BERLinPro
Berlin Energy Recovery Linac Project

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The menue

Energy Recovery Linacs - Why ?

B*ERL*inPro

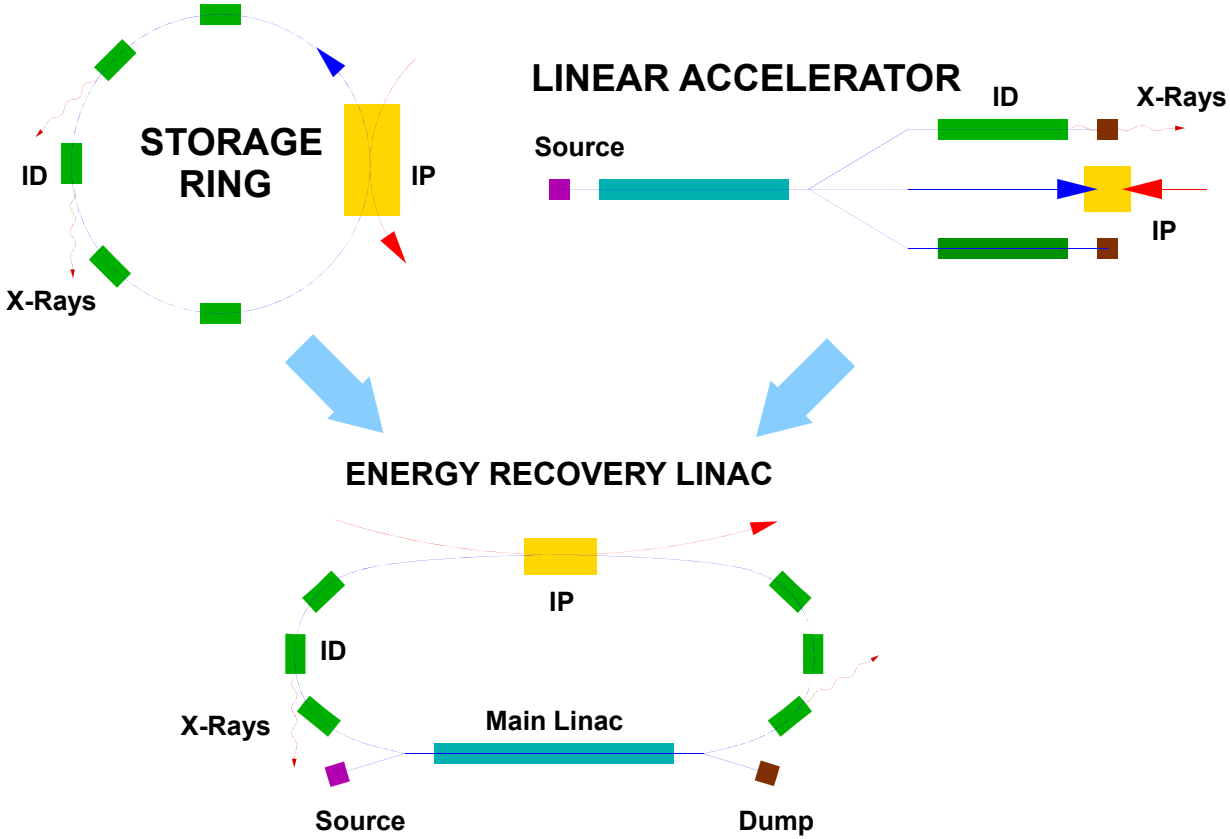
The project – concept and goals

Present Status

The idea

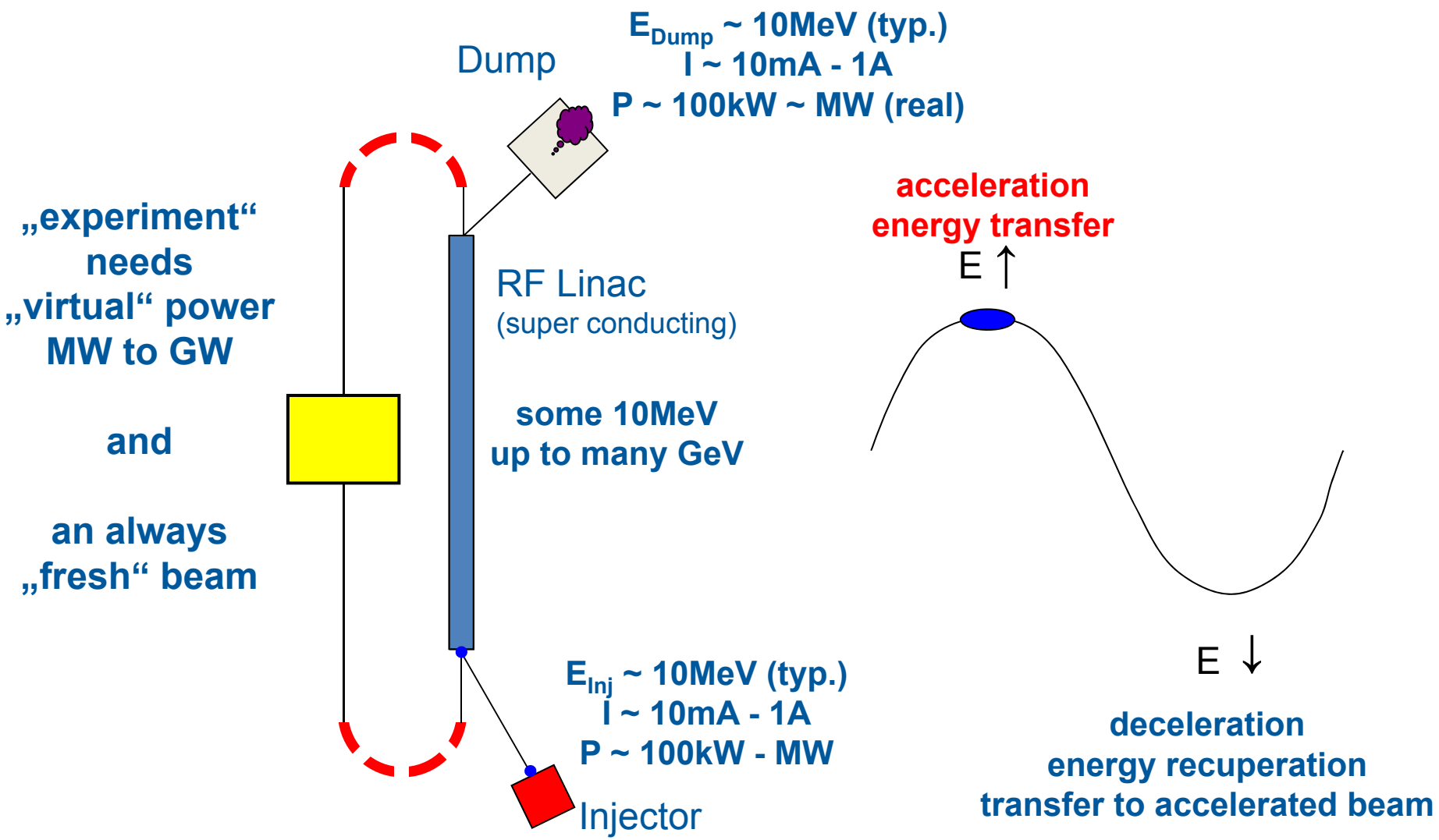
- high average („virtual“) beam power (up to A, many GeV)
- mature technology – many users
- resonant system interaction experiment ↔ ring
- beam parameter defined by equilibrium

