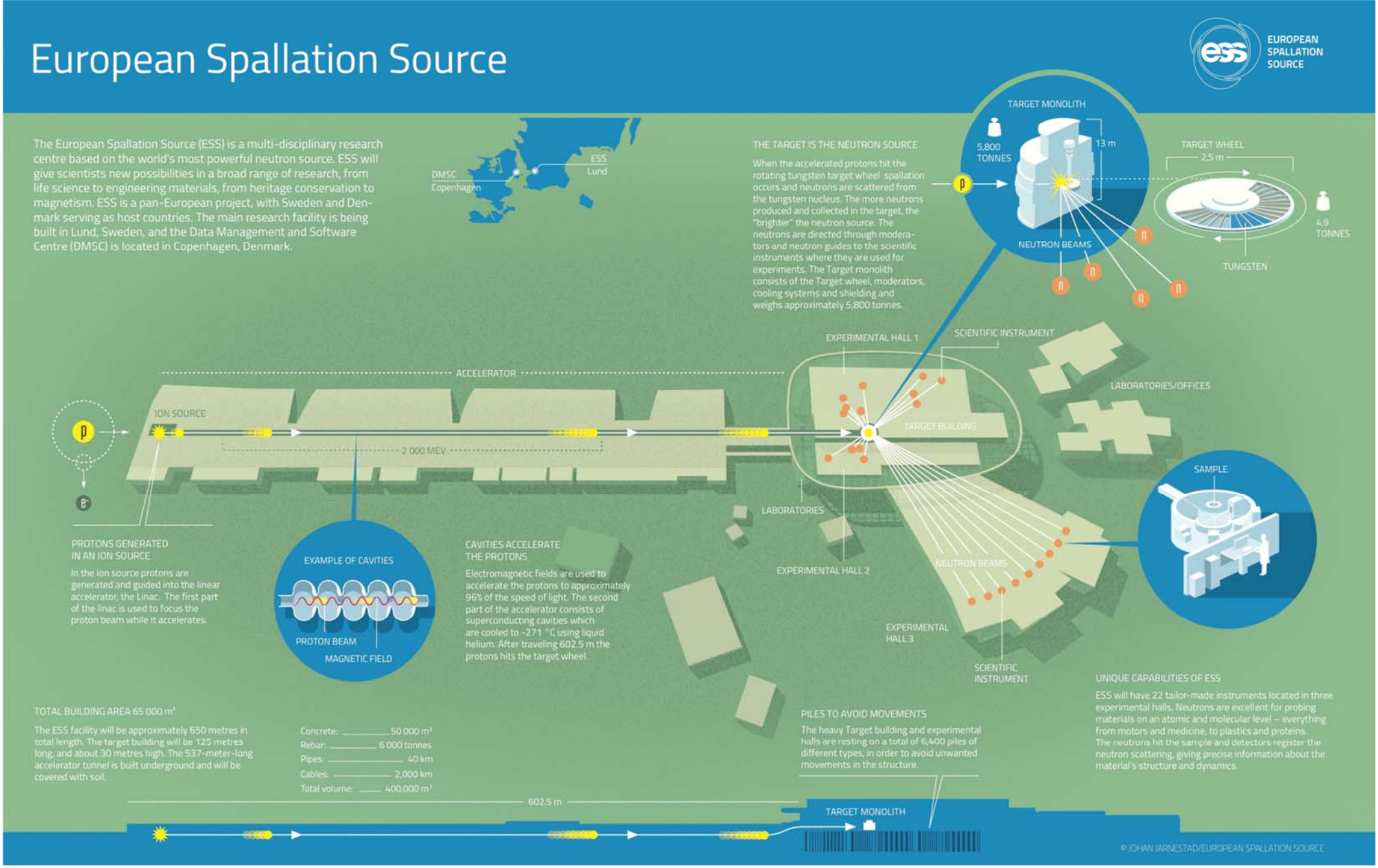
Joint Annual Meeting

of ⟨S|P|S⟩ swiss physical society and Φ

Genève, Switzerland

August 21 – 25, 2017

11/08/2017



Proton accelerator

Proton kinetic energy: 2 GeV

Average macro-pulse current: 62.5 mA

