BESSYII and B*ERL*inPro

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ESLS XVIII

elettra

Trieste
25. – 26.11.2010

Menu

- Helmholtz-Zentrum Berlin and BESSY
- Status of BESSYII accelerator projects
  - fast orbit feedback
  - new injector linac
  - top-up operation
  - femto-slicing
- B*ERL*inPro
  - compact ERL project is funded
- BESSY II perspectives

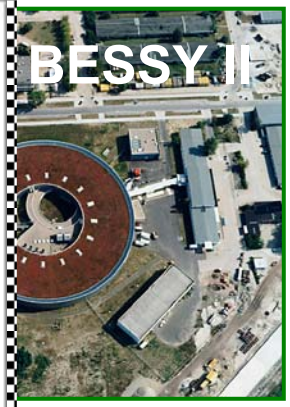
Helmholtz-Zentrum Berlin: Science with photons + neutrons

HZB: Member of the Helmholtz Association like DESY, KIT/ANKA, GSI

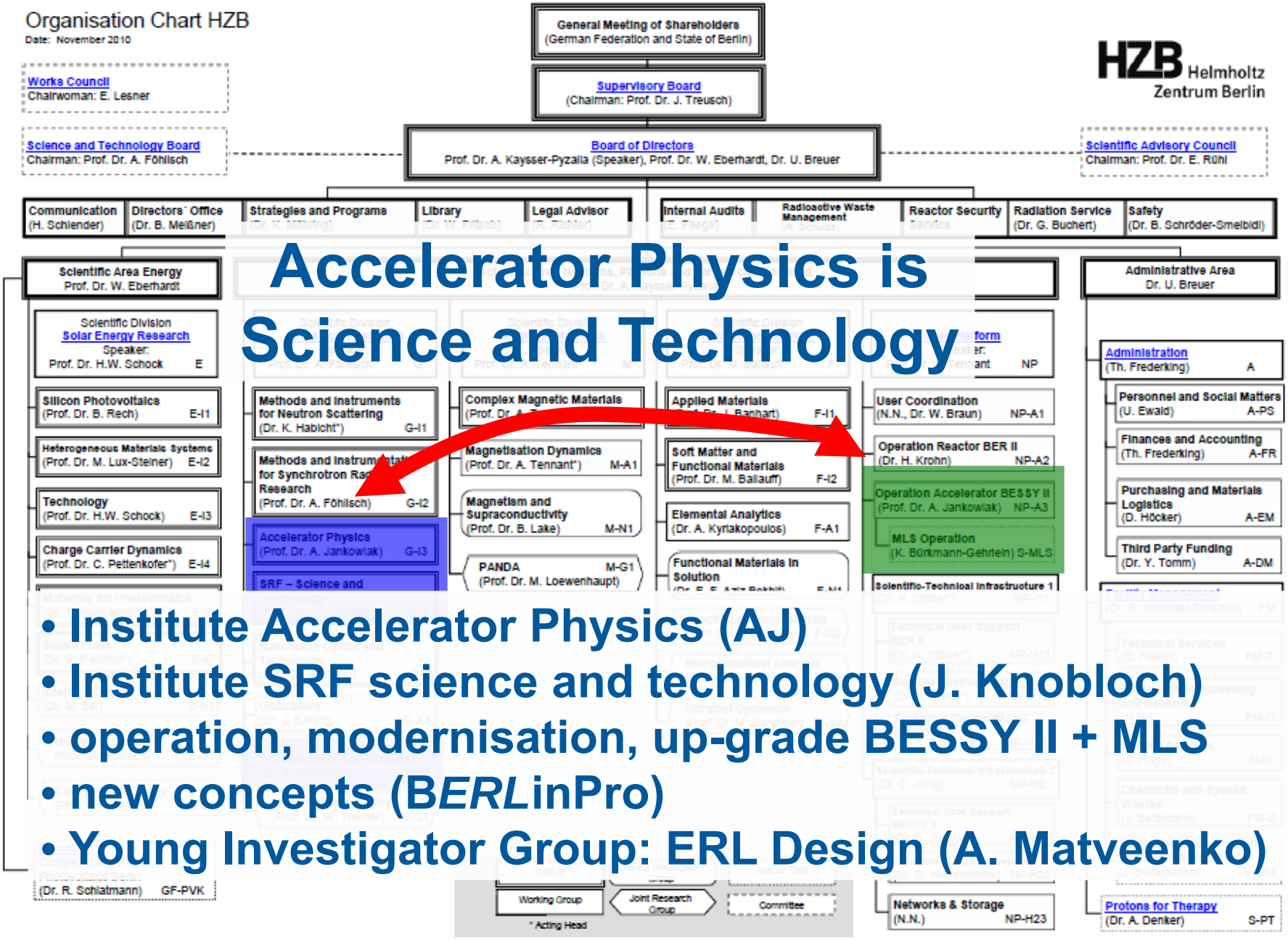
Wannsee:
Hahn-Meitner Institut
Research Reactor BERII

merger
01.01.2009

Adlershof:
BESSY GmbH
Light Sources BESSY II + MLS



Helmholtz-Zentrum Berlin: The new structure

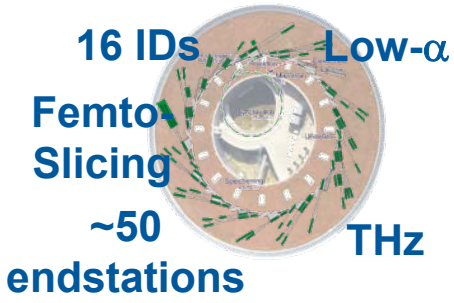


Accelerator Physics is Science and Technology

- Institute Accelerator Physics (AJ)
- Institute SRF science and technology (J. Knobloch)
- operation, modernisation, up-grade BESSY II + MLS
- new concepts (B*ERL*inPro)
- Young Investigator Group: ERL Design (A. Matveenko)

BESSY II Operation

Beamtime Schedule in 2009:



- Standard Mode: Hybrid, Decaying Beam, fs-Slicing on Demand
  - fs-Slicing OFF: 300x 0.96mA + 1x 10mA, 0 mrad Bump
  - fs-Slicing ON : 297x 0.94mA + 3+1x 5mA, 0.6 mrad Bump
- Every Monday: LHe Refill, Maintenance, Commissioning
- Single Bunch:
  - 2x 2weeks 20mA
- Low Alpha: 4x 3 days, 2 shifts a 12h
  - "THz mode": 15mA, 1.75kHz (non-bursting)
  - "Short Pulses": 40mA, 1.7kHz or lower
- Machine Development / Beamline Comm.: 9 weeks
- Shutdown: 2 x 3weeks plus 3 days

Last 12 month: 4290h hybrid, 742h single, 584h low-α, 1040 commissioning

BESSY User Shift Schedule

Shift	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Early 7-15h	Machine Servicing						Main User PTB except where denoted with an asterisk in the operation schedule
Late 15-23h	ID/BL Commis-sioning						
Night 23-7h	Machine Commis-sioning						Machine Commis-sioning

User operation | Parasitic use possible (in general, special beam conditions) | See TV Monitor for status | No user operation

User/Machine support: Monday 7:00 -23:00, Tuesday 7:00 - Sunday 23:00

Change of Operation Concept:

- BESSYII control room service since 1998:
  - pool of nearly all technicians, engineers and scientists of machine group
- Present Plan and Modification:
  - dedicated operations group (for BESSY and MLS)
  - ~50% machine operation / ~50% special skills (12 persons)
- Status:
  - 7 persons hired. Well trained at the MLS, BESSY needs to measure up.

