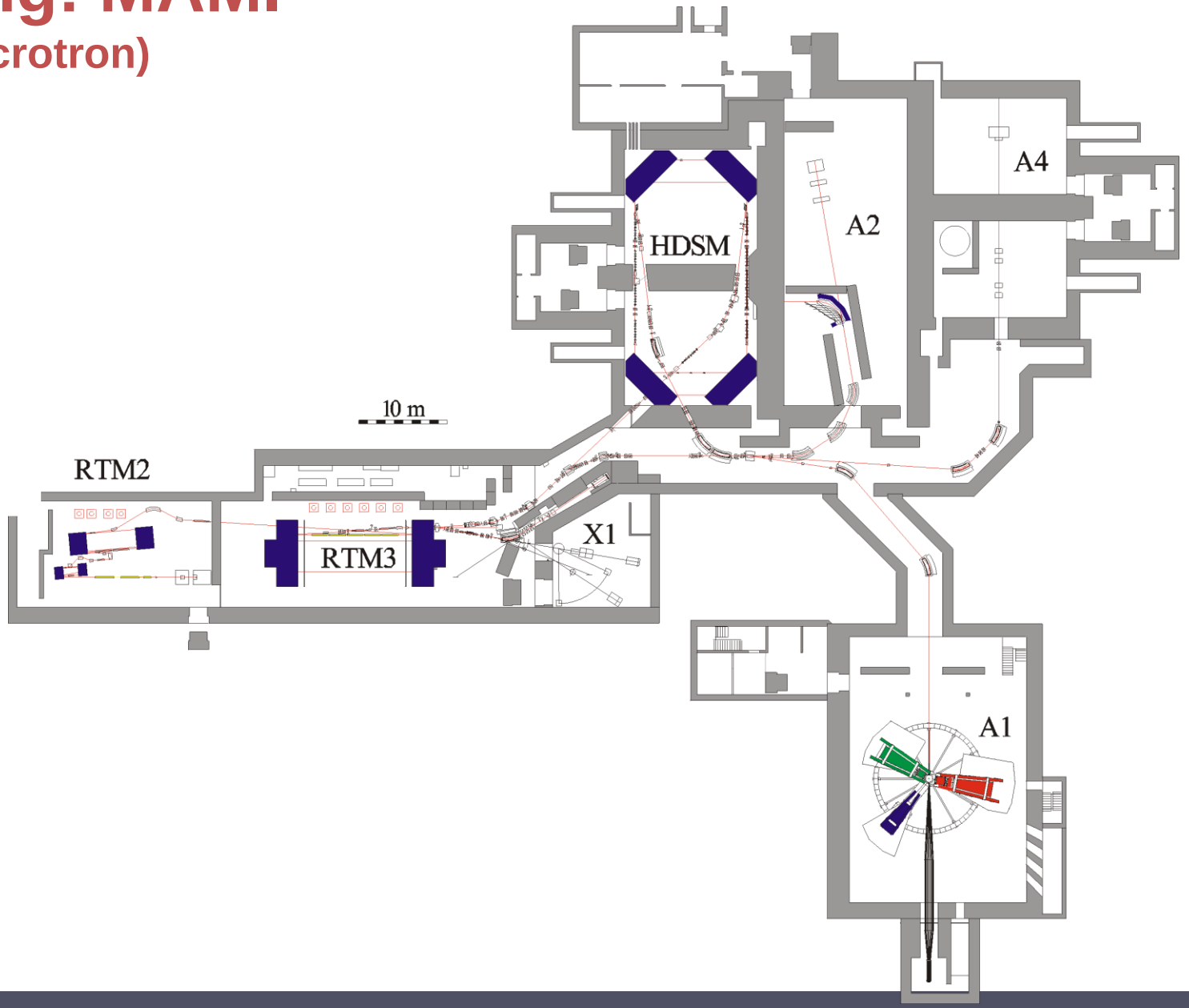
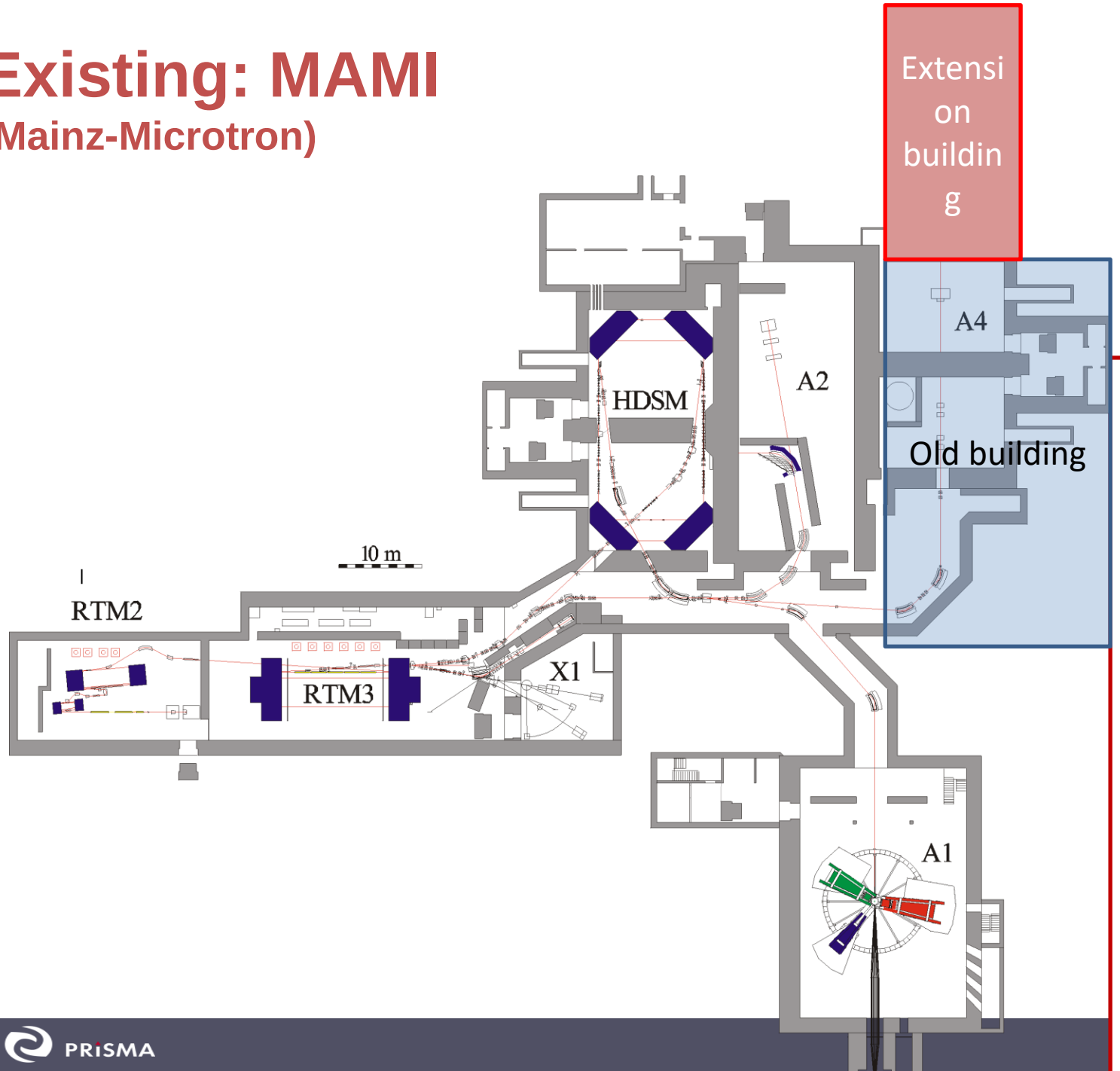
Development of the Polarized Electron Source at MESA

International workshop on future linear colliders
by Kurt Aulenbacher
Presenting work of department B at
Institut für Kernphysik
Johannes Gutenberg-Universität Mainz

Existing: MAMI
(Mainz-Microtron)



Existing: MAMI
(Mainz-Microtron)



New project: MESA
(Mainz Energy-recovering Superconducting Accelerator)

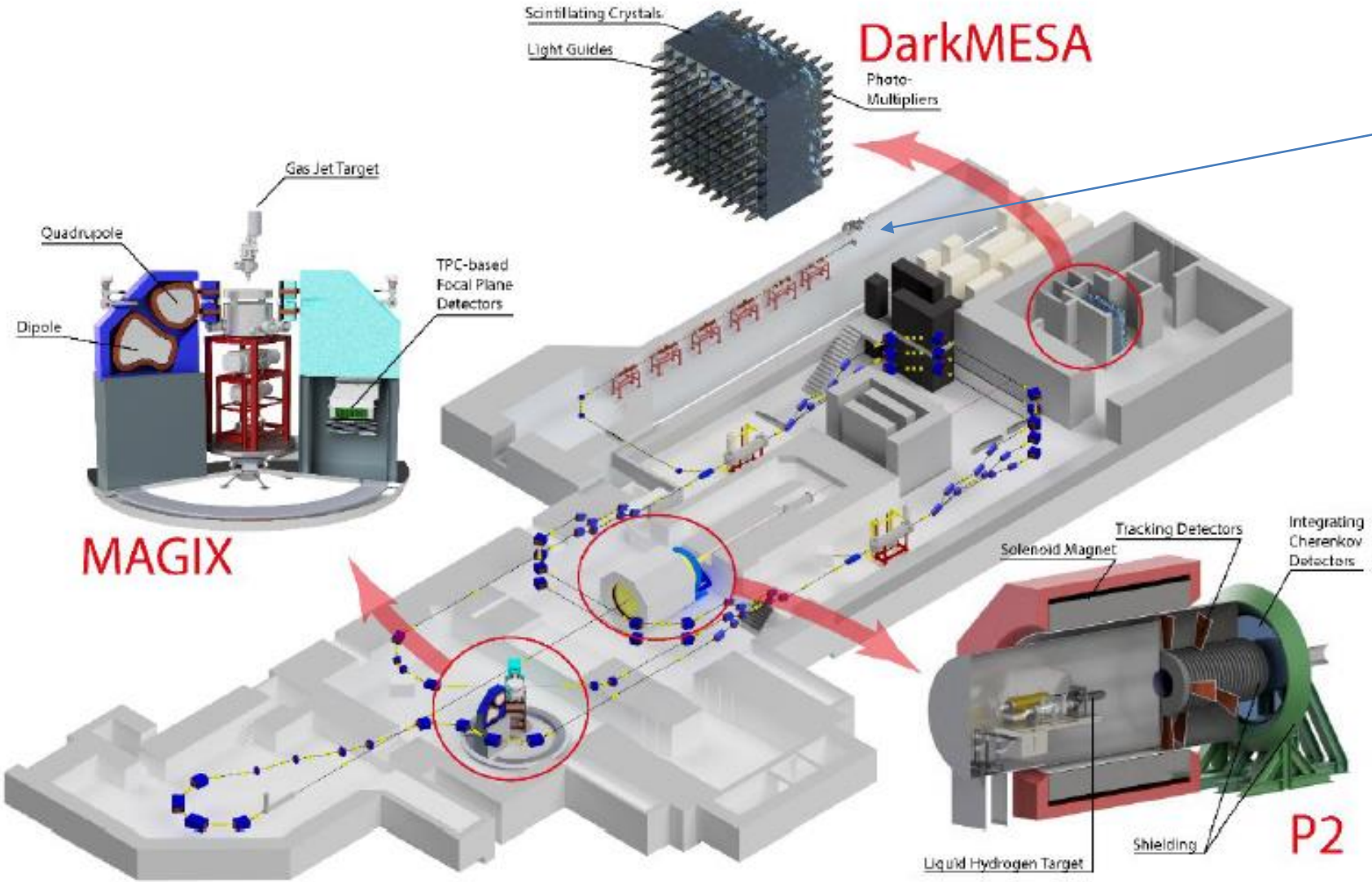
- „World class“ electron scattering experiments below Pion production threshold
- Requires at least 10 times beam intensity of MAMI (1-10mA vs. 0.1mA)
- MESA energy consumption 30% of MAMI
- Blue area available for MESA + extension building