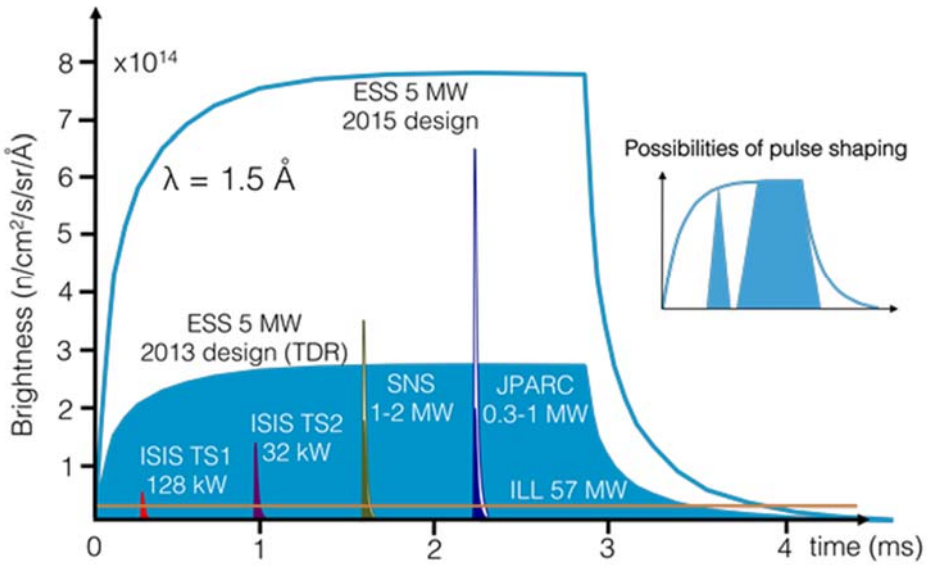
Tungsten target

Neutron production rate: 10^{18} n/s

Beam footprint on target: 6 x 18 cm²

Advantages of the EUROPEAN SPALLATION SOURCE

- 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

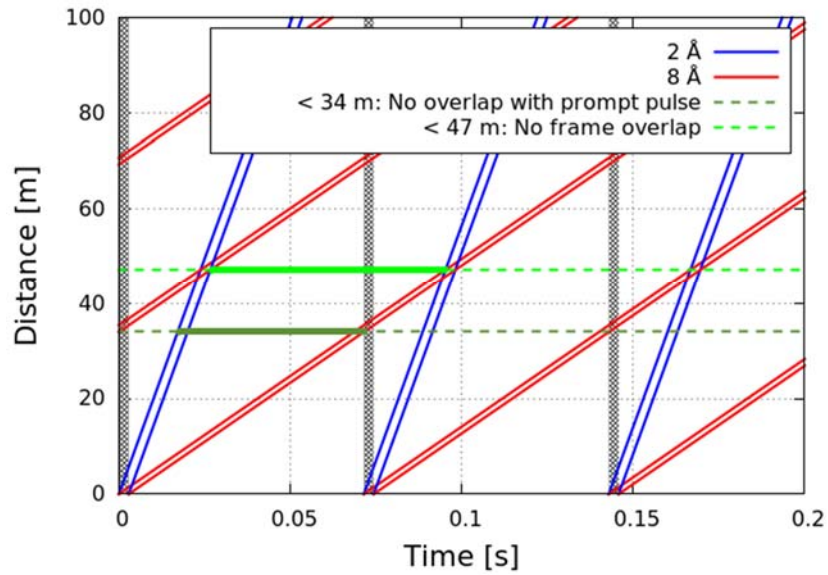