Fast orbit feedback (FOFB) Phase I

Status:

Fast BPM Data Acquisition: Existent (100%)

- 2.4 kHz Sampling Rate
- FFT Diagnostic Use: 0.5 – 200Hz

Fast Set Point Distribution: Operational (100%)

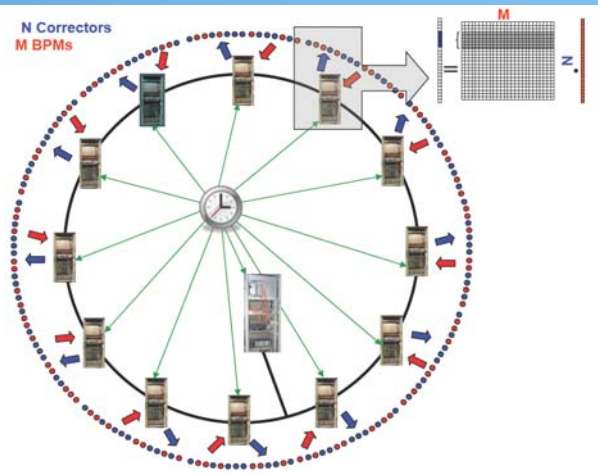
- Digital I/O board modified
- Reflective Memory: BPM DAQ, PS IOCs
- Known Time Budget: < 8ms/cycle

Optimized Algorithms: currently tuned (20%)

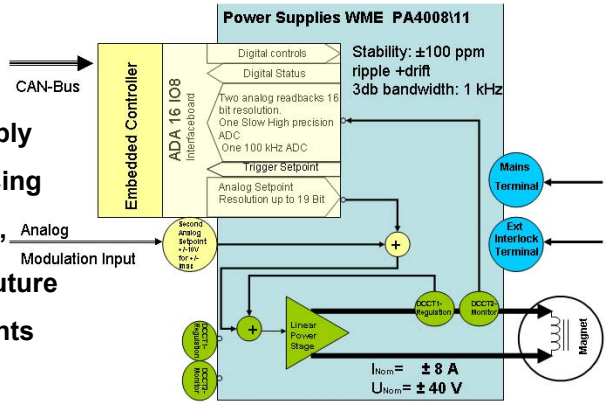
New Fast Powersupplies: 8/112 Installed

- Transfer function: up to 200Hz
- Control flexibility
- Comparable Specs @ +/- 8A, 40V

Components of General FOFB Set-Up



Power Supply Control: Using existing I/O, Open for Future Requirements



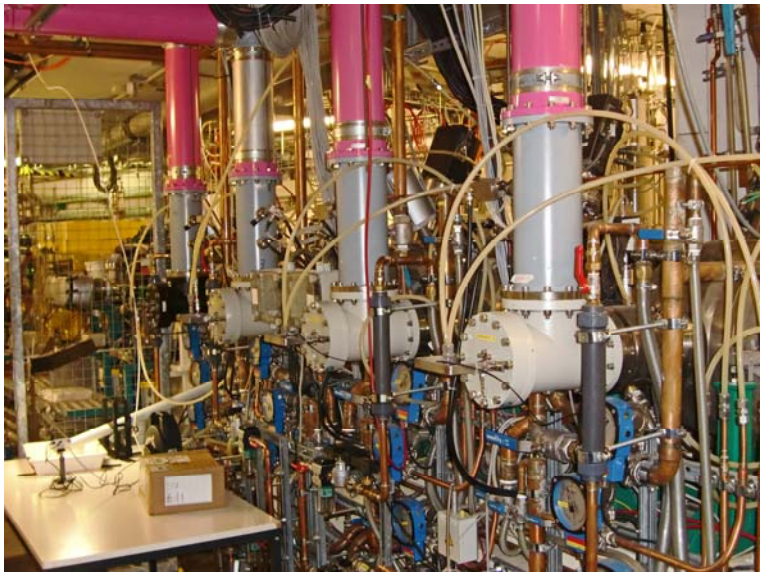
- **Purchase and Installation of all new 112 corrector power supplies till beginning of 2012**

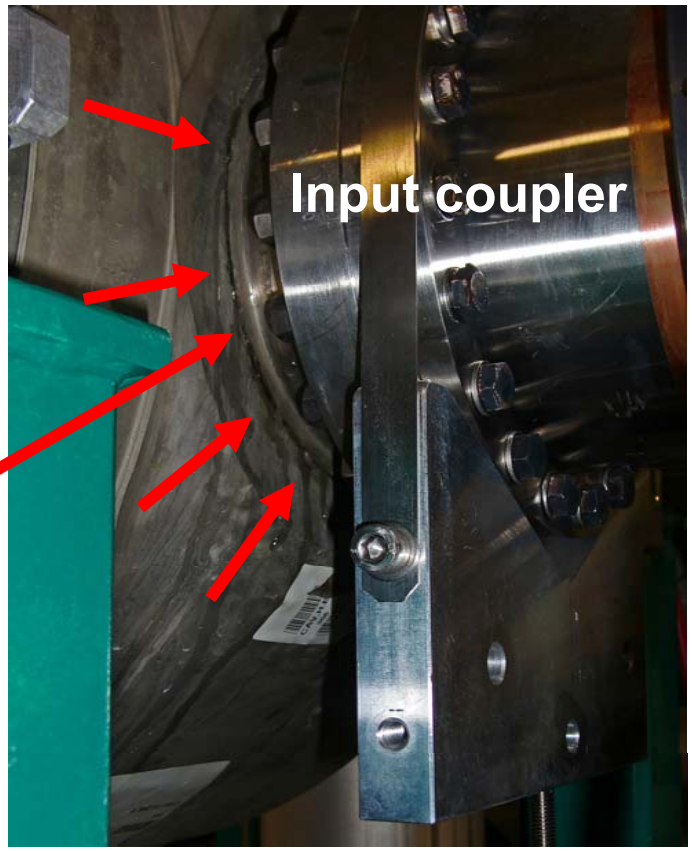
- **Incremental setup, characterisation, tuning**
  → routine operation of fully completed system mid 2012
  → expected bandwidth 50 - 100 Hz

This was the plan till 01.11.2010

Preservation slows down up-grade

01.11.2010 massive water leakage at one out of four DORIS cavities detected





water leakage at welding joint

- cavity replaced by our last spare (DORIS)
- now BESSY II operates without backup
  (three cavity operation with reduced parameter possible; but no operational headroom)
- replacement of cavities was planed for 2009/2010; sacrificed by HZB merger
- slow down FOFB upgrade and immediately start purchase of two HOM damped cavities (modified BESSY design) → will take ~ 12 – 18 month
- design of new girder + cooling water distribution to install 2 new cavities together with 2 DORIS cavities → later replacement of all old DORIS cavities