MESA: 2 turn ERL Mode :105MeV CW
Alternatively; 3 „extracted beam“ 155MeV, CW

Building status November 2020

Occupation readiness planned for January 2022

MESA Experiments



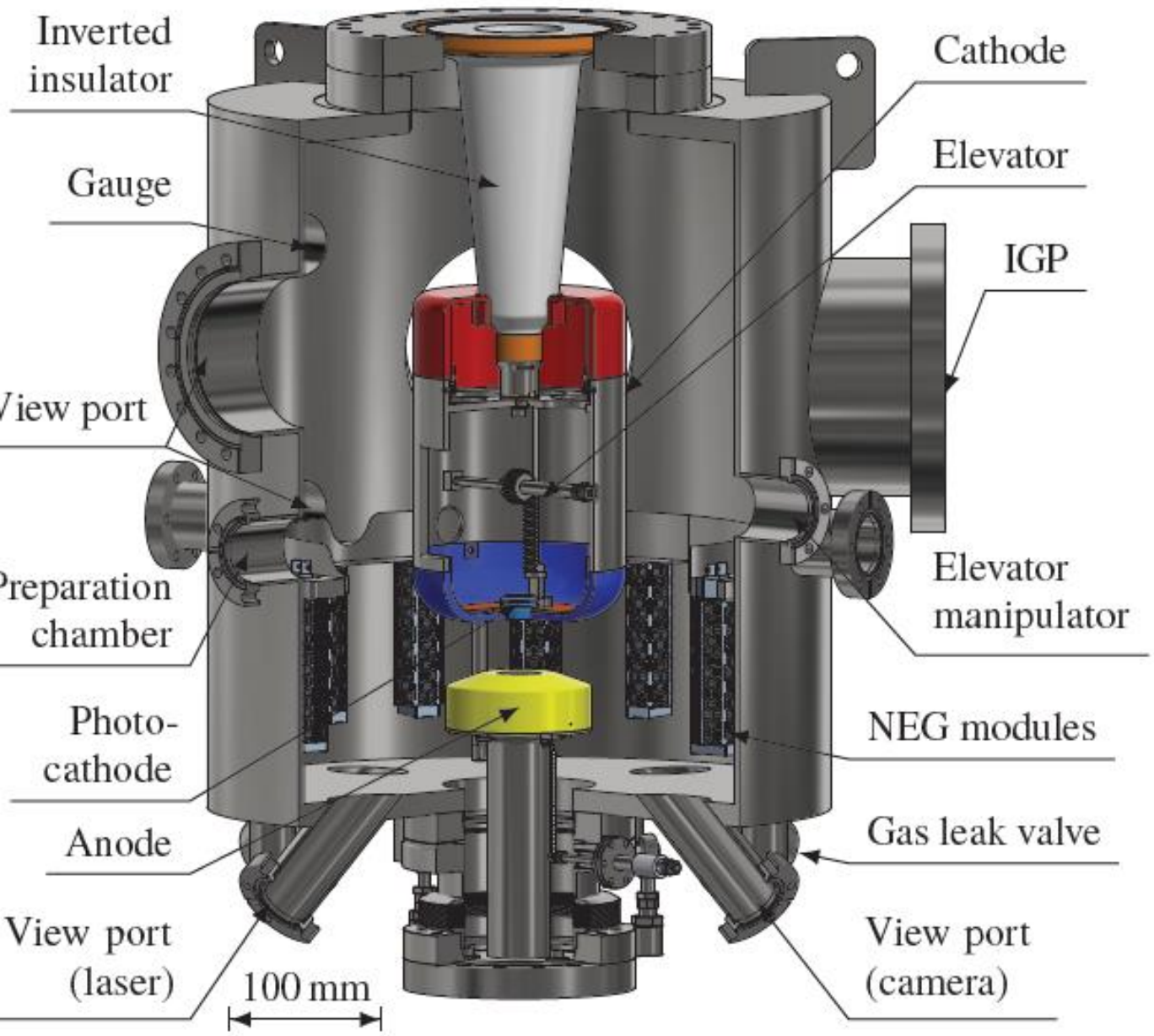
Polarized Source

~10m

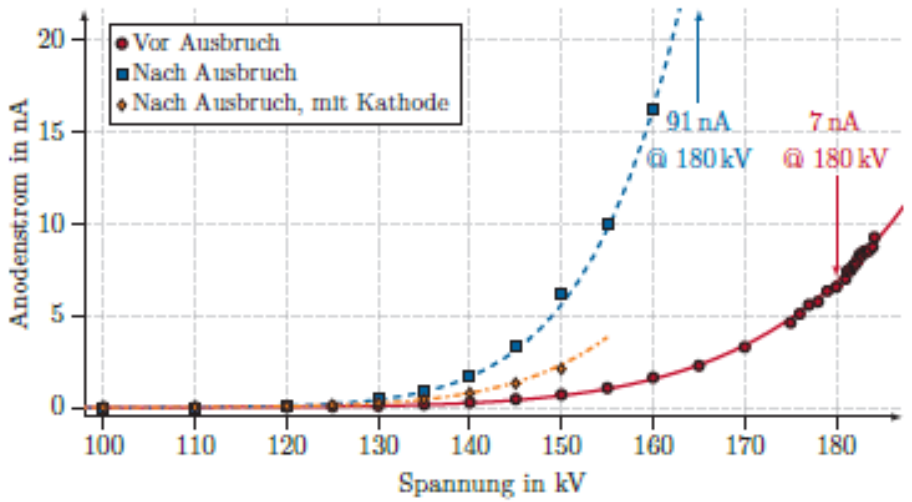
MESA Experiments: typically at low q^2

Experiment	Mode Energy/MeV	Polarisation	Challenge for MESA	Current/mA
P2-H	EB/155	YES	Systematics	0.15
P2-C	EB/155	YES	Polarization accuracy	~0.15
P2-other (Skin,weak FF)	EB/155	YES		~0.15
DarkMESA	EB/155	---	background	As in P2 (parasitic)
MAGIX-p (Formfaktor,dark photons)	ERL 30-105	NO	ERL with target	1 (10^{35}-10^{36}cm^{-2}s^{-1})
MAGIX S-Factor, e.g. ^{16}O(e,e'α)^{12}C	ERL 105	NO	Beam loss	<1 ($2*10^{34}$cm^{-2}s^{-1})
MAGIX (polarized target)	ERL or Stretcher	YES	Lifetime and/or bunch charge	10-100 (10^{31}-10^{32}cm^{-2}s^{-1})

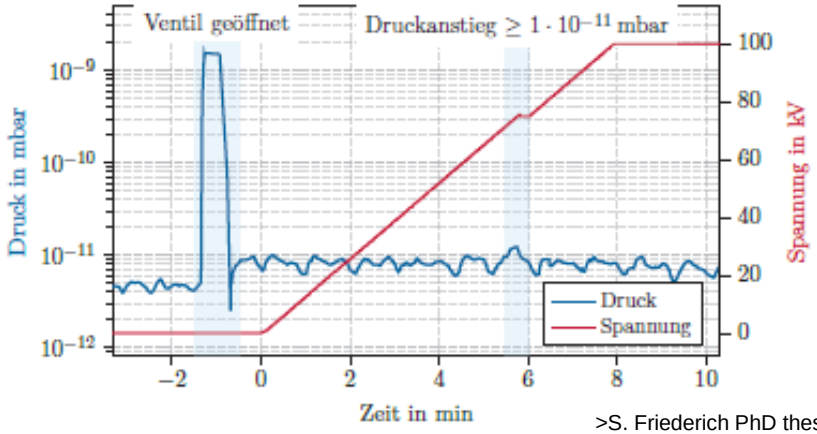
Source: Small thermalized electron source at Mainz (STEAM), -soon to be renamed Mesa Injector Source Tier-1 (MIST-1)



HV- conditioning (only vacuum,)



Stable operation at 100 kV
(150kV possible)



>S. Friederich PhD thesis JGU 2019

Source/beam preparation (MEsa Low energy Beam Apparatus (MELBA)