- outstanding beam parameter
- single pass experiments
- high flexibility
- low number of user stations
- limited average beam power (<<mA)



high average beam power for single pass experiments, excellent beam parameters, high flexibility, multi user facility

The Energy Recovery Linac Principle

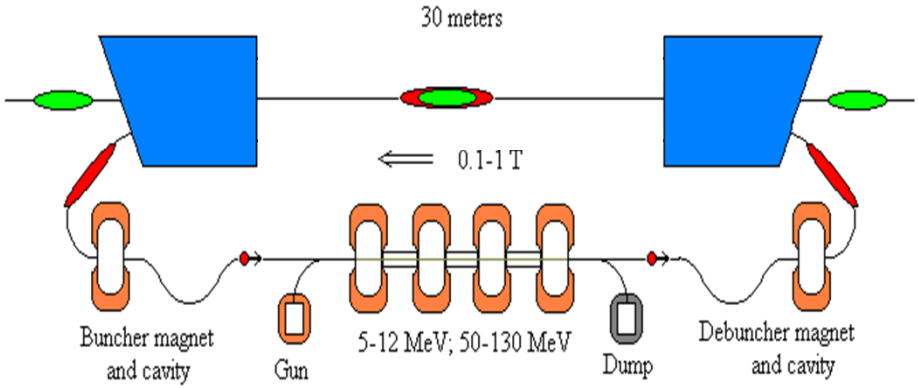


Applications of Energy Recovery Linacs

- **electron cooler for ion storage rings (nuclear and hadron physics)** → **future**
  (high intensity beams with low transverse beam momenta in an energy range where electrostatic accelerators are no longer and storage rings not yet applicable)

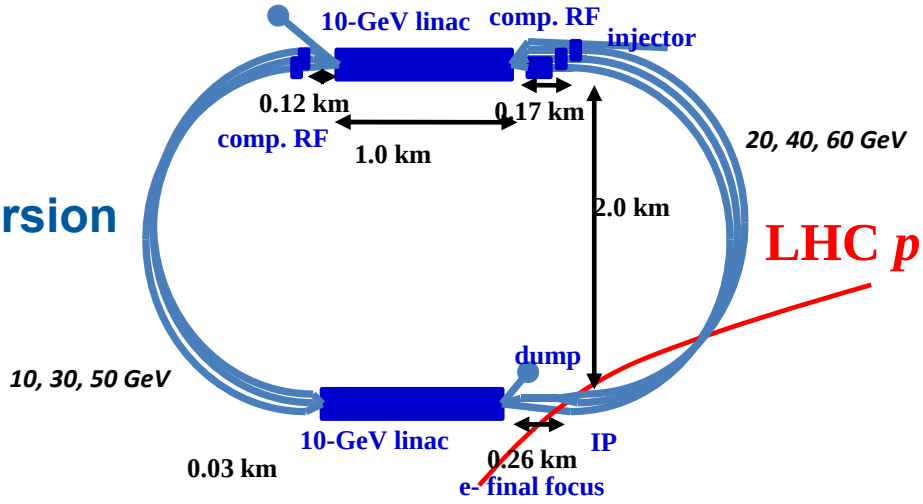
BROOKHAVEN NATIONAL LABORATORY

e.g. RHIC II
Cooling of 100GeV/u Au



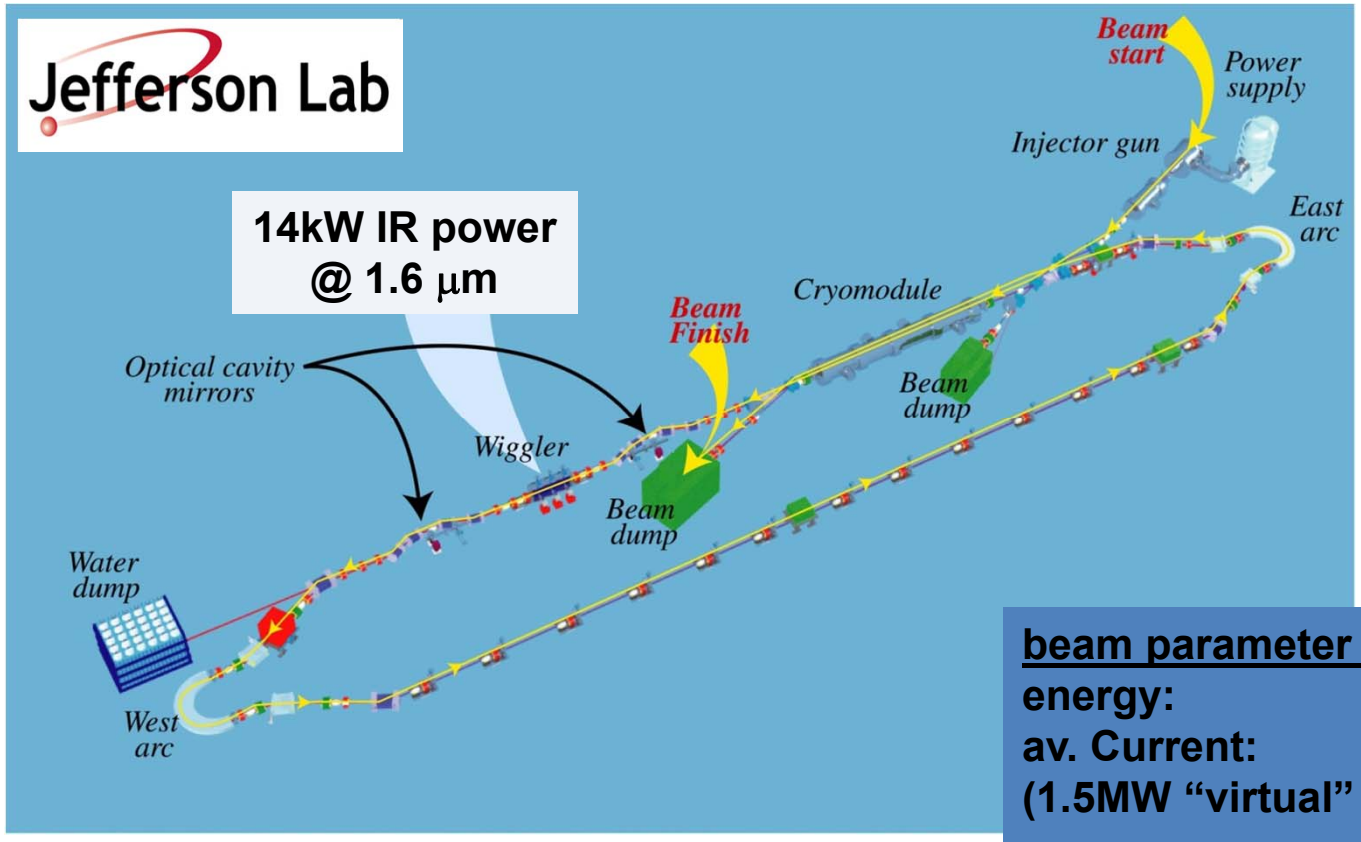
- **electron – ion collider with highest luminosities** → **future**
  (as replacement of the limiting electron storage ring)