→ Include versatile chopper system

→ Provide flexibility

→ Include ep/n separator

→ Access full high-intensity part of spectrum without frame overlap

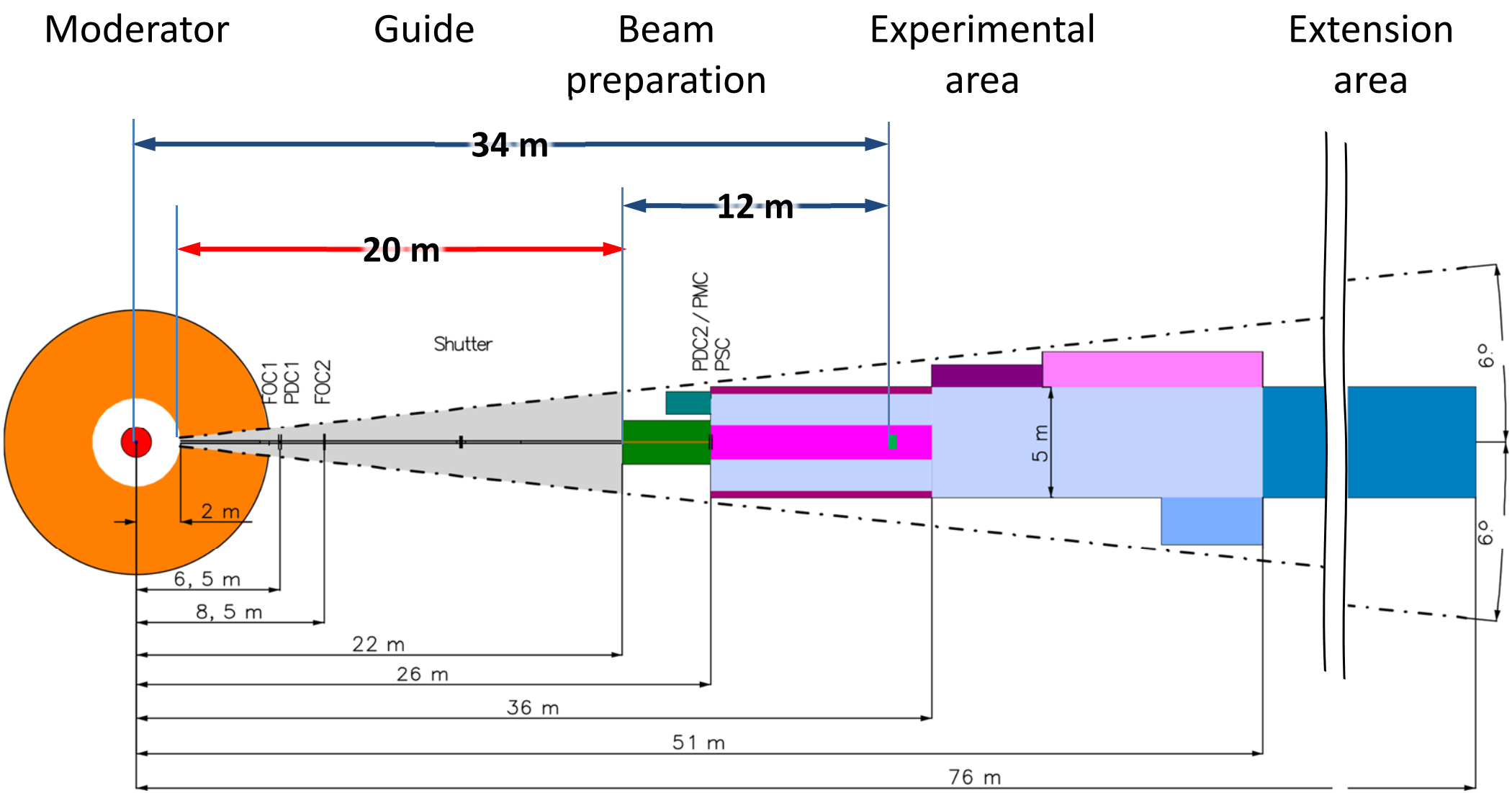
→ Limit dilution of neutron pulse



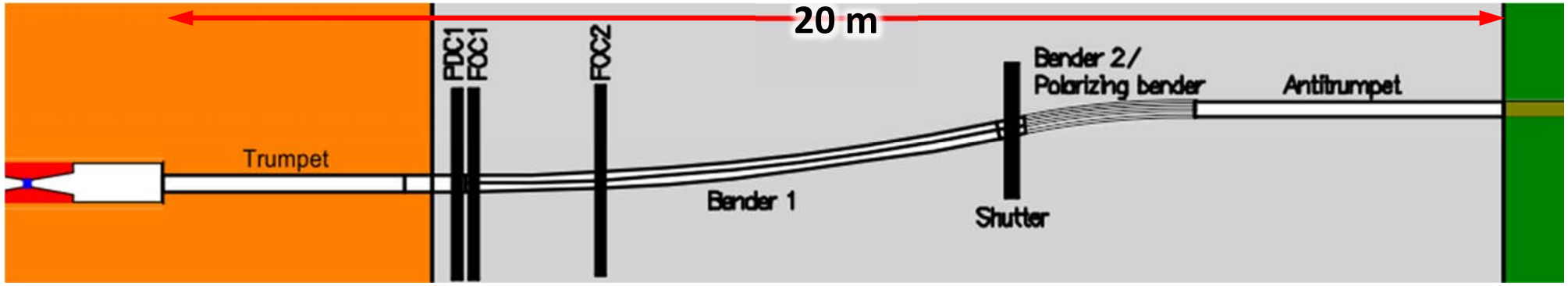
➔ Short instrument

14 Hz ESS, 8 Å → maximum length: 34 m

Instrument layout



Guide design



- Go out of sight twice within short distance
- Optimize for flux and polarization

→ S-shaped geometry

→ Curvature in vertical plane (flat moderator!)