MELBA in spring 2019

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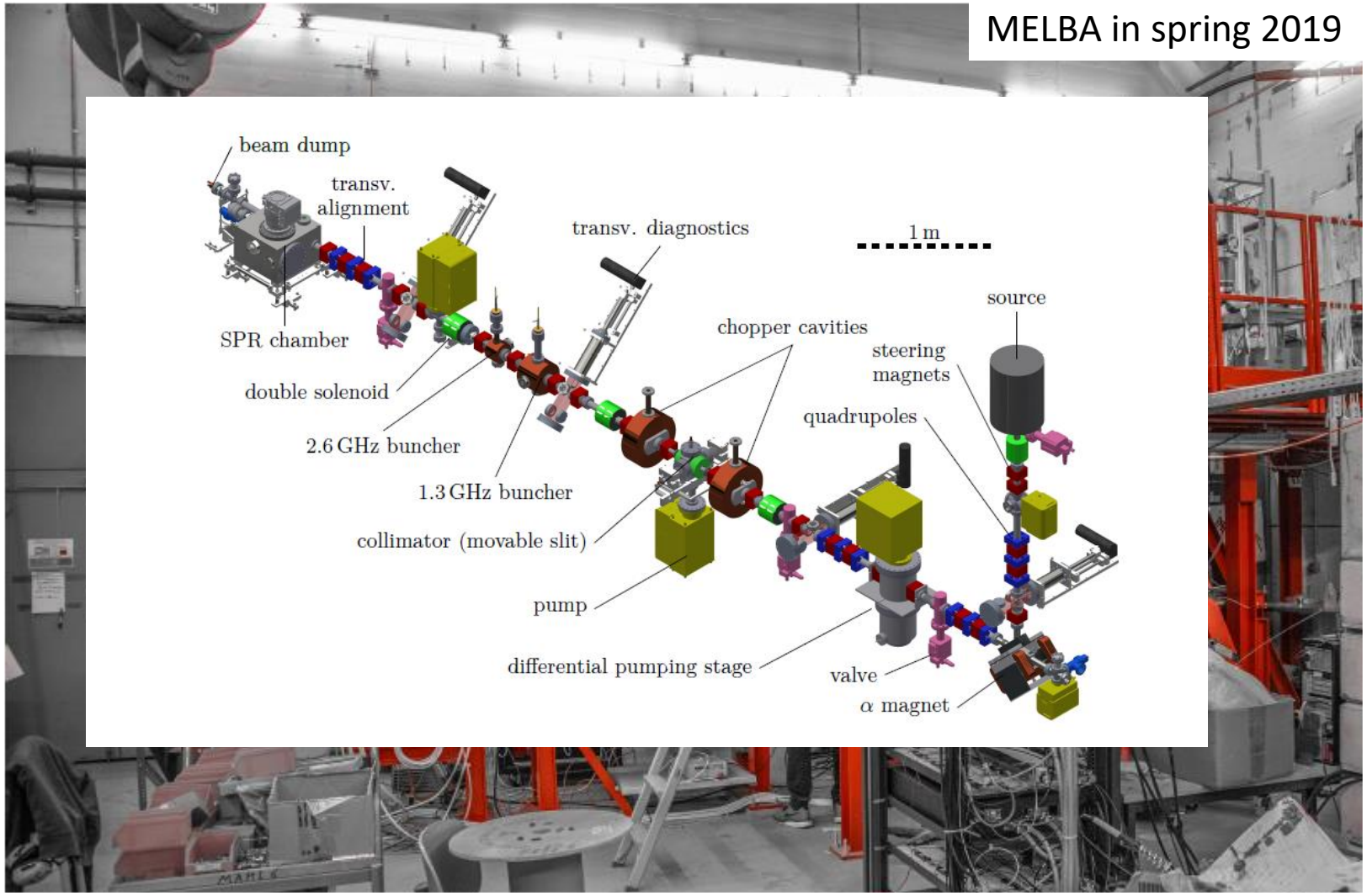
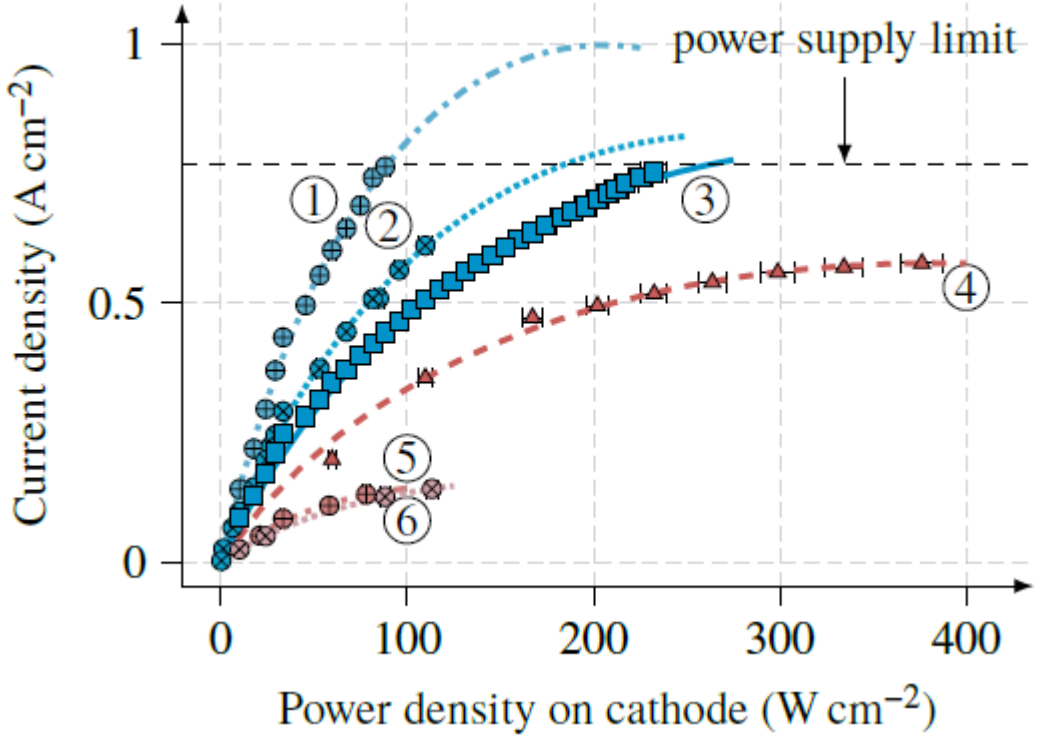
MELBA in spring 2019



10mA „ spin-polarized mode“ beam with source „STEAM“

Surface charge limit effect in NEA photocathodes!

S. Friederich et al. IPAC 2019 doi:10.18429/JACoW-IPAC2019-TUPTS011
Fits according to model by G.A. Mulhollan et al. / Physics Letters A 282 (2001) 309–318



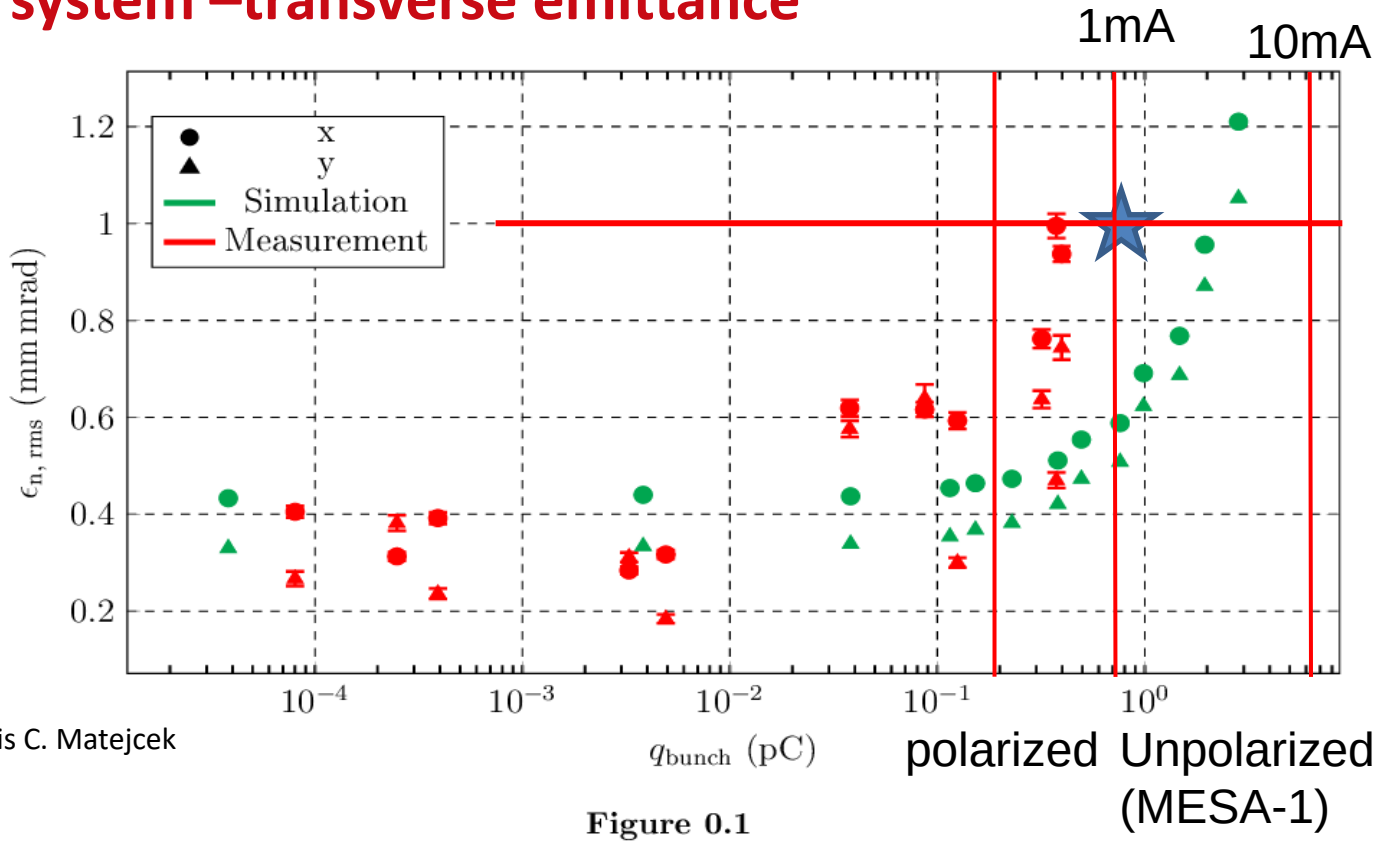
No.	QE_0
①	2.40 %
②	1.55 %
③	1.15 %
④	0.85 %
⑤	0.50 %
⑥	0.39 %

PhD thesis Simon Friederich

steady state-current measurements with the MESA-source
at 2.5MV/m, 500µs long pulses, doping level 1-2*10^{19}

For practical purposes it is obviously important **to avoid reduction of q.e.**

MELBA result - spin polarized beam after beam preparation system –transverse emittance



PhD thesis C. Matejcek

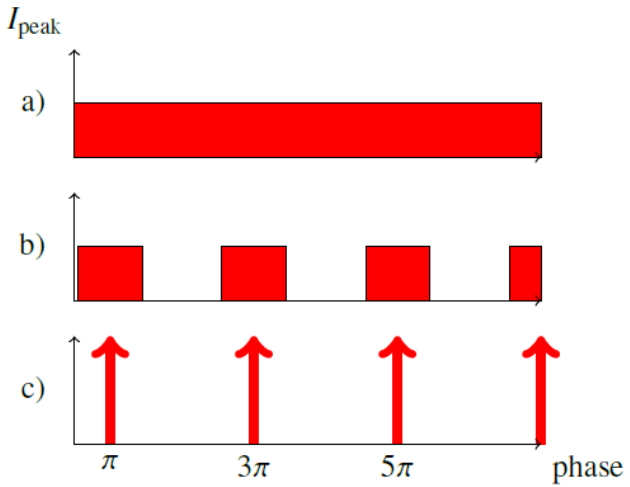
Figure 0.1

See also proceddings IPAC 2019 CH. Matejcek et al. doi:10.18429/JACoW-IPAC2019-TUPGW028