e.g.
eRHIC / BNL: ERL-ring high lumi version
LHeC / CERN : LHC with 60GeV ERL



Applications of Energy Recovery Linacs

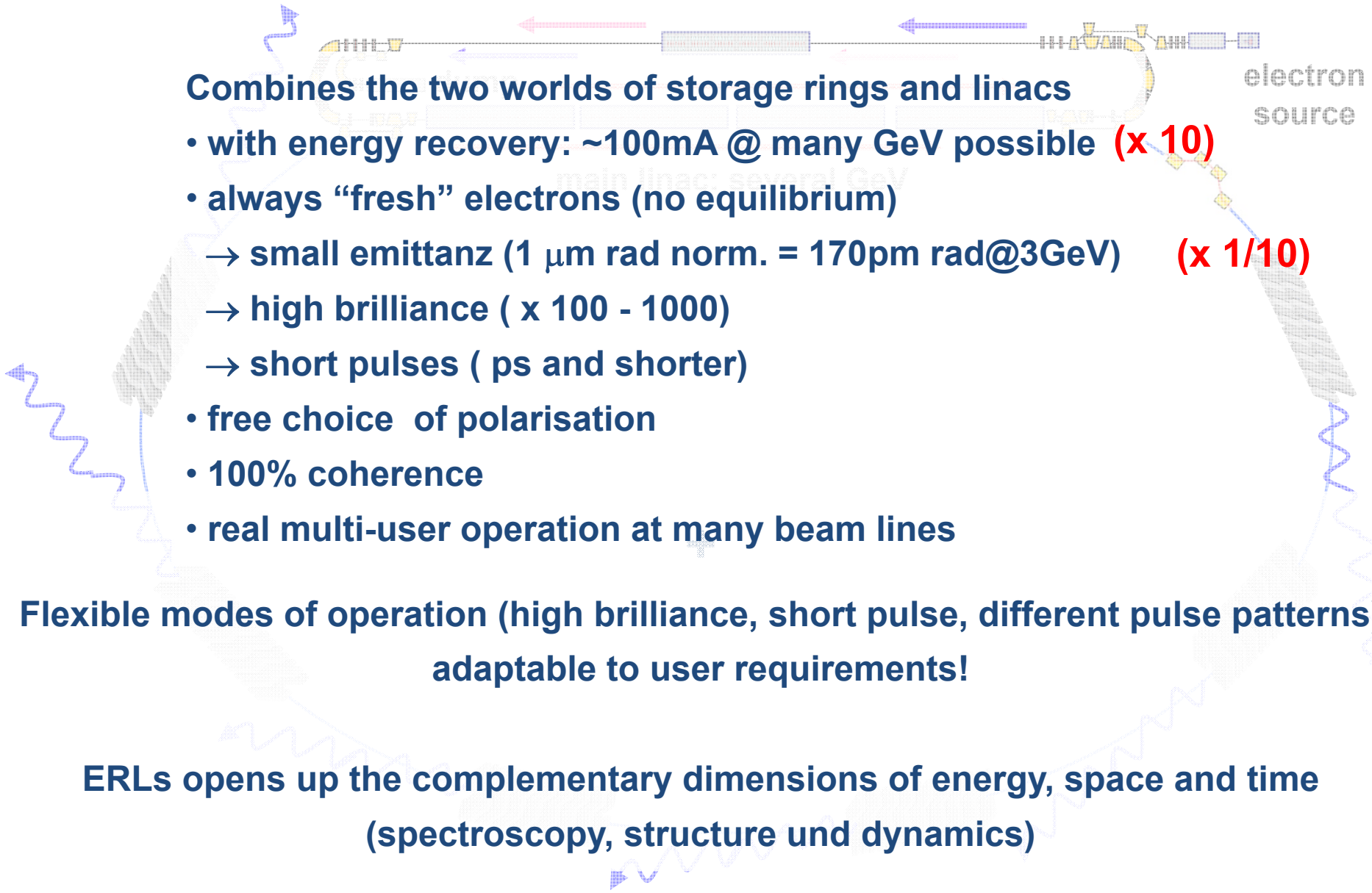
- **Basis for high power Free-Electron Laser (IR and UV)** → **presence**
  (e.g. JLAB (since 2000), JAERI, Novosibirsk ERL)



beam parameter achieved:

energy:	160MeV
av. Current:	9.1mA
(1.5MW "virtual" beam power)	
emittance (norm.):	7 μm
min. pulse length:	150fs