New injector linac (from THALES)

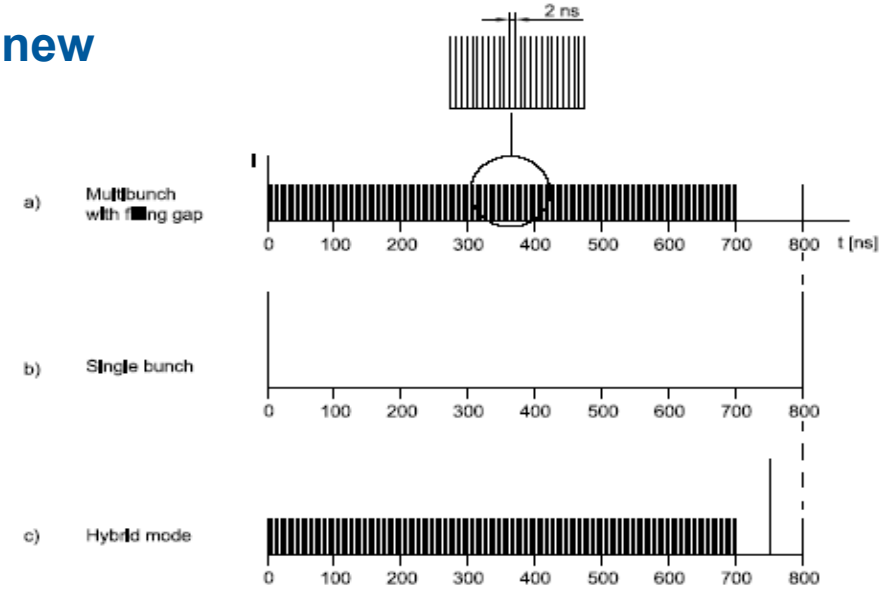
Why replacing the microtron by a new injector linac?

Increase capability for flexible bunch population patterns (bunch pattern equalizer)

→ for femto sec slicing, and other time domain experiments

Provide high single bunch current

→ for top-up operation



Microtron 50MeV, 10Hz max.

Multi-Bunch: 3nC

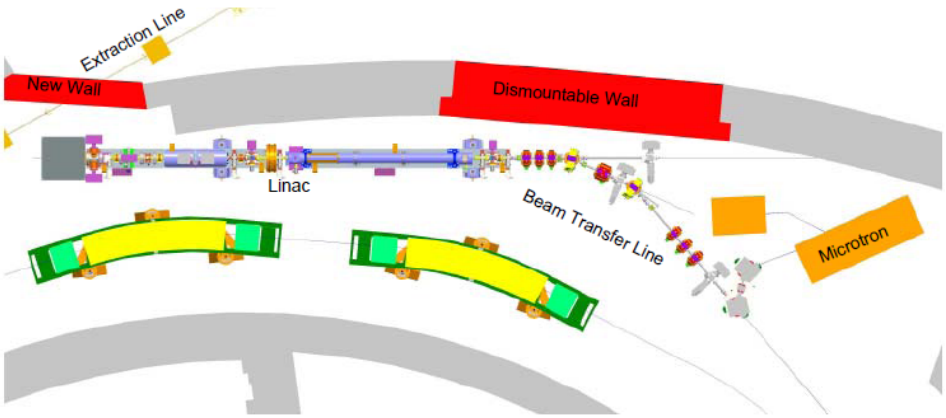
Single-Bunch: 0.012nC

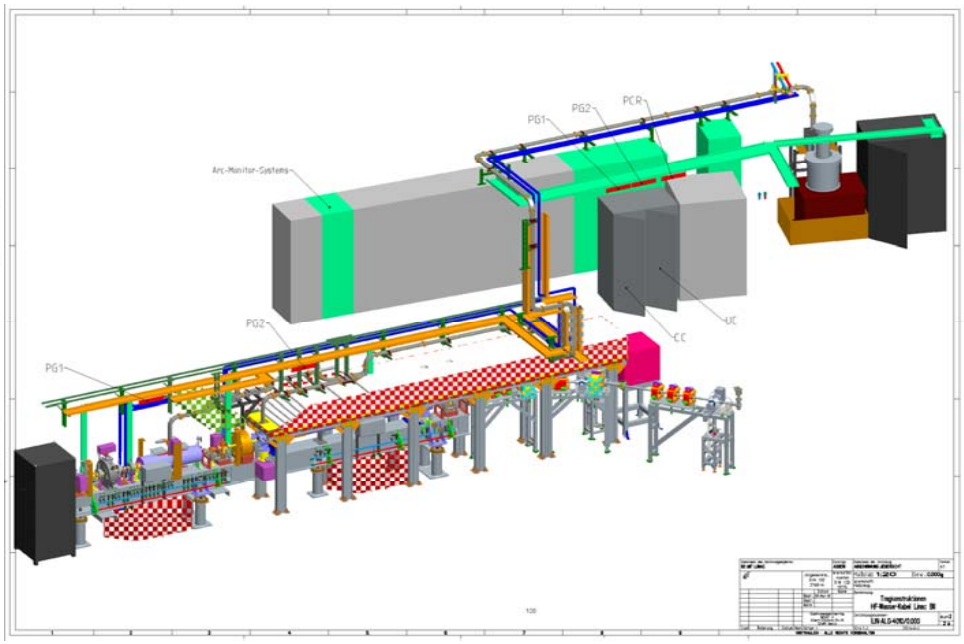
Linac 50MeV, 10Hz max.

Multi-Bunch: 3nC

Single-Bunch: 0.35nC (x30)