MELBA with STEAM: Specs for polarized beam achieved/ falls a little short of stage-1 goal for unpolarized beam

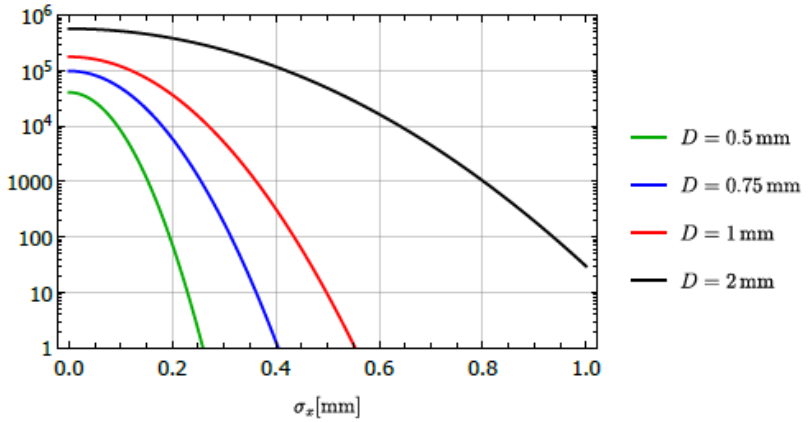
Deviation to simulation is attributed to sextupoles of correctors and large excitations because of insufficient magnetic shielding→ new correctors designed

MELBA result - spin polarized beam after beam preparation system – longitudinal emittance

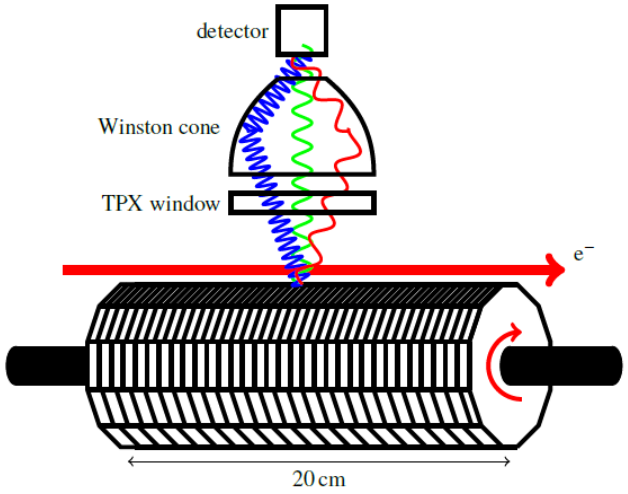


Bunching scheme

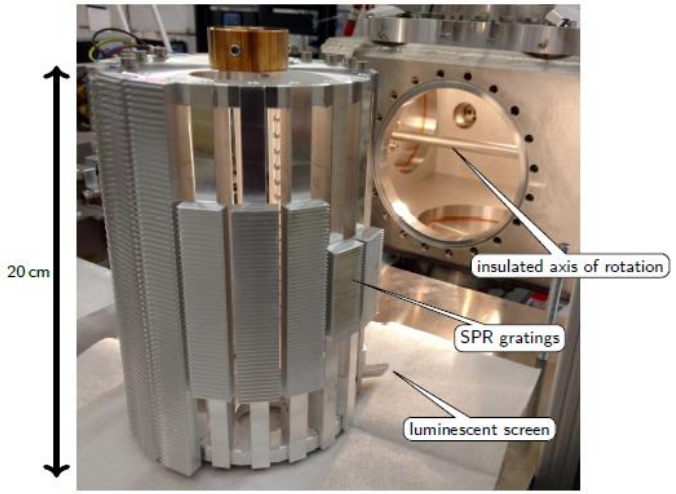
Non interfering bunch length measurement at buncher focus by coherent Smith Purcell radiation
- controlling function of harmonic buncher



Coherent Signal as function of bunch length & various grids periods

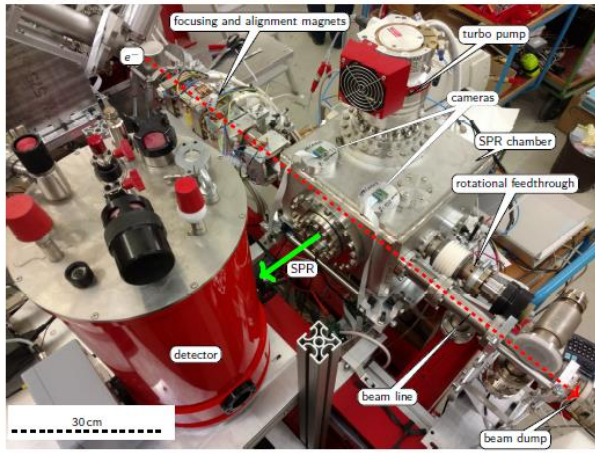


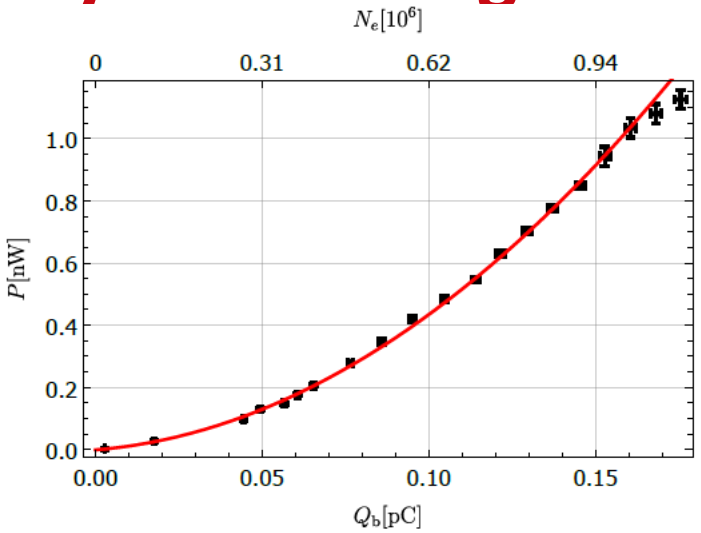
Schematic of detector



Grid drum

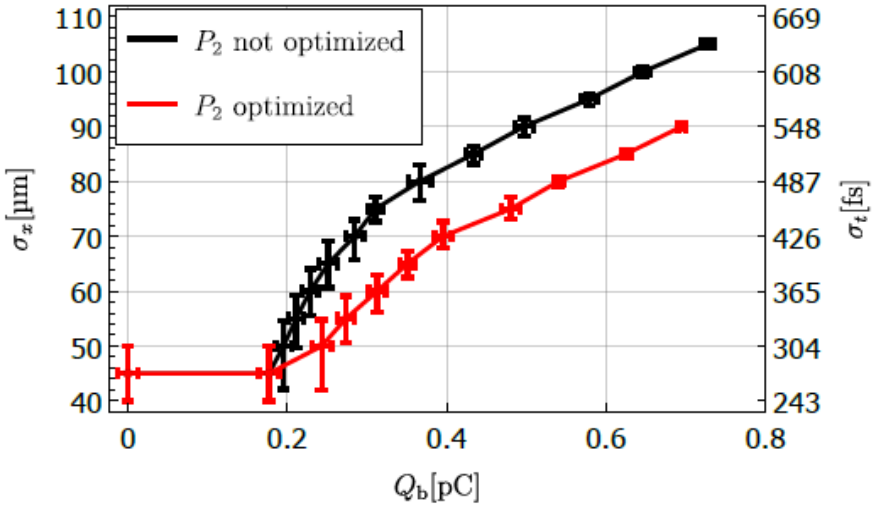
MELBA result - spin polarized beam after beam preparation system – longitudinal emittance





Signal increases quadratically with bunch charge

→ Bunch length < grating period/2



Bunch length increase because of space charge

RMS 4ps is required for Injection in MAMBO…

- Achievable for beam currents of a few mA
- Beam loss at grating can be <1%
- Minimum buch length at lower charge <1ps.

Results Source/beam preparation (MELBA) until July 2019

→ **Operation with up to 100keV**
beam and up to 10mA dc.
beam current (>150kV possible, but not required)

→ **0.5mA (0.4pC/bunch)**
with emittance <1μm possible

→ **3mA at <1μm expected by improved**
corrector/shieldinfg

→ **MELBA was dis-assembled and put in storage**
due to start of hall renovation for MESA

→ **New Set-up MELBA 2.0 for MESA**

MELBA in spring 2019

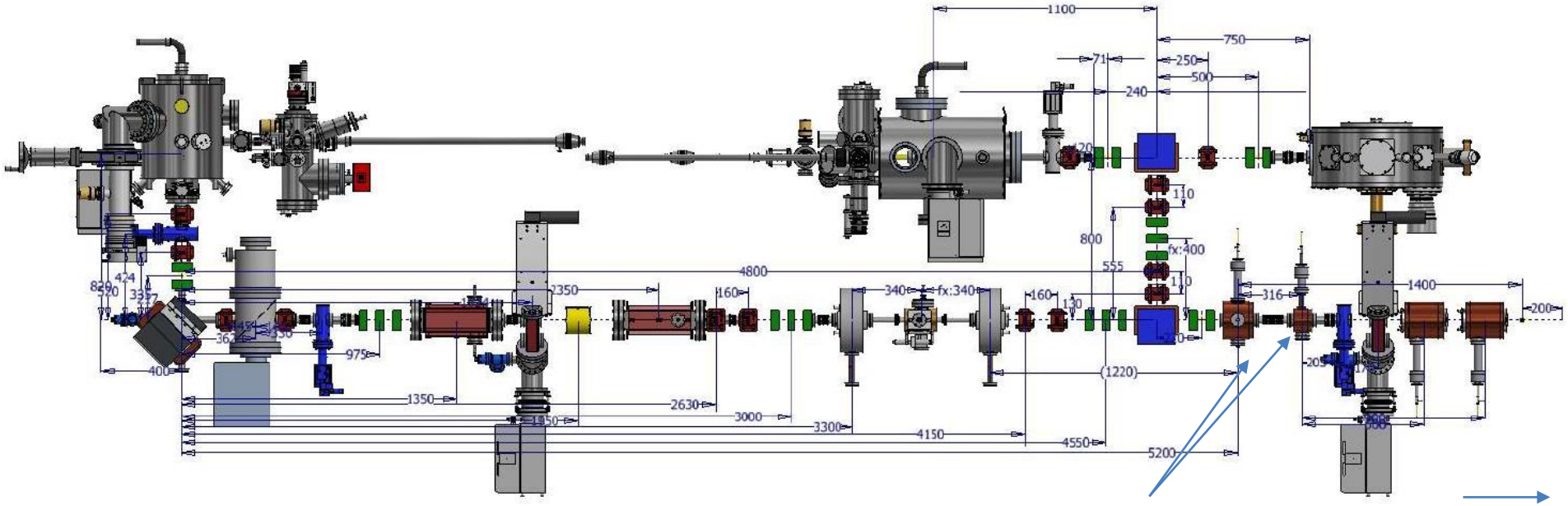
Buncher cavity assembly

Source/beam preparation (MELBA 2.0) commissioning in 2021

Photosource „STEAM“
(polarized beam)