ERL as next Generation Multi-GeV, Multi-User SR-Source



Combines the two worlds of storage rings and linacs

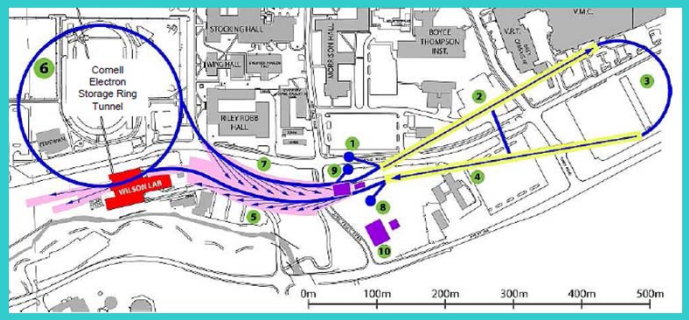
- with energy recovery: ~100mA @ many GeV possible (x 10)
- always “fresh” electrons (no equilibrium)
  - → small emittanz (1 μm rad norm. = 170pm rad@3GeV) (x 1/10)
  - → high brilliance (x 100 - 1000)
  - → short pulses (ps and shorter)
- free choice of polarisation
- 100% coherence
- real multi-user operation at many beam lines

Flexible modes of operation (high brilliance, short pulse, different pulse patterns) adaptable to user requirements!

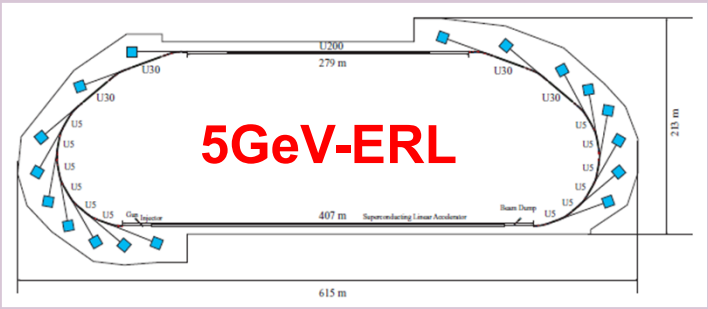
ERLs opens up the complementary dimensions of energy, space and time (spectroscopy, structure und dynamics)

ERL SRS world-wide:

X-Ray ERL
Cornell, USA



Future light source
KEK – JAEA, Japan



Many open questions:

Electron source: 100mA cw with $\varepsilon < 10^{-6}$ m rad (1.3GHz, 77pC) not yet demonstrated!

Injector: 100mA @ 5 – 10MeV = 500 – 1000kW beam loading (coupler, HOM damper)

Main-Linac: 100mA recirculating beam → Beam Break Up, Higher Order Modes
highest cw-gradients (>15MV/m) with quality factor > 10^{10} → cryo costs

Beam dynamics: flexible bunch compression, **CONTROL OF BEAM LOSS**!

Berlin Energy Recovery Linac Project: B*ERL*inPro @ HZB

100mA / 100MeV low emittance ERL that includes all the key aspects of large scale ERL

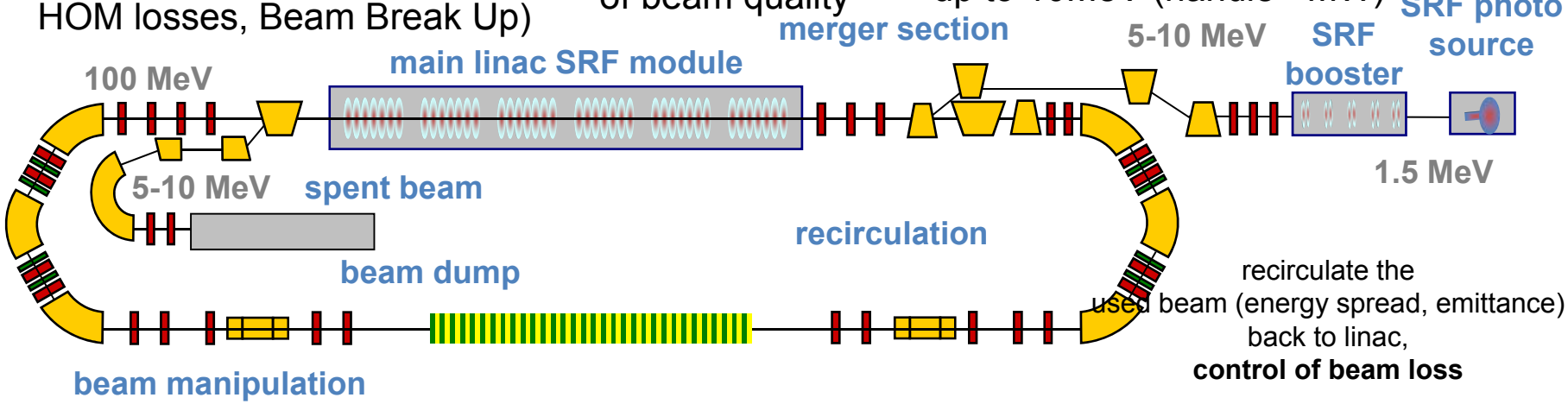
Accelerator Physics and Technology

accelerate/ de-accelerate to / from 100MeV (energy recovery, HOM losses, Beam Break Up)

transport through merger without deterioration of beam quality

generate a **low emittance (1mm mrad)** high current beam (**100mA**)

accelerate the beam up to 10MeV (handle ~MW)



recirculate the used beam (energy spread, emittance) back to linac, **control of beam loss**

manipulate the beam (pulse compression)

	High flux	flexibility
max. beam energy	100MeV	100MeV
max. current	100mA	
nominal bunch charge	77pc	up to ~10pC
pulse length	2ps	down to ~ 100fs
Rel. energy spread	~10^{-4} range	~10^{-2}
rep. rate	1.3GHz	variable
normalized emittance	< 1mm mrad	some mm mrad

Objectives

Demonstrate energy recovery with

emittance: **< 1 π mm mrad (normalised)**
current: **100mA cw**
(at 1.3GHz with 77pC bunch charge)
pulse length: **~ ps**

$$\varepsilon_n = \beta\,\gamma\,\varepsilon_{geo}$$

100MeV : γ = 200, β = 1

at ~ 100MeV and stable, reliable operation with „user-quality“ beam conditions

Challenges

- **electron source (sc rf gun), photocathodes (efficiency, life time) and laser-system**
- **emittance preservation (merger, compression)**
- **HOM-damping and suppression of beam break up (linac + optic)**
- **beam power (~MW) in booster and on dump**
- **control of beam loss**
  (light source: only some pA at some 100mA and 10h lifetime)