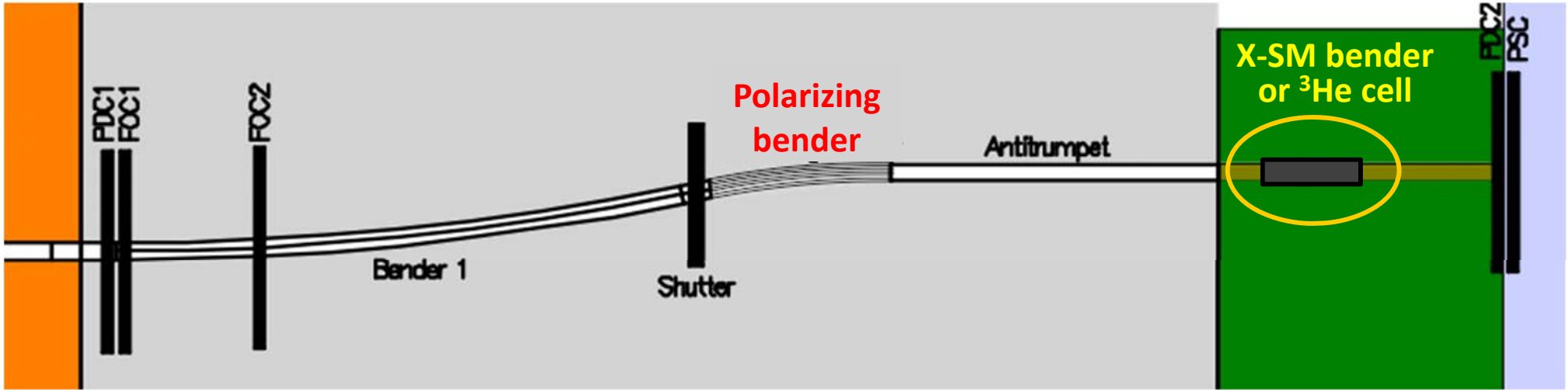
→ Benders for maximum flux

→ Polarizing option for second bender

→ Natural way to implement X-SM geometry, beam remains horizontal

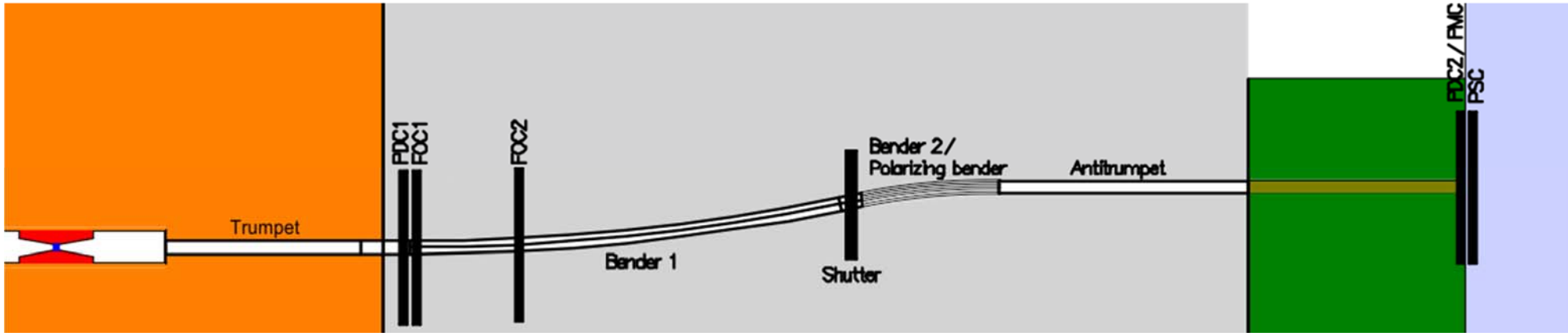
Details optimized by McStas simulations for reference experiments

Polarization options

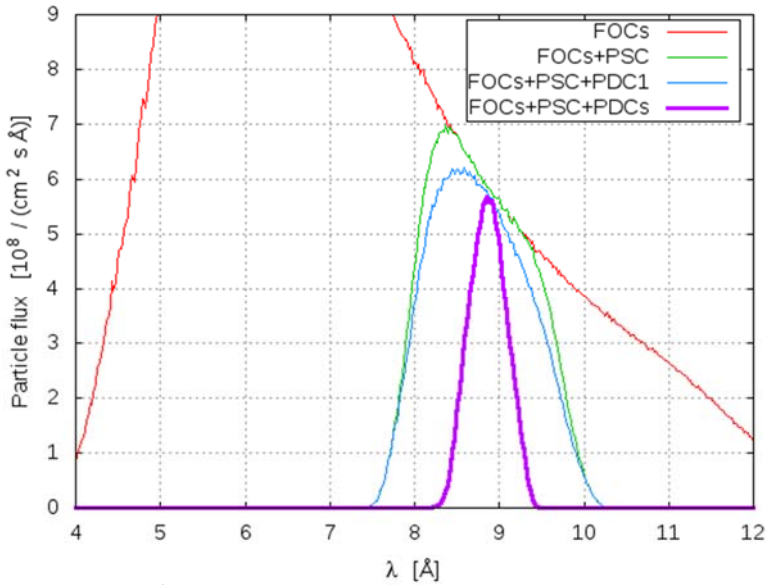


1. Moderate polarization (98%) at highest intensity
   Bender 2 replaced by Polarizing bender
2. Highest polarization (>99.9%)
   Polarizing bender + bender in beam preparation area in X-SM geometry
3. Polarization with analytic wavelength dependence
   ^{3}He spin filter in beam preparation area