MIST-2

Double scattering
Mott polarimeter



Spin Manipulation

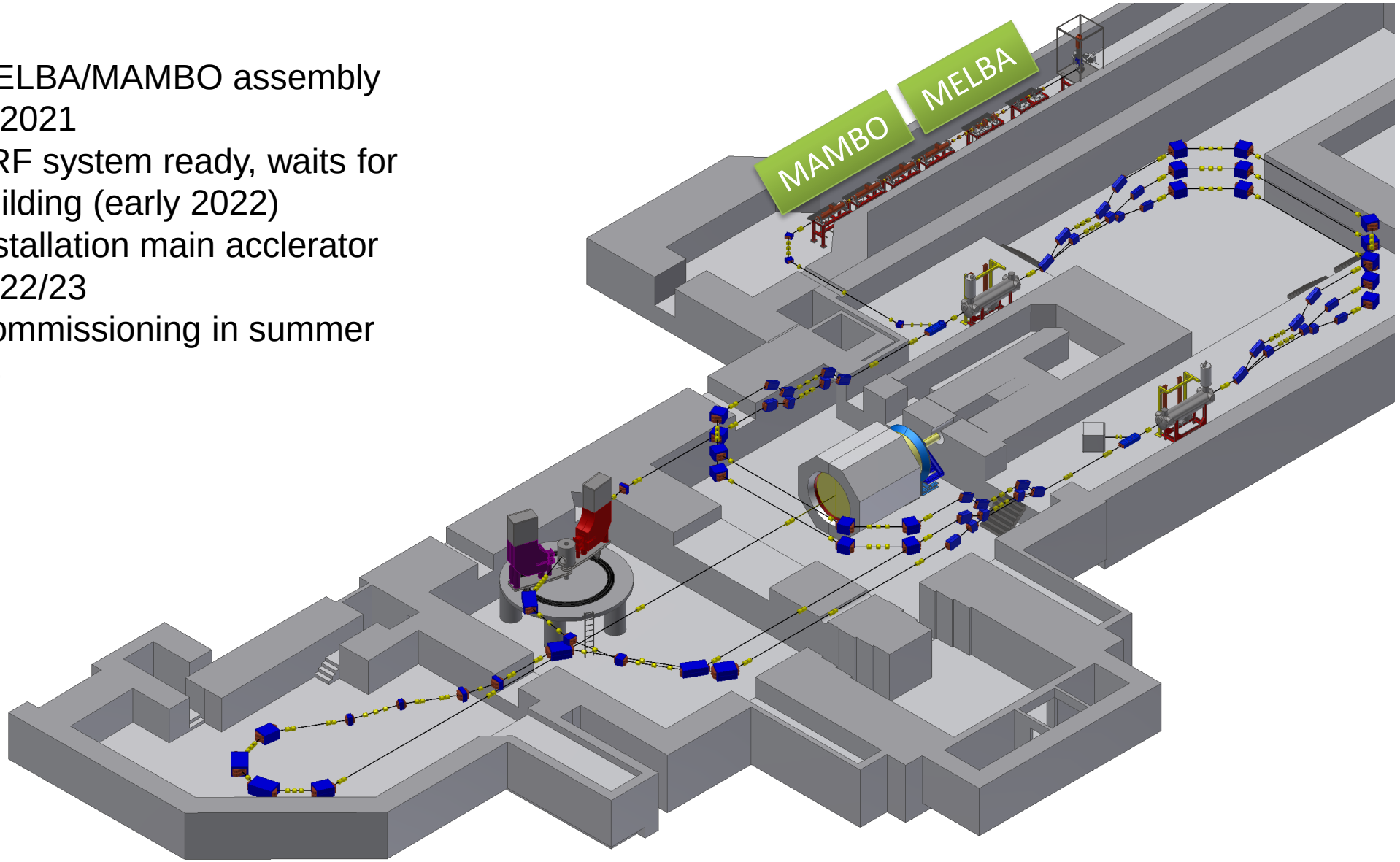
Circular
Chopper

f/2f buncher
cavities

To MAMBO
injector

MESA Accelerator time schedule

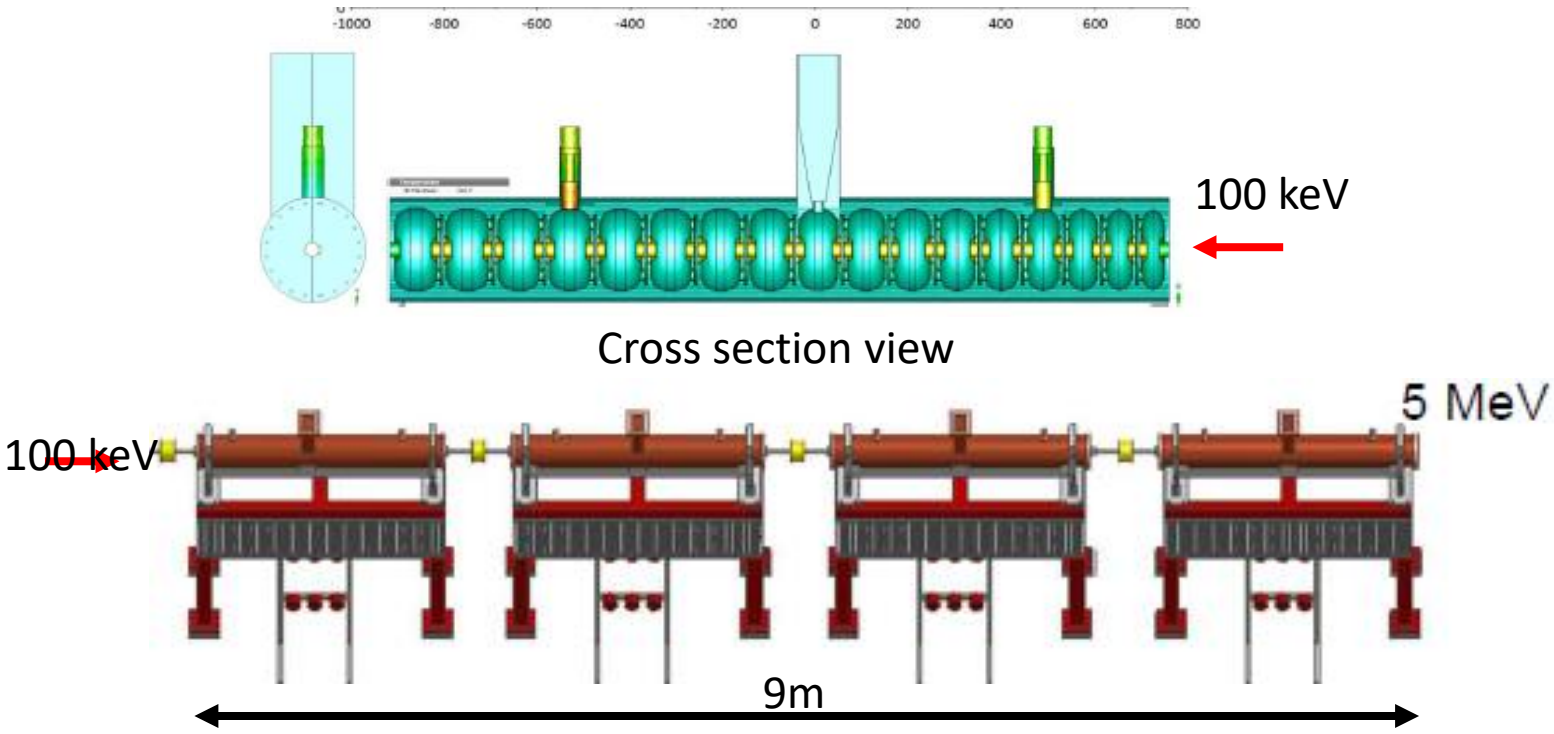
- MELBA/MAMBO assembly in 2021
- SRF system ready, waits for building (early 2022)
- Installation main acclerator in 22/23
- Commissioning in summer 23



Thank you!

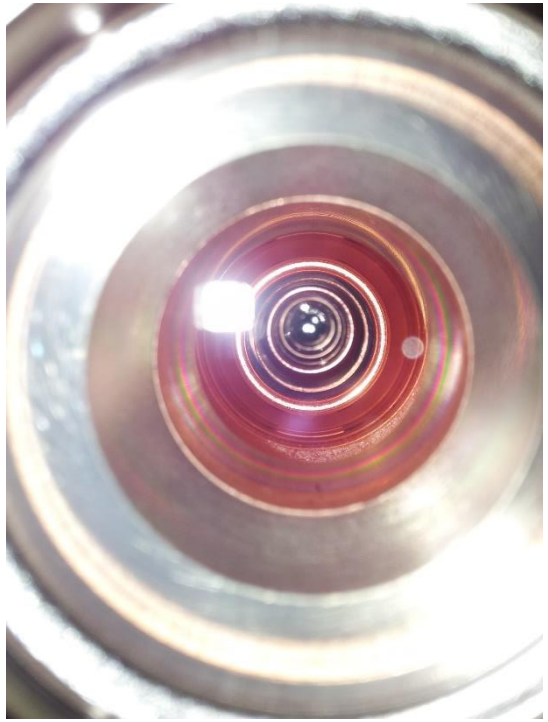
MAMBO Booster Linac

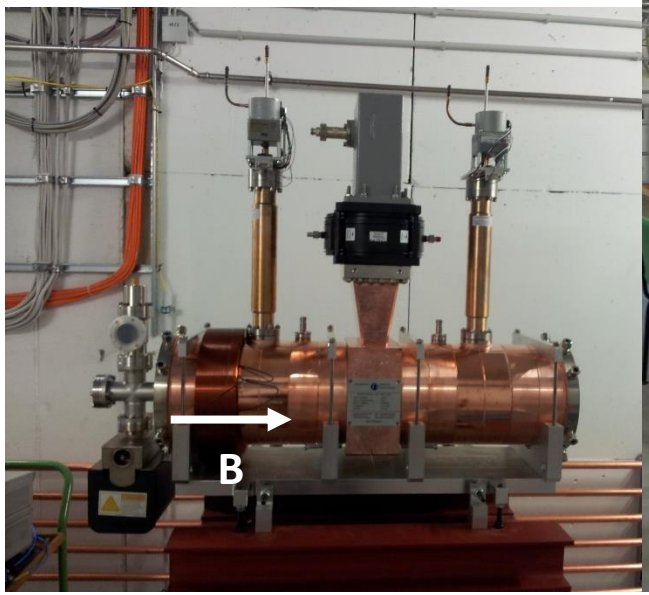
- Design inspired by the robust MAMI injector LINAC
- Energy gain 4.9MeV, beam power up to 50kW
- 4 room temperature RF structures
- RF-Amplifiers: one with ~75 kW (section 1) and 3 x ~60 kW (sections 2-4)