Objectives

demonstrate flexibility

- bunch compression well below ps
- higher bunch charges
- variable pulse repetition rates

→ explore the parameter space
emittance, pulse length, energy spread, charge

experiment

- exploration of ERL applications

„The experiment“ for BERLinPro + ERL SRS

education

- Bachelor- and Master Thesis's / Dissertations

B*ERL*inPro: Milestones

Application (to HGF) in 2008 (excellent evaluation); approval in 2010

Project Start: 01.01.2011; 25.8Mio€ (5Mio€ Berlin, 15 Mio€ HGF, 5.8Mio€ HZB)

MS 0	04/2011	first beam from a sc rf photo electron source
	08/2012	TDR ready
	2012	ground braking building
MS 1	2013	building and infrastructure ready
MS 2	08/2013	first beam from test source with new cathode
	04/2014	booster module ready
MS 3	07/2014	sc rf photo source in *BERL*inPro
MS 4	07/2015	first beam booster
	09/2015	linac module ready
MS 5	12/2015	first beam through linac
	2016	recirculation, energy recovery → ERL Physik Program starts

Preliminary

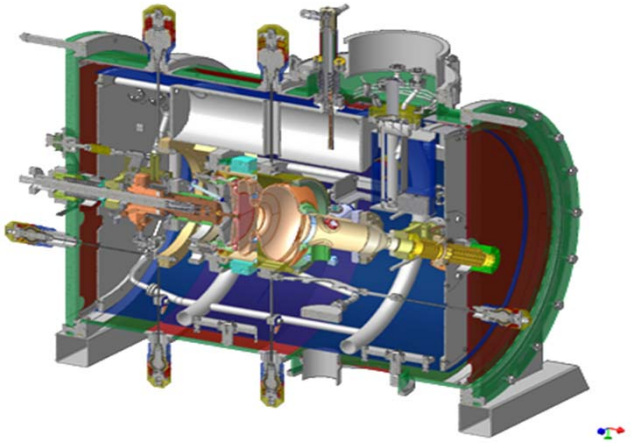
Status: super conduction RF photo electron source

Stage A (Beam dynamics):
Study beam dynamics
of SC RF photoinjector:
– Emittance
– Field levels
– Stability
• Full SC mass design
• Starting point for design
and operation of SRF gun

Stage B (Peak Brightness):
Study + develop cathode
insert into SC injector:
• Lifetime and QE
of cathode materials
• Reliable cathode
replacement scheme

Stage C (High avg. Current):

• SC design for ERL design
current
• High power operation
• HOM damping
• Cathode lifetime

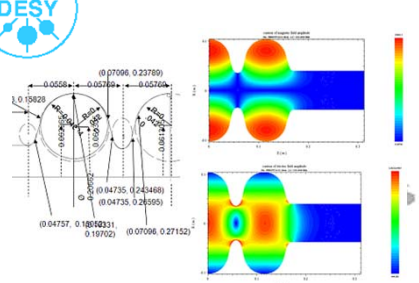


Status: super conduction RF photo electron source

Stage A / Gun 0

The cavity collected some 20.000 air miles…
keeping its Q vs E_{pk} performance

EM Design at DESY in Hamburg



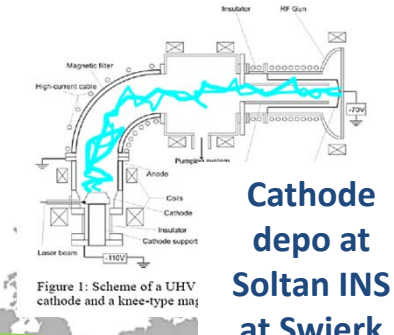
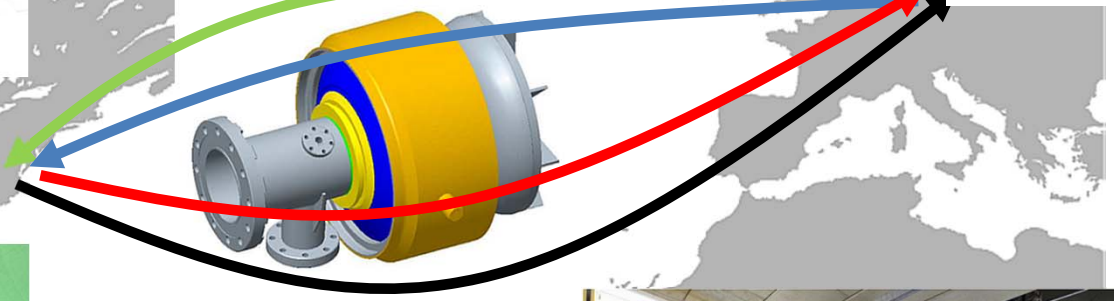