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

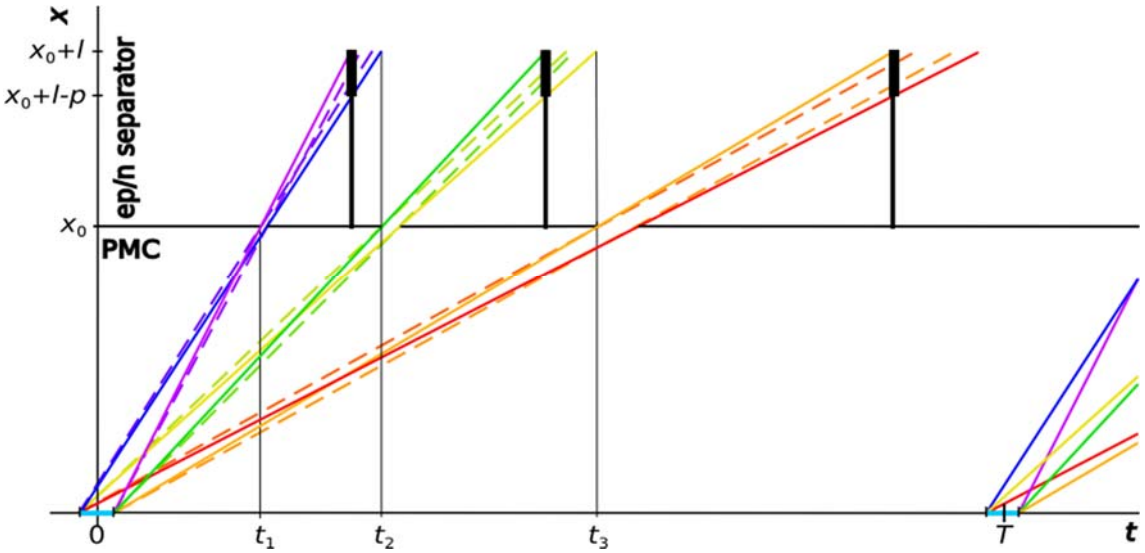


Example:
Resolution at 8.9 Å: 0.55 Å (FWHM)

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_{ESS} = 14 Hz)



Expected performance

Parameter	Value
Capture flux full spectrum	$5.4 \cdot 10^{10}$ n/(cm^{2}s) at guide exit $1.8 \cdot 10^{10}$ n/(cm^{2}s) at start of experimental area
Capture flux 2—8 Å (FOCs)	$4.0 \cdot 10^{10}$ n/(cm^{2}s) at guide exit $1.4 \cdot 10^{10}$ n/(cm^{2}s) at start of experimental area
Particle flux @ 8.9 Å	$5.8 \cdot 10^{8}$ / (cm^{2}sÅ) at start of experimental area (with additional guide in beam definition area)
Divergence distribution FWHM	42 mrad horizontal 22 mrad vertical
Instantaneous bandwidth	0.43 Å

Benchmarks

Experiment	Facility	Gain Event rate	Gain Signal / Background	Comment
NPDGamma	FnPB (SNS)	**15**	1	Wavelength information
PERC	MEPHISTO (FRM II)	**17** **34**	1 1	Pulse localization in space With PMC
PERKEO III	PF1B (ILL)	**6** **16**	1 1	Pulse localization in space With PMC
aSPECT	PF1B (ILL)	1 0.4	**3** **10**	Pulse localization in time at ANNI only
BeamEDM	PF1B (ILL)	**25**	1	Wavelength information, time dependent optical elements

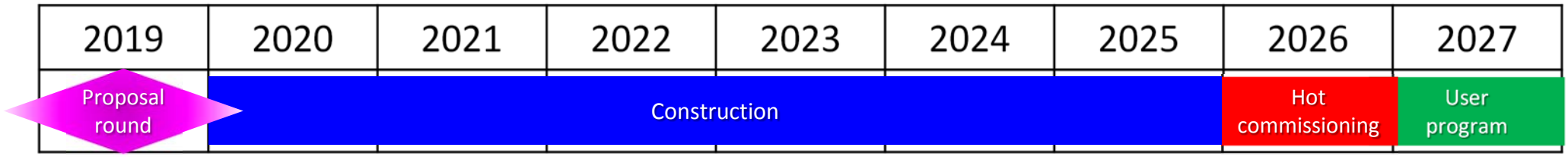
➔ World leading from 1 MW ESS power

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



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!