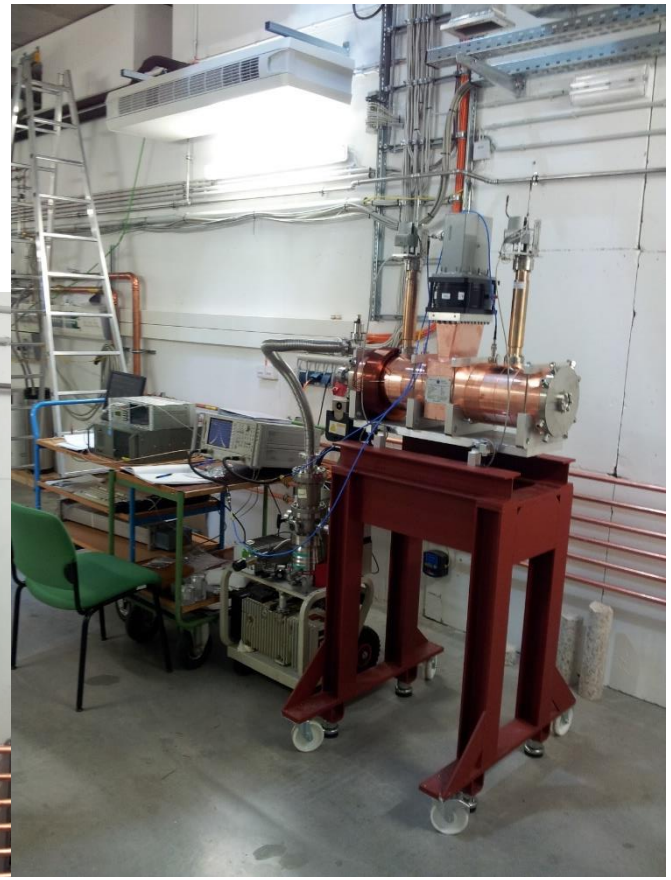


MAMBO Booster: Prototype Cavity

- Prototype needed for testing „multipacting“ behavior
  (Result: Prototype is stable also with longitudinal field, if processed correctly)



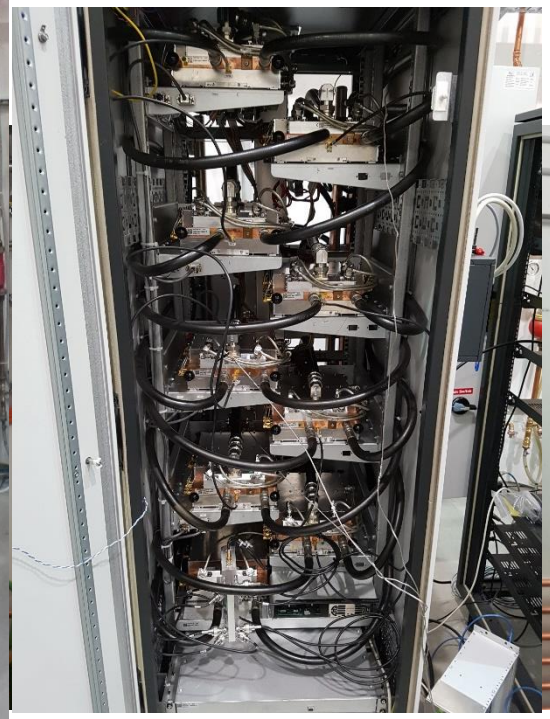


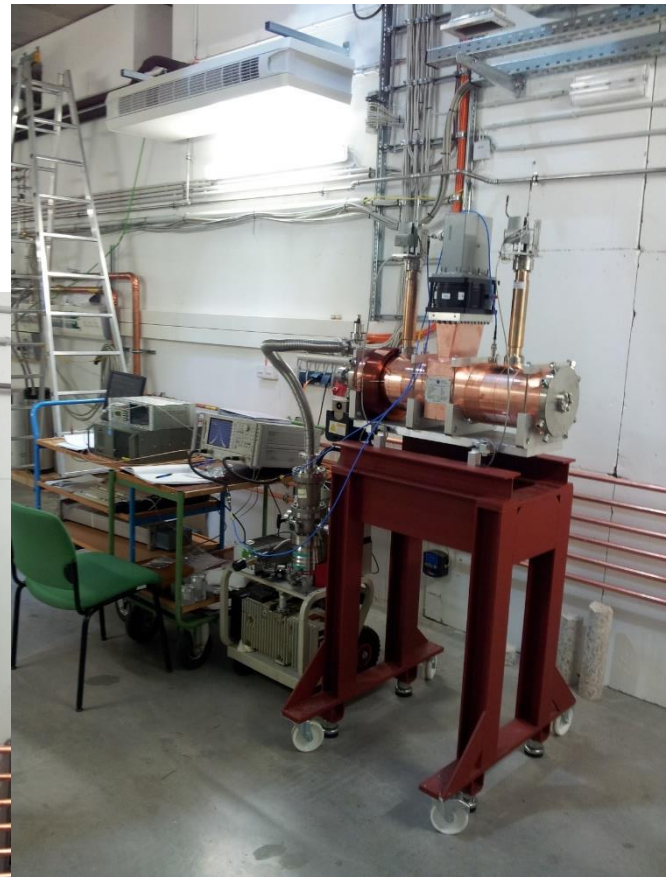


Pictures: R. Heine

MAMBO Booster: Prototype RF-Amplifier

- 15kW RF-powersource prototype :
- Modular (8*2kW, combined) Solid State Amplifier
- Used for tests of MAMBO RF-section …and also for Cryomodule tests
- ~25 Amplifiers needed for MESA RF-system
- Redesign/optimization completed

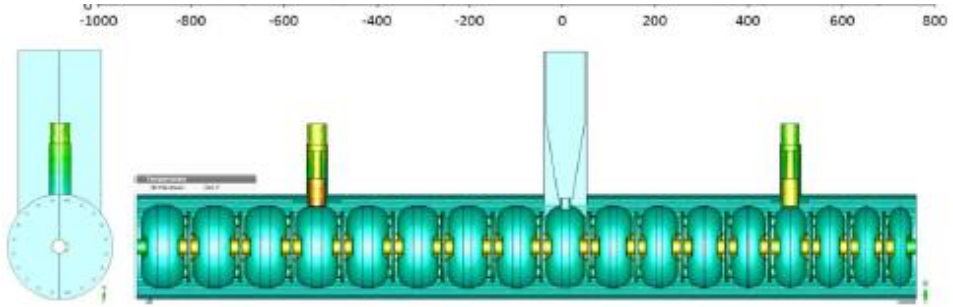


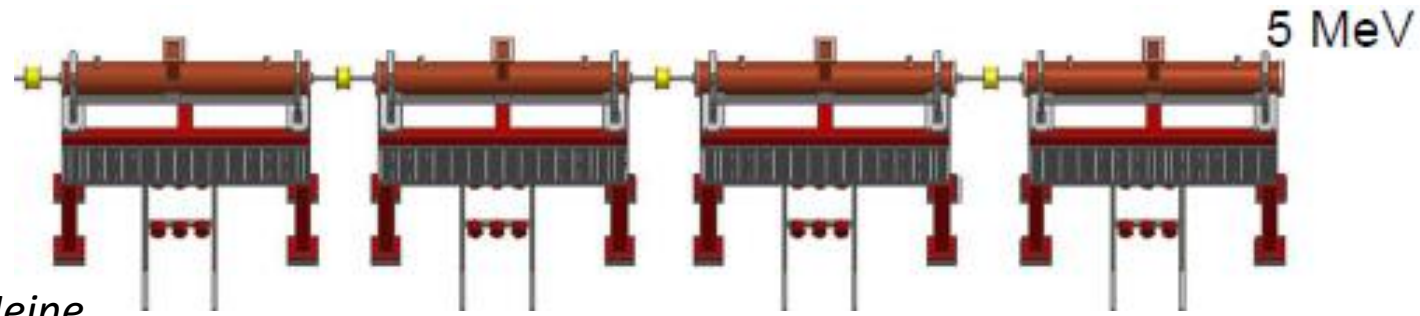


Pictures: R. Heine

MAMBO Booster Linac-Status

- Final design and ordering of Rf-cavities in Spring 19 (delivery starts Jan 21)
- Ordering of Rf-amplifiers: December 19 (delivery of first unit mid 21)