Figure 1: Scheme of a UHV cathode and a knee-type mag

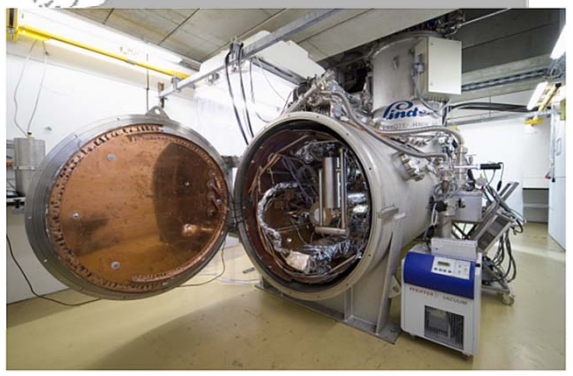
Cathode depo at Soltan INS at Swierk



Production, RF-tests, Cleaning

Jefferson Lab

Test of cold mass and beam operation at HZB in Berlin



Status: super conduction RF photo electron source

Stufe A / Gun 0

Cold mass:
already integrated into HoBiCaT cryo module

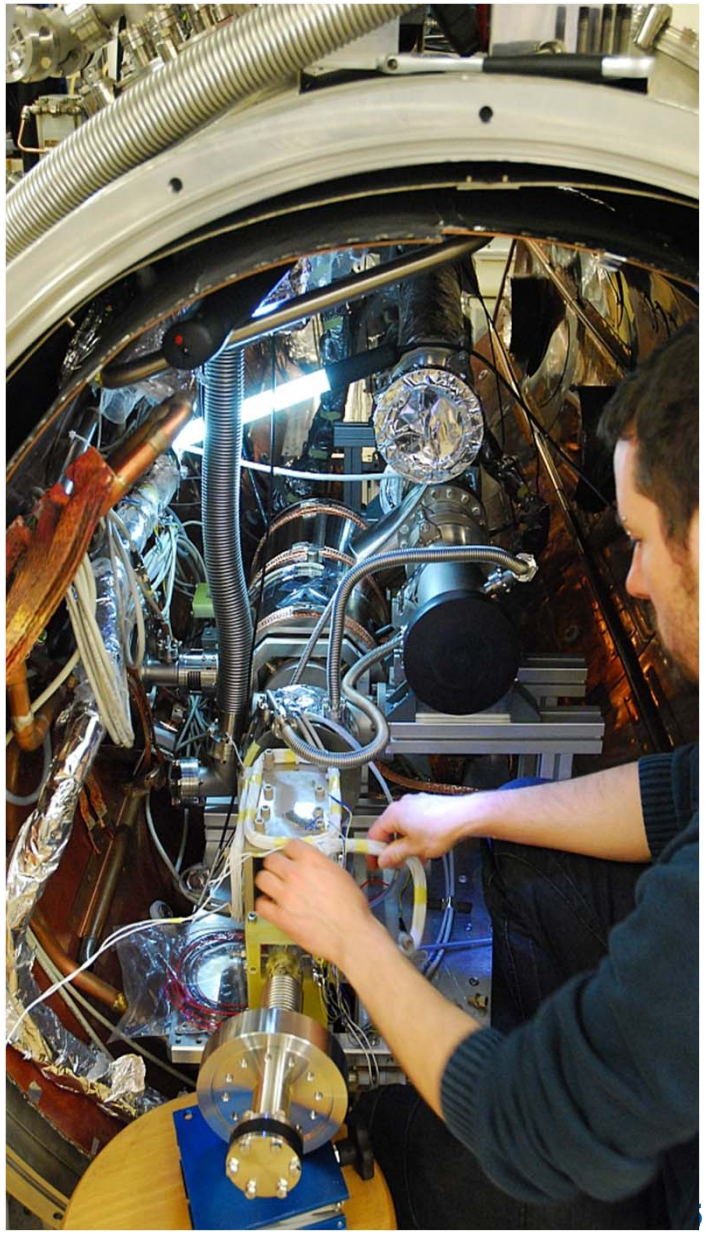
UV-Laser:
15 kHz reached (target 30 kHz) with design values
beam transport installed, synchronisation

Electron beam diagnostics:
beam line installed, tests of cabling

Operation allowance (rad. protection):
received

rf-tests of cavity:
will start next week, check of quality factor Q_0 and max. gradients

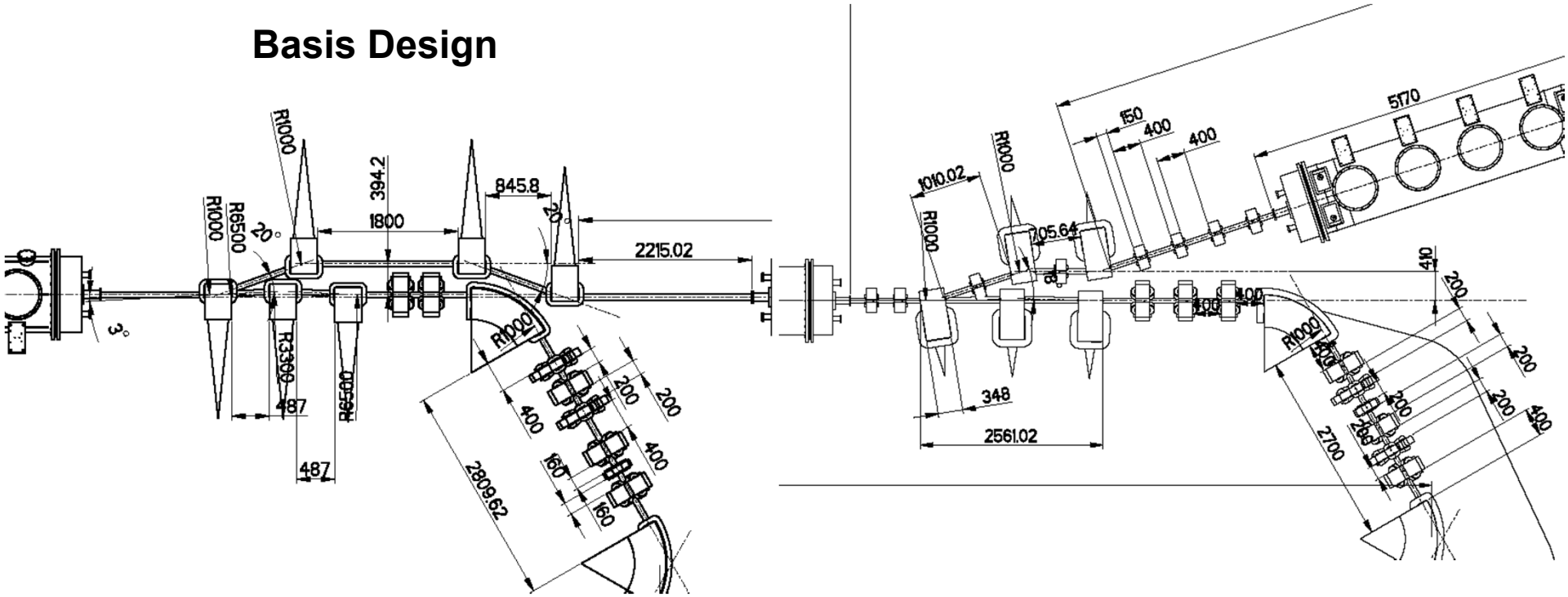
beam tests:
immediately after rf-tests
→ beginning of April



Merger Designs:

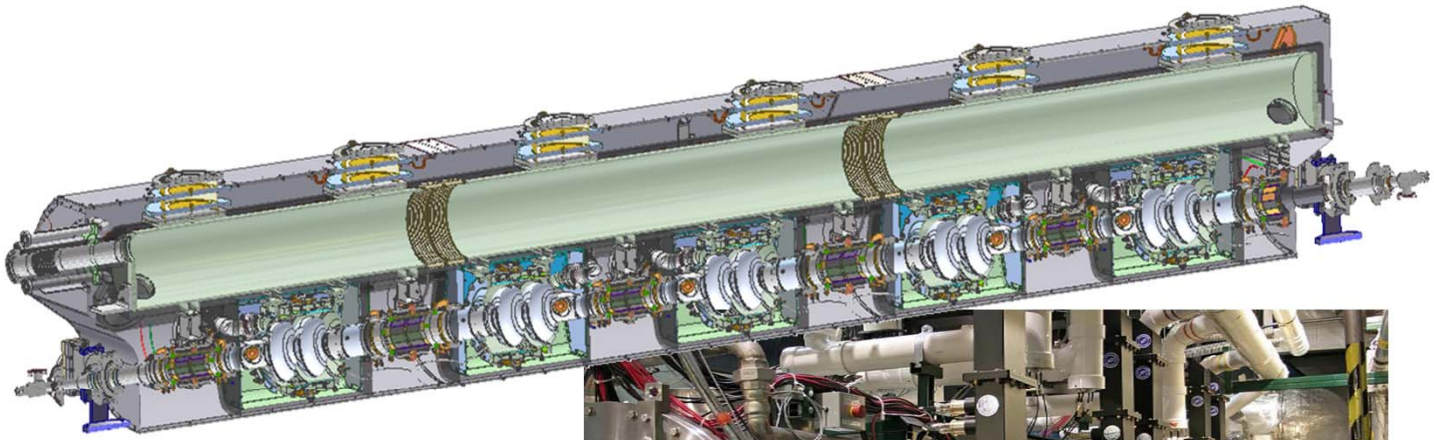
Dog-Leg Design

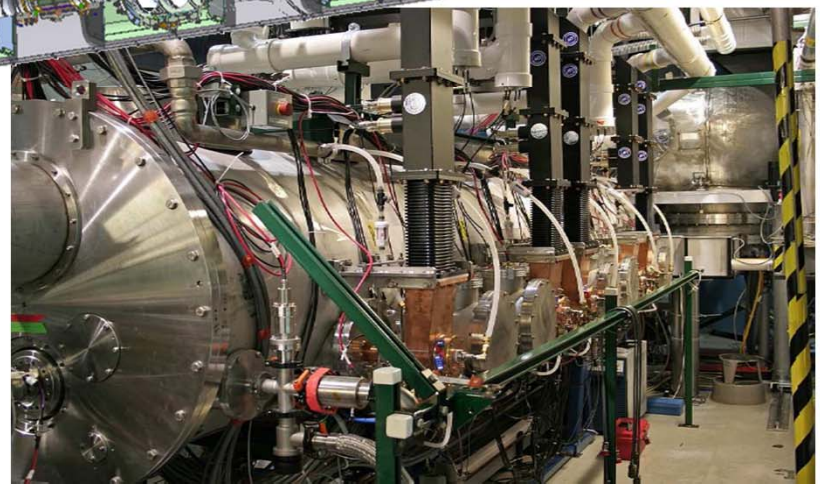
Basis Design



- great influence on machine performance
- basis layout: fulfils requirements of basis parameter
- Dog-Leg Layout: allows for shorter pulses at higher charges
- Influences machine size (bunker space)

Status: scRF systems – booster and linac cavities





booster
+ sc rf

Booster Technology together with Cornell University

Linac cavities:
Verbundforschung +
Accelerator Research and Development Initiative
Helmholtz-Association

Universität Rostock Traditio et Innovatio

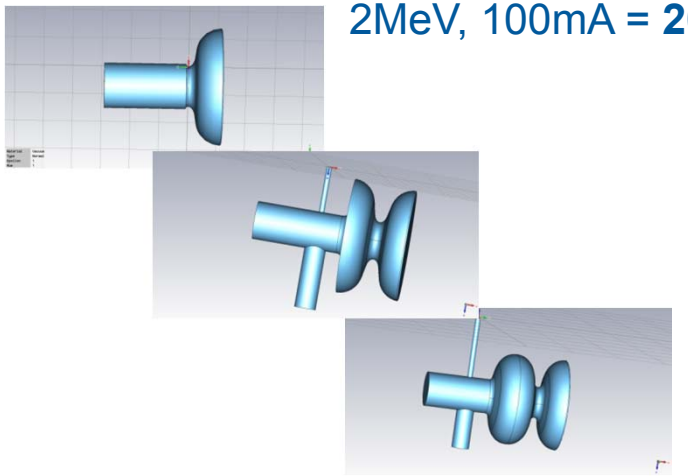
DESY

technische universität dortmund

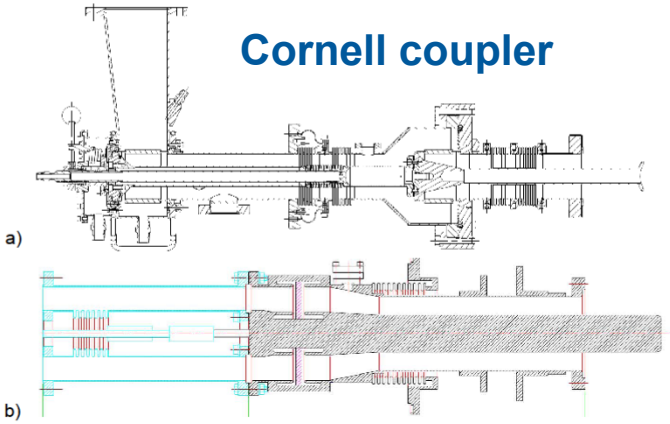
Status: scRF systems – high power components

cavities for electron source

2MeV, 100mA = **200kW**



Cornell coupler

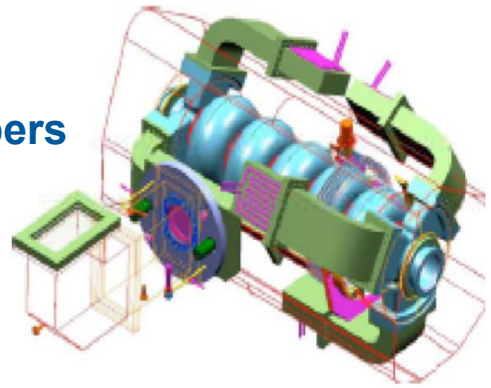


KEK coupler

300 kW Toshiba klystron at KEK

8.5 kW transmitter (Bruker)

CEBAF cavity with waveguide HOM dampers 5 cells? 7 cells?