New injector linac



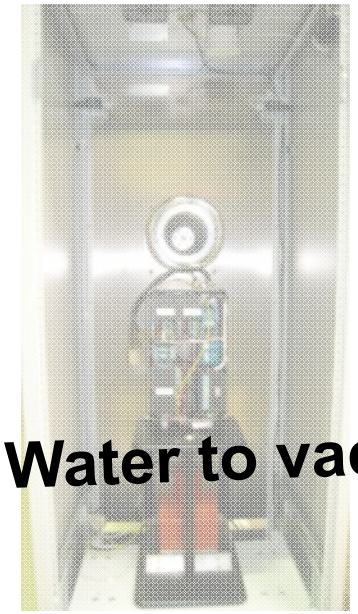


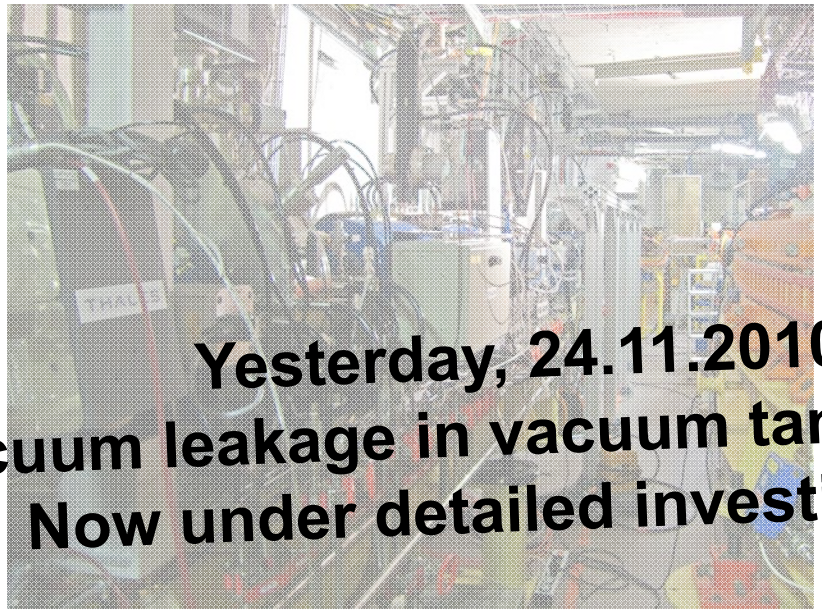
- Installation of “big” linac components take place in BESSY shutdown 08/09-2010
- Installation continued parallel to BESSY user operation (cabling, interlock, hardware tests)
- 18.10.2010: successful verification of radiation protection concept and installations
  → operation permit issued 28.10.2010
  → rf-conditioning, gun conditioning started, first beam tests 12/2010
- 02-2011: site acceptance test of linac

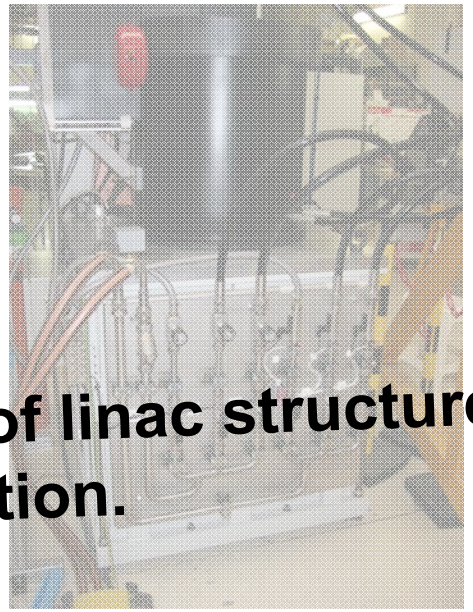
New injector linac

electron gun and linac in booster synchrotron tunnel

klystron modulator
on galllery







Yesterday, 24.11.2010:
Water to vacuum leakage in vacuum tank of linac structure.
Now under detailed investigation.

Repair on site ?

- 03-2011 start up of transfer channel linac to booster
- 03/04-2011 first injections into synchrotron
- start of injection into BESSY

still parallel to user operation /
in accelerator test shifts

Repair in factory ?

(de-installation needs deconstruction of concrete brick wall,
BESSY shutdown for 2 – 3 weeks)

- training of operators
- establishing of linac operation routines

→ standard user operation

microtron still available
as fall back

Top-Up operation

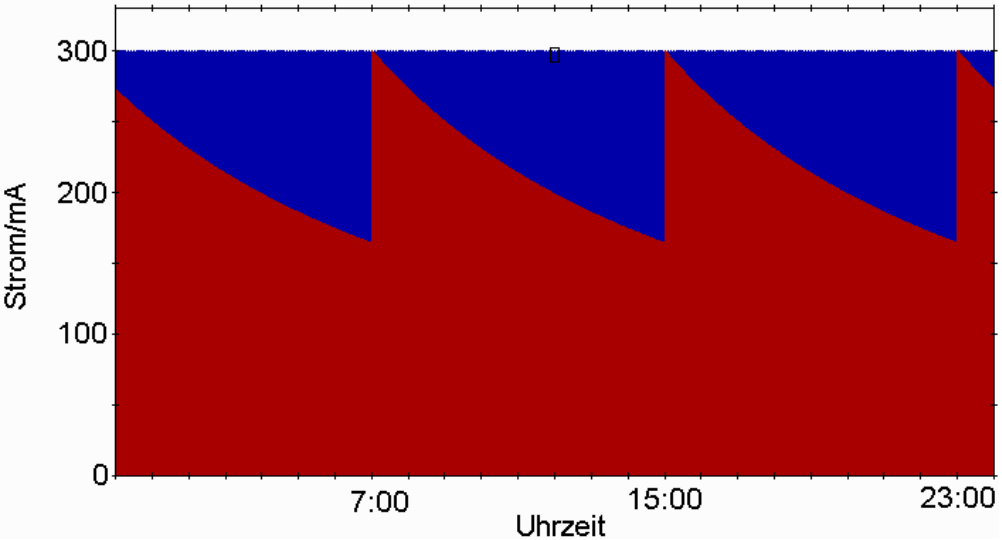
"Continuous" injection of flexible adjustable charge portions
(for 10^{-3} current stability at 300mA and τ=8h $\rightarrow$ 0.24nC all 30s)

Accelerator and beamlines
in optimized thermal equilibrium !
(Goal: Heat death of the universe)

$\rightarrow$ increased stability

Constant single bunch charges

$\rightarrow$ higher efficiency

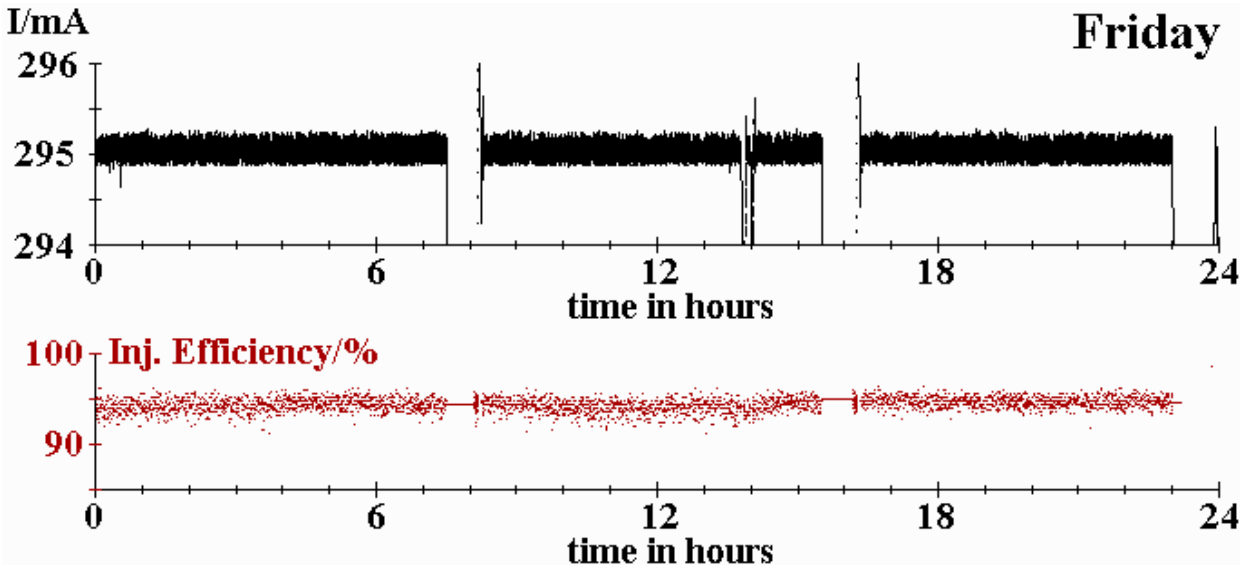


- Injections with open beam shutters
- Injections with closed IDs (to be precise: under all possible configurations of the complete set of IDs)

Drawback: BESSY was not designed for TopUp (injection systems, shielding, ...)
- **radiation protection (must guarantee nearly the same losses as in decay mode)**
  $\rightarrow$ guarantee 90% injection efficiency under all conditions
  $\rightarrow$ establish new restricted areas near to front ends
  $\rightarrow$ test period necessary with BESSY floor as control area (restricted access)

Top-Up operation

Test Run in 02-2008: (only selected user, BESSY floor was inaccessible)



- large orbit distortion of stored beam due to non closure of injection bump (~mm)
- injection efficiency strongly depends on ID settings; especially APPLE II undulators (dynamic aperture limitation)

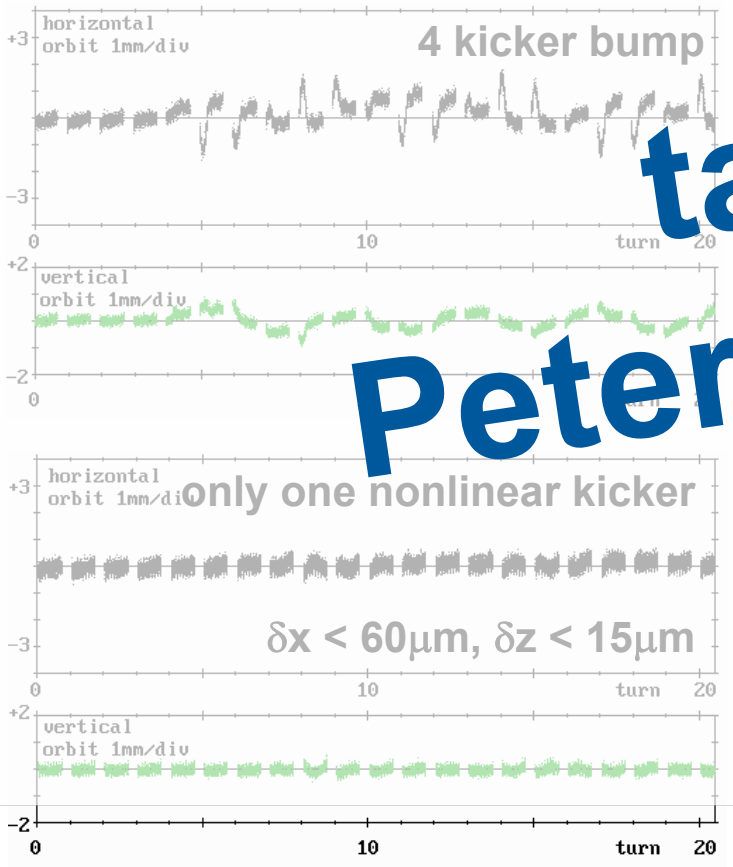
→ new concept for injection kicker ("non linear kicker" = no field on axis of stored beam)
→ sophisticated compensations schemes for IDs ("magic fingers", "L-shims", "current filaments")

Top-Up operation

Shutdown 08/09-2010

- 2nd current monitor for injection efficiency interlock
- new power supplies for booster sextupoles (dynamic chromaticity compensation for high single bunch currents)
- installations for radiation interlock systems

- Installation of first prototype of a “non linear pulsed injection kicker” (worldwide first)



talk

Peter Kuske

- immediately allows for accumulation (efficiencies > 80% and more, not fully optimised)
- up to 300 mA → no beam instabilities beyond impedance OK)
- dramatically reduced orbit distortions
- unfortunately kicker heated up (beam induced) → vacuum deteriorated → kicker needs to be dismounted

→ modification seems to be possible

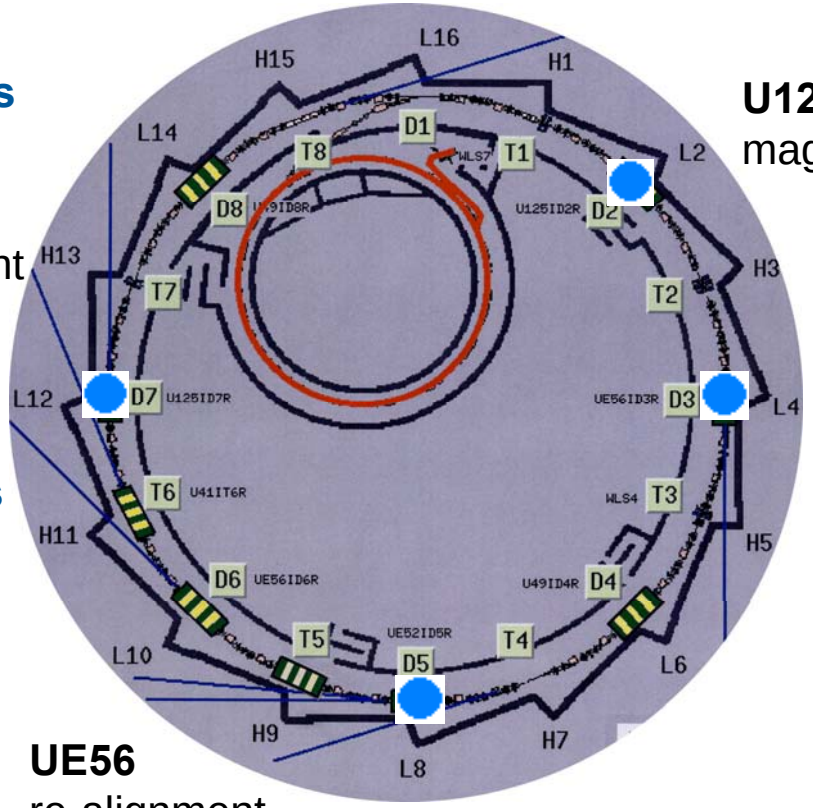
Top-Up operation

- **1.Q - 2011**
  interlock systems ready
- **2.Q - 2011**
  high single bunch currents from new linac ??
- **3.+4. - Q 2011**
  all IDs compensated and determination of influence on inj. efficiency (alone and as orchestra)
  Outcome ?
  → maybe parameter space of certain IDs needs to be restricted for TopUp operation
- **2012 Start Top-Up**

Still to be studied:

- operation of 7T multipole wiggler with 20K vacuum chamber in terms of **LHe consumption and refilling procedures**
- re-organisation of BESSY operation under Top-Up conditions (Top-Up periods as long as possible, low-α mode, ...)
- Influence of new optics and IDs (SISSY)
- Establishing a machine model describing BESSY as it is

UE112
more current filaments

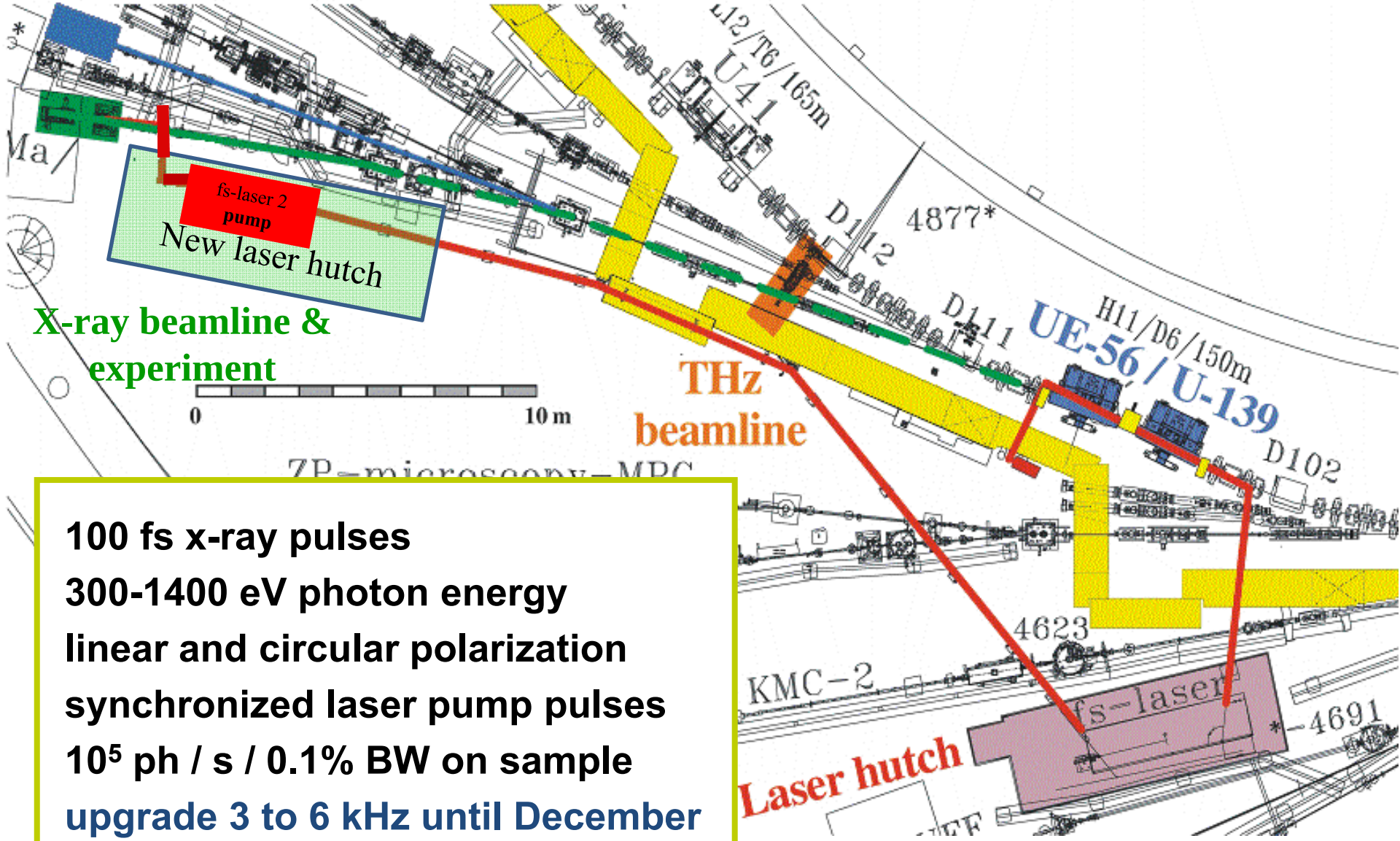


U125
magic finger

UE56
work in progress

UE56
re-alignment

Upgrade Femto-Slicing



100 fs x-ray pulses

300-1400 eV photon energy

linear and circular polarization

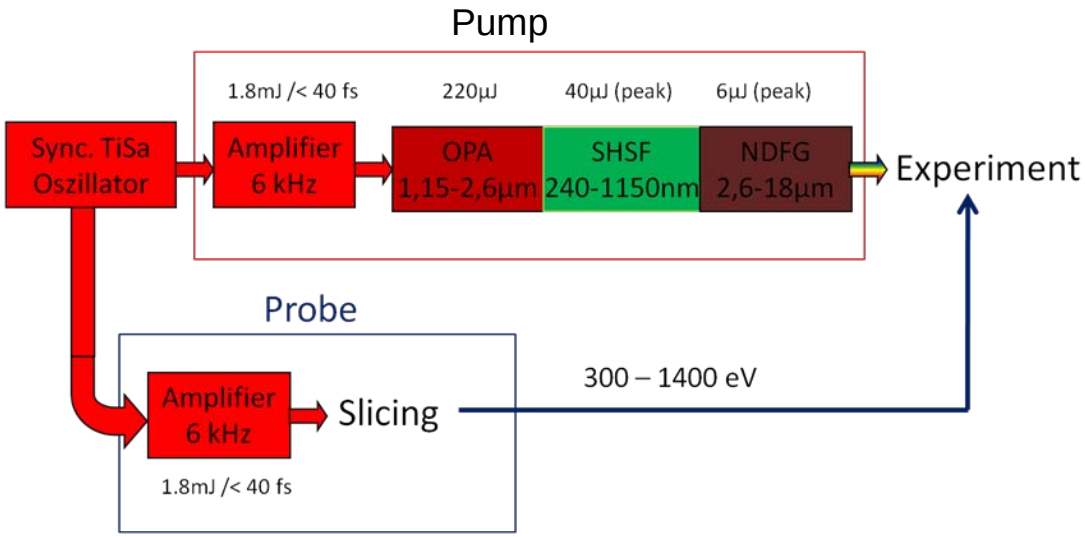
synchronized laser pump pulses

10^5 ph / s / 0.1% BW on sample

upgrade 3 to 6 kHz until December

Laser Upgrade 2010 – FemtoSPEX*

Replacement of the slicing laser system by a coupled two amplifier system seeded from one oscillator



Objectives

- **6 kHz repetition rate (instead of 3 kHz)**
- **Variable wavelength excitation 0.24-18 µm**
- **Improved day-to-day performance**

Commissioning underway – variable wavelength 2011

Further projects

- Upgrade zone plate monochromator
- Energy dispersive detection
- Long-term: in-vacuum undulator and hard x-ray beamline

* BMBF funding, Prof. U. Bovensiepen (Univ. Duisburg-Essen)

BERLinPro = Berlin Energy Recovery Linac Project

100MeV, 100mA ERL that includes all the key aspects of ERL based light sources

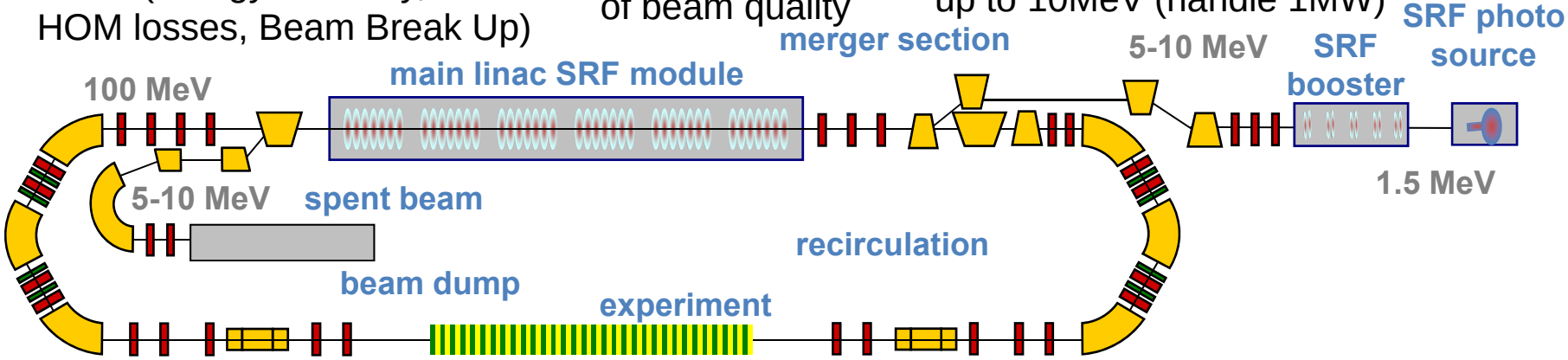
A accelerator science and technology experiment

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

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

transport through merger
without deterioration
of beam quality

accelerate the beam
up to 10MeV (handle 1MW)



beam manipulation

manipulate the beam
(pulse compression)

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

	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}	~10^{-3}
rep. rate	1.3GHz	variable
normalized emittance	< 1mm mrad	some mm mrad

- Application to Helmholtz-Association (HGF) in 2008
  → Excellent rating for B*ERL*inPro (together with FLASHII)

- Lack of funding for 2011 + 2012 (due to change in financing for large investments > 15Mio€ of HGF)
  → Decision of Helmholtz-Asociation to fully finance only one project: FLASH II

but:

- June 2010: Federal State of Berlin and HZB decide to provide each 5Mio€ for 2011 to 2012

- 8th of October 2010: Senat of Helmholtz-Association decide to finance B*ERL*inPro with 15Mio€ in 2013 - 2015

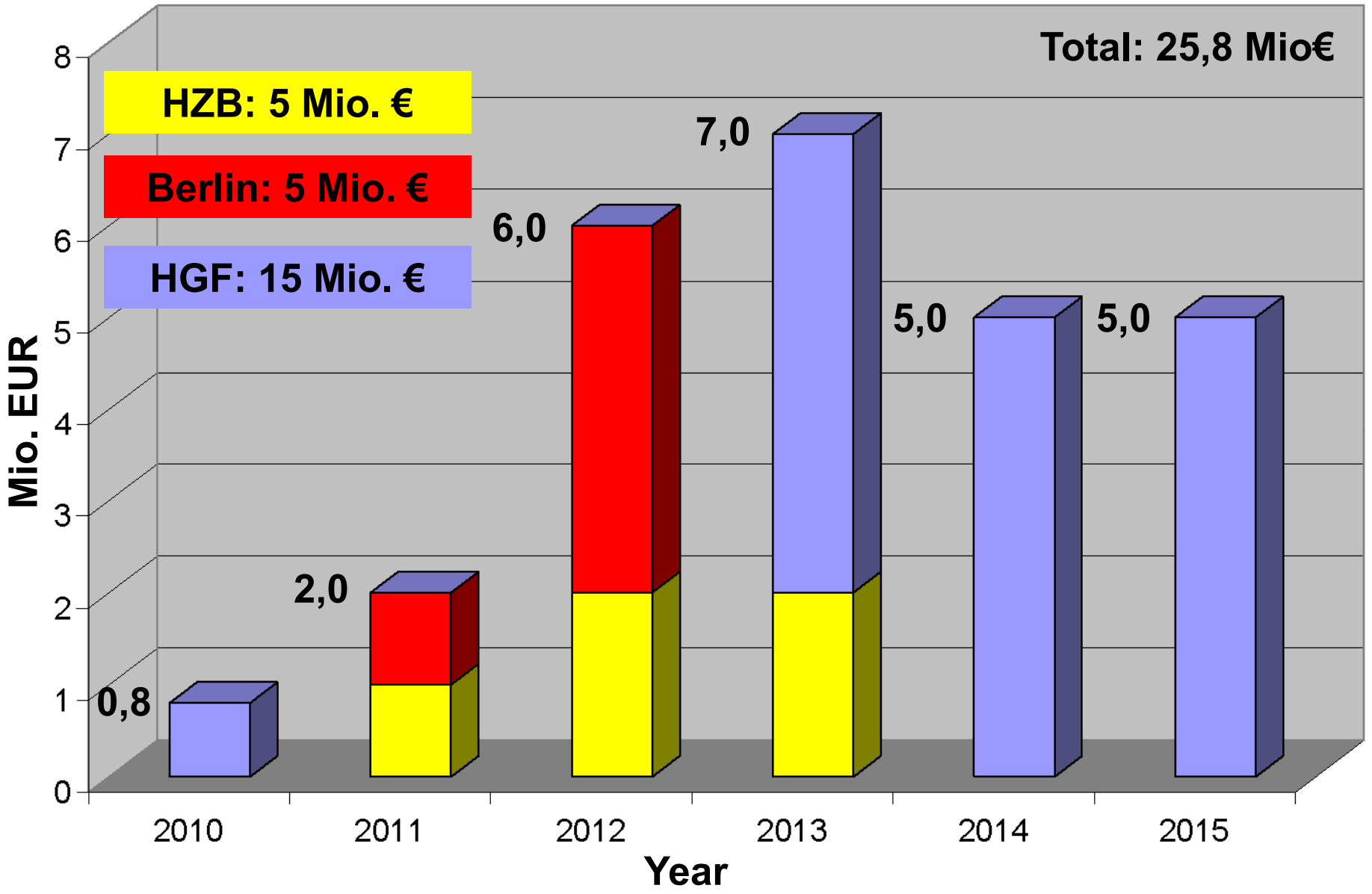
We already started in 2010 (with 600k€) the sc RF gun business!

B*ERL*inPro: Milestones

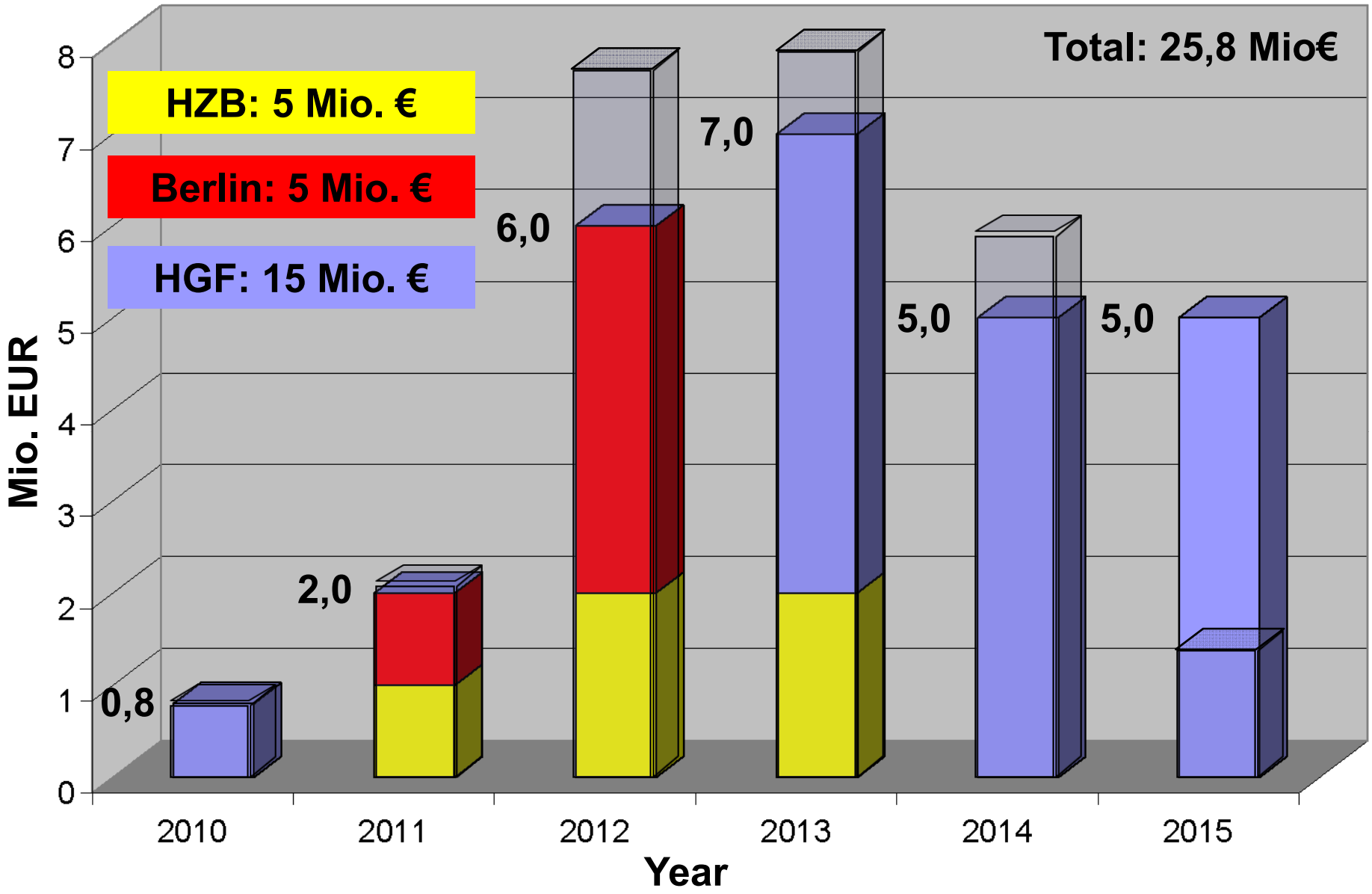
We already started in 2010 (with 600k€) the sc RF gun business!

	01/2011	first beam of srf photo electron source (start of accelerator physics experiments)
	08/2012	technical design report ready
MS 1	12/2012	building ready
	06/2013	infrastructure ready
MS 2	08/2013	first beam of srf photo electron source No. 1
	04/2014	booster module ready
MS 3	07/2014	start srf photo electron source at B*ERL*inPro
MS 4	07/2015	first beam through booster
	09/2015	linac module ready
MS 5	12/2015	first beam through linac
	2016	**recirculation, energy recovery → ERL accelerator physics program**

B*ERL*inPro: Budget from HZB, Berlin and HGF



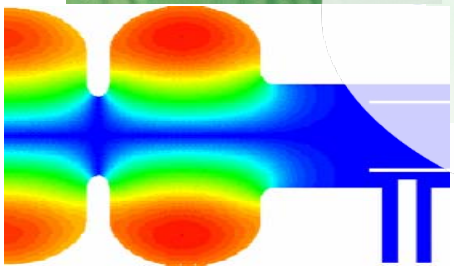
B*ERL*inPro: Project costs (from project plan) versus funding



BERLinPro: Status gun development

SRF Cavity – BNL/DESY/JLAB/HZB/Soltan collaboration

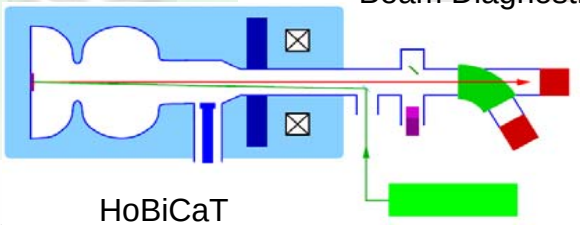
SRF Cavity Test Facility – HoBiCaT at HZB



Towards an electron source for BERLinPro

SRF Gun Cavity

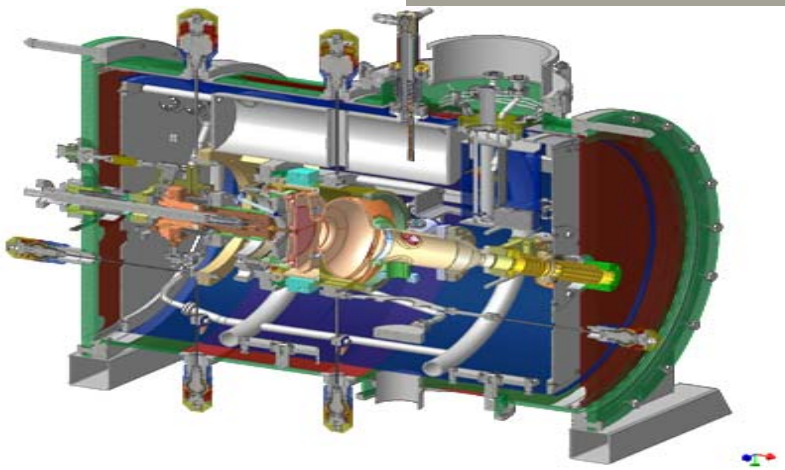
Beam Diagnostics



HoBiCaT

Laser

First Pb coated srf photo gun: operational 02/2011



Joint activity with FZD started to develop a generic cryo module design.

Development of 1.6 cell sc gun cavity with nc high quantum efficiency cathode (CsK_2Sb).

Staged approach:

Gun 1: Beam dynamcs

Gun 2: cathode integration

(low emittance, high bunch charge ~ 10mA)

Gun 3: high current, high rep. rate

Forschungszentrum Dresden Rossendorf