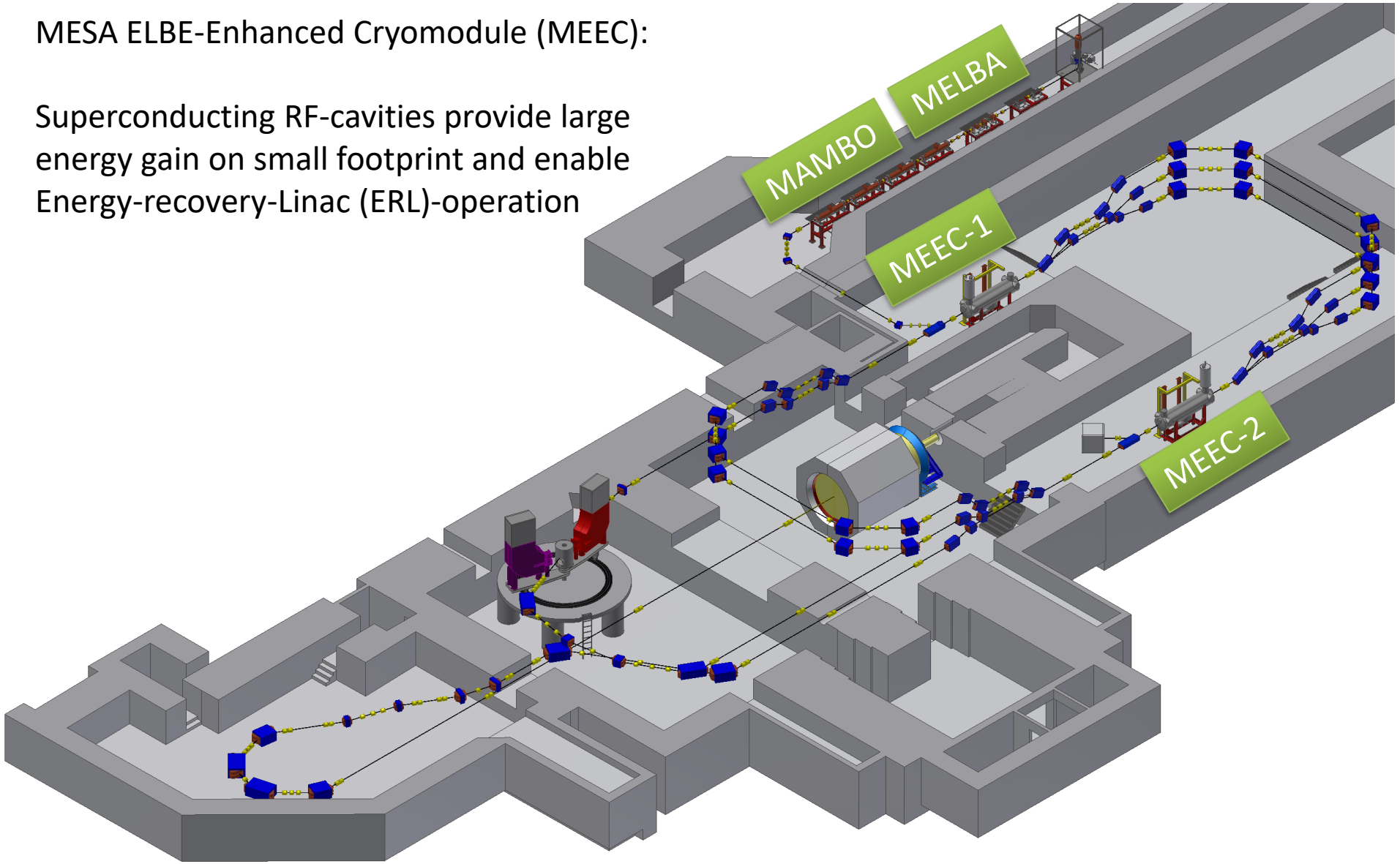


Pictures: R. Heine

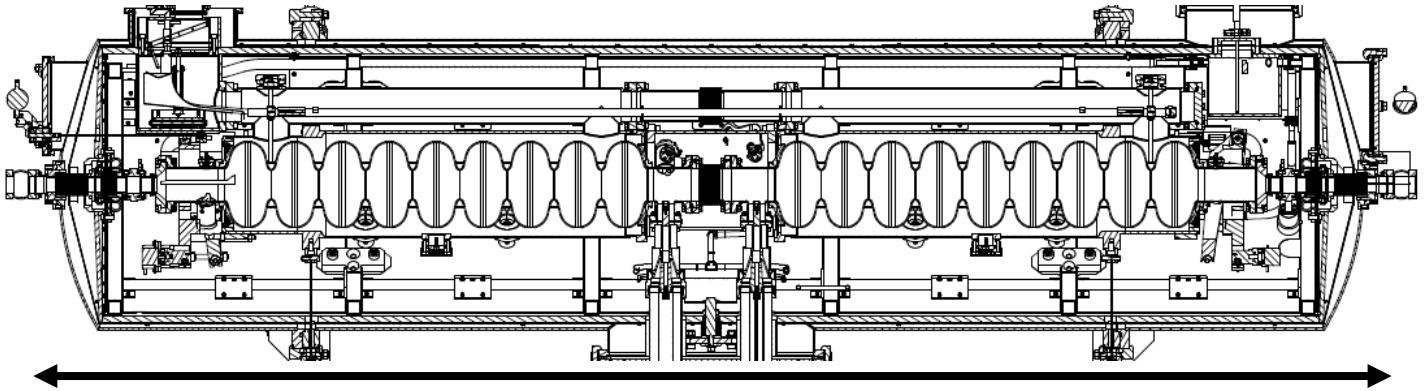
Cryomodules

MESA ELBE-Enhanced Cryomodule (MEEC):

Superconducting RF-cavities provide large energy gain on small footprint and enable Energy-recovery-Linac (ERL)-operation



SRF-System: MEEC-Cryomodules

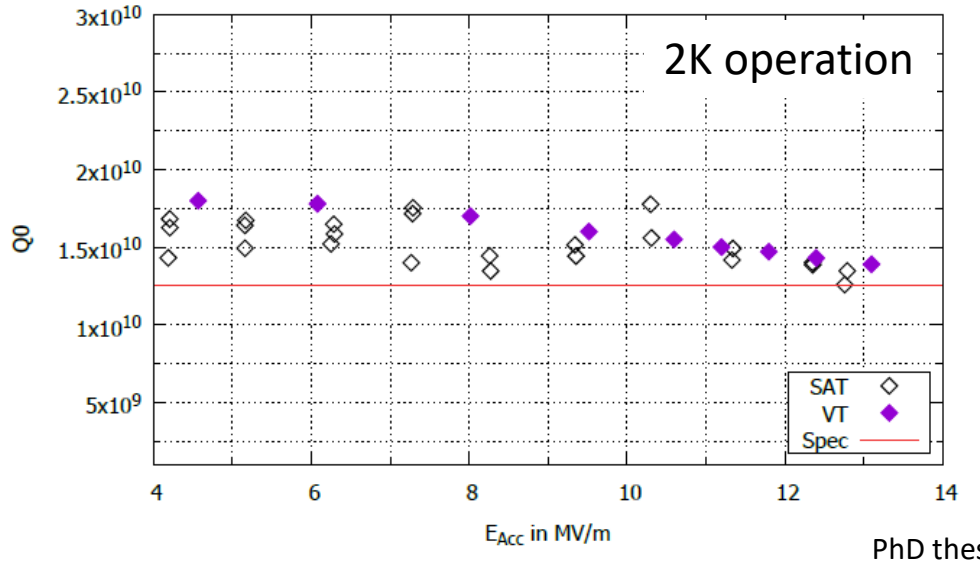


3.5 meter

Specs: 25MeV Energy gain at <40 Watt thermal loss at 2Kelvin

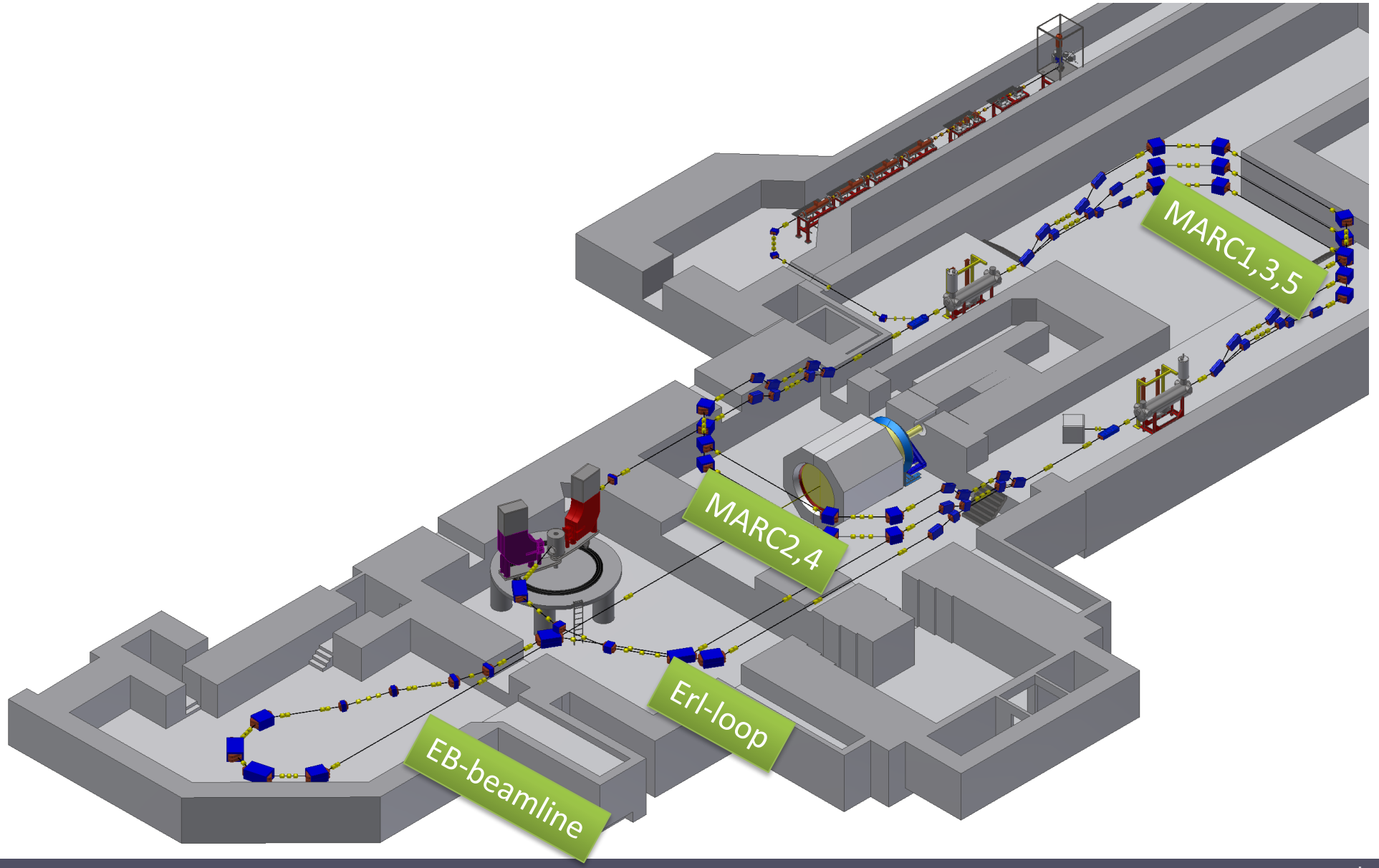
Production of 2 Cryomodules

- 2015: 2 MEEC's ordered at RI Research Instruments GmbH
- Until 2017 SRF testing infrastructure became available at HIM
- 9/2018: First cryomodule does not meet specs at HIM → refurbishment by vendor,
- 3/2019: Second tested cryomodule achieves specs during test at HIM/Mainz
- 8/2020 :refurbished cryomodule tested and fulfills specs.

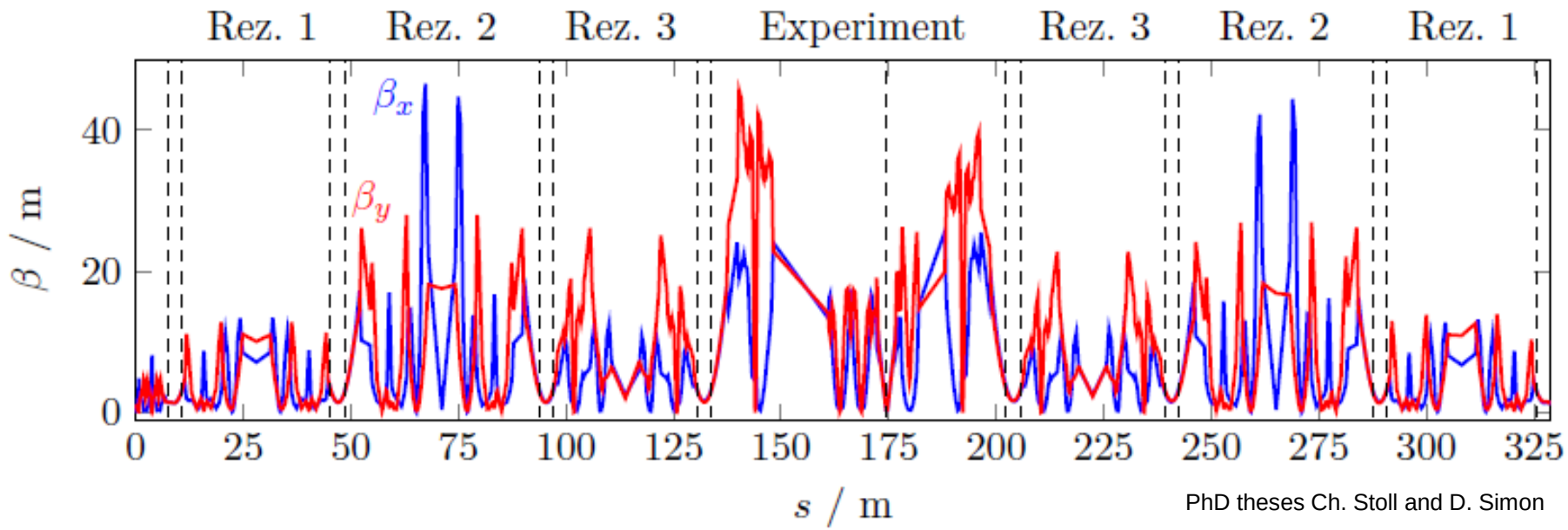


PhD thesis Timo Stengler
See also: T. Stengler et al. Proc. SRF 2019
doi:10.18429/JACoW-SRF2019-TUP041

Lattice ERL/EB mode



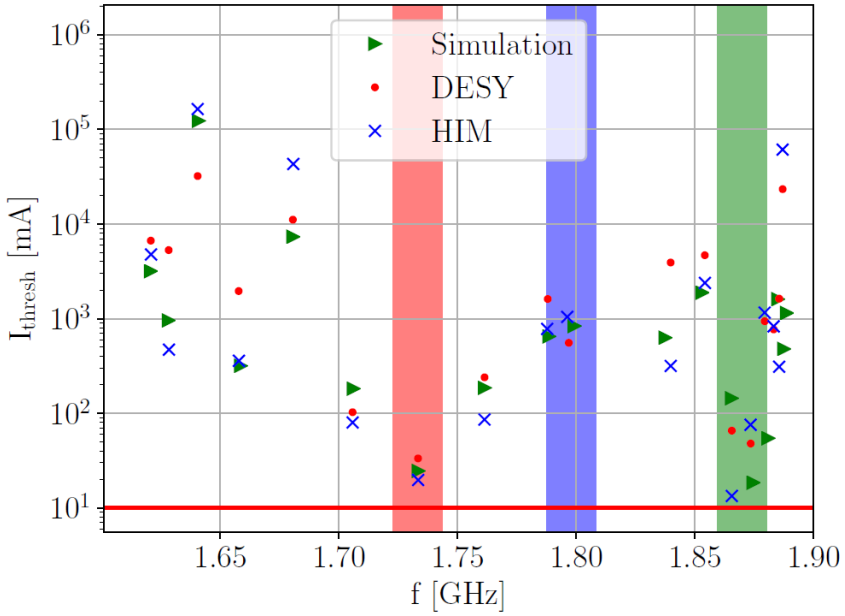
Lattice



PhD theses Ch. Stoll and D. Simon

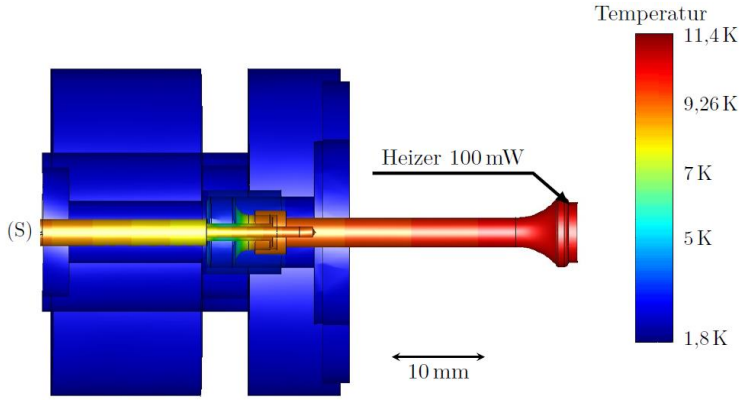
ERL-Lattice – not completely symmetrical due to enery (gain) dependend focussing of RF-structures.

BBU investigation



13mA BBU limit at Target
in 4pass configuration 2up/2down
(without countermeasures)

PhD thesis Christian Stoll,
See also: C. Stoll and F. Hug: proceedings IPAC 2019
doi:10.18429/JACoW-IPAC2019-MOPGW025



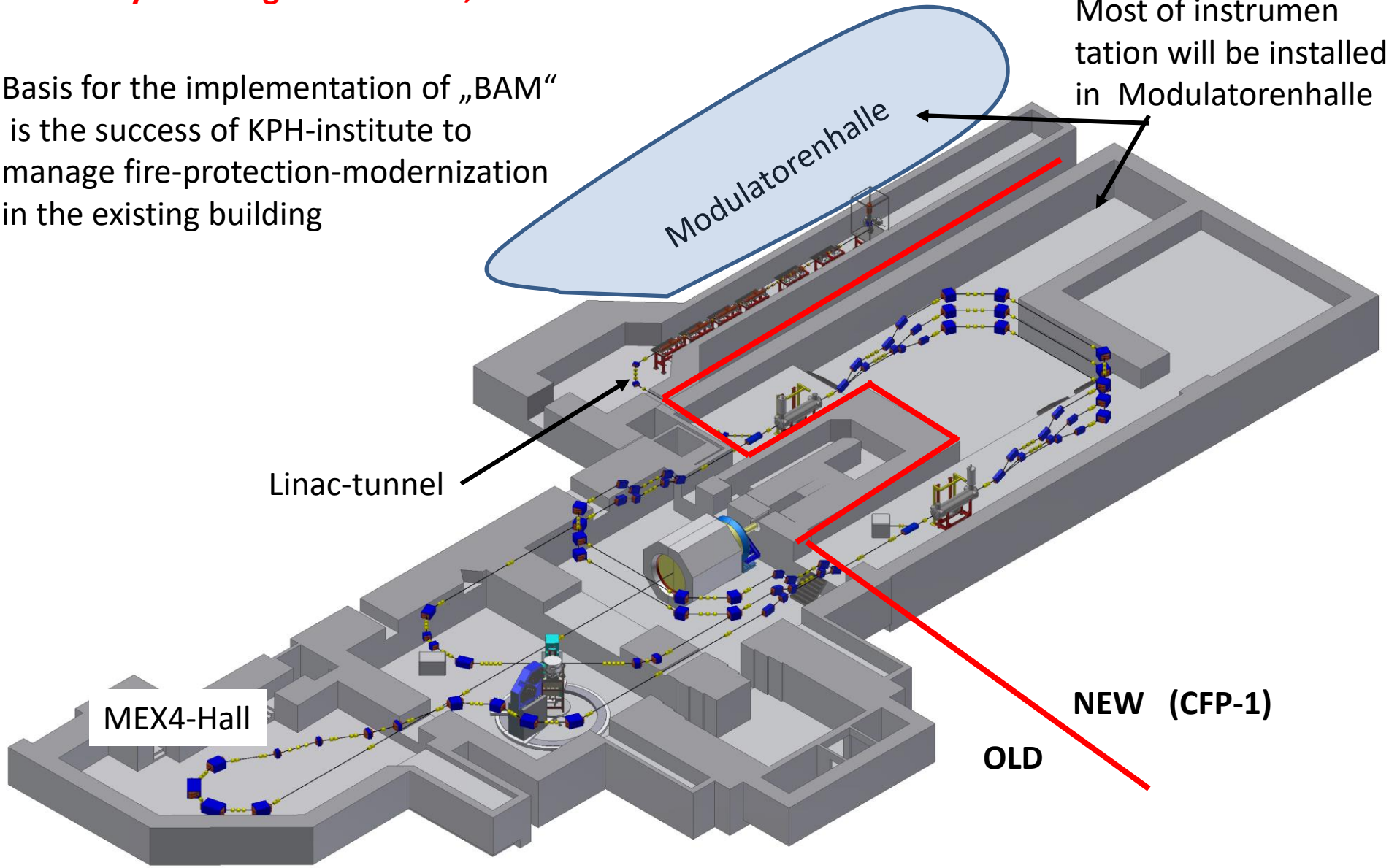
Note:
Technical limitation: Heating
of HOM coupler in TESLA cavities.
(~1mA CW estimation, but needs to
be determined experimentally)

Beschleunigte Aufbaumassnahme MESA (BAM)

2019: Layout using Linac tunnel, Modulatorenhalle and MEX-4

Basis for the implementation of „BAM“ is the success of KPH-institute to manage fire-protection-modernization in the existing building

Most of instrumentation will be installed in Modulatorenhalle



Status CC/BAM
and implications for schedule

- Our goal: 5MeV injector operational when CFP-1 is finalized
- Installation of MESA recirculator can begin 1/2022
- 15 month installation, 6 month comissioning
- begin of operations for experiments 10/2023

Thank you