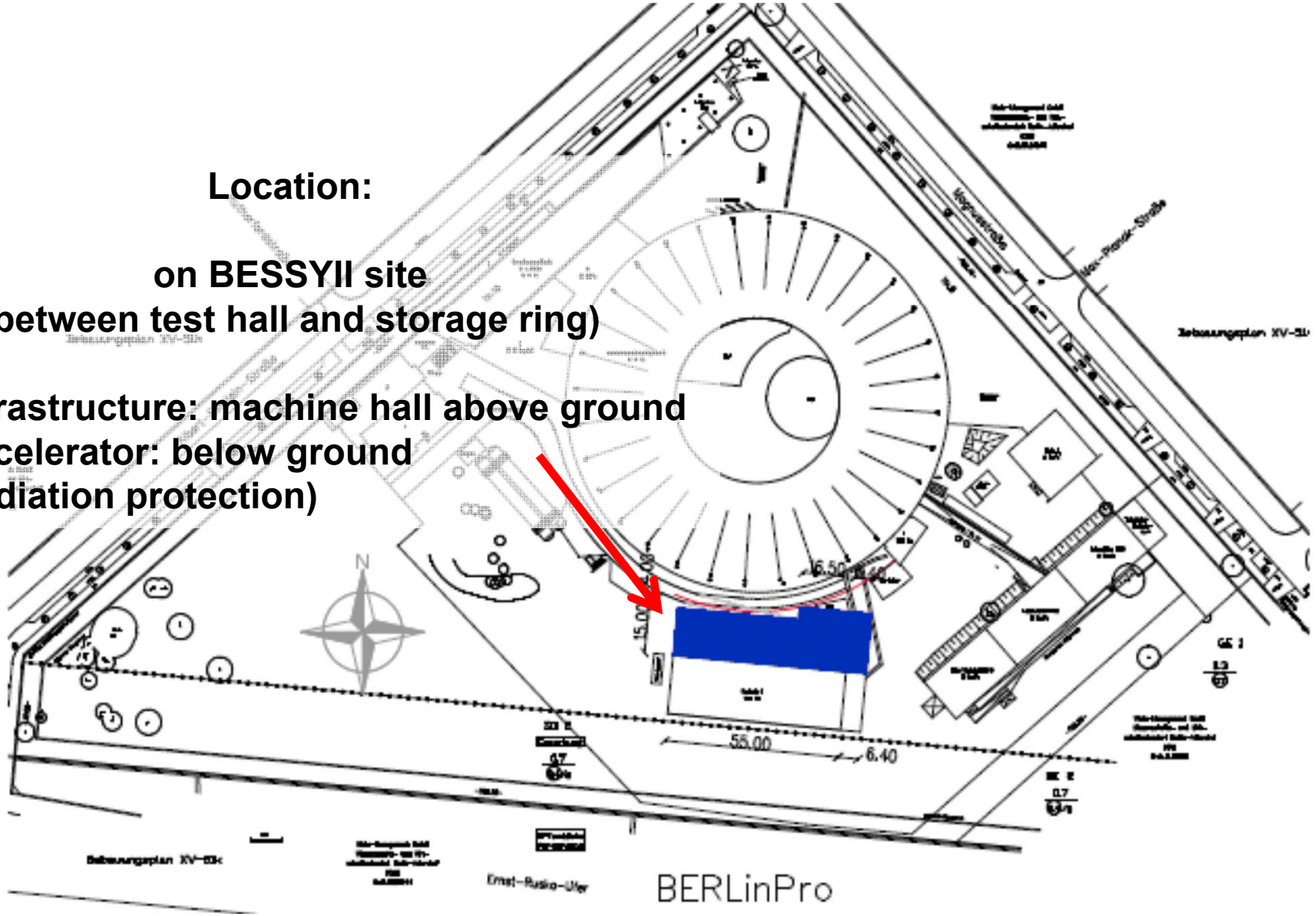


Status: Building + Infrastructure (Planning)

Location:

on BESSYII site
(between test hall and storage ring)

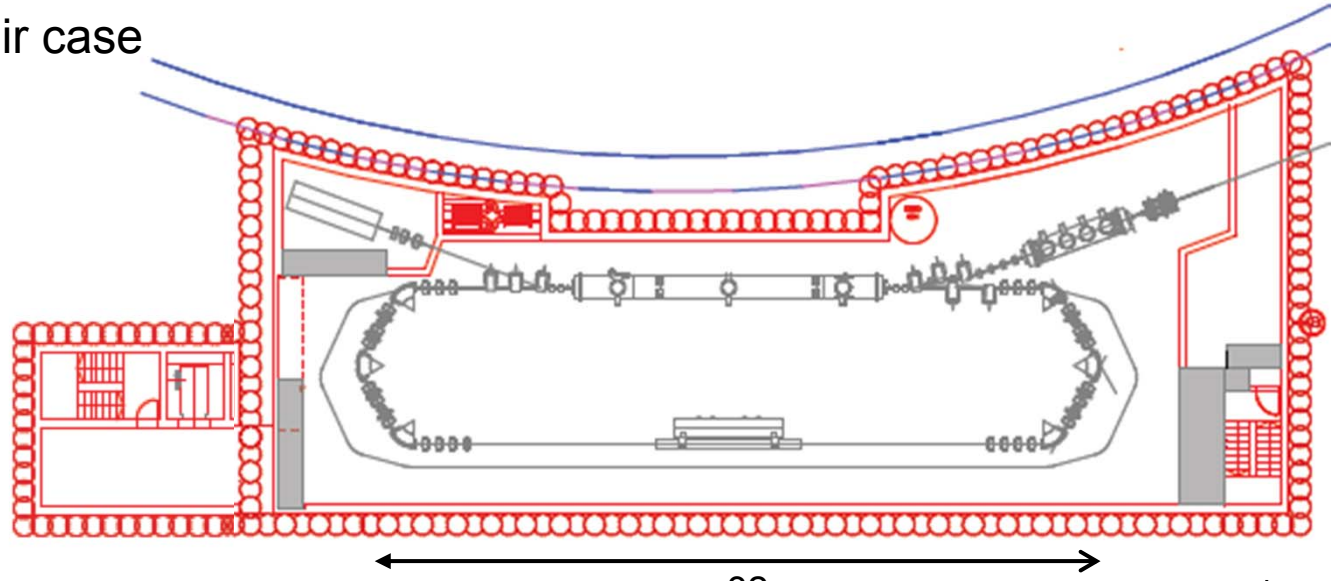
Infrastructure: machine hall above ground
Accelerator: below ground
(radiation protection)



Status: Building + Infrastructure (Planning)

current footprint (under ground) – still work in progress

equipment shaft +
stair case



2nd stair case +
media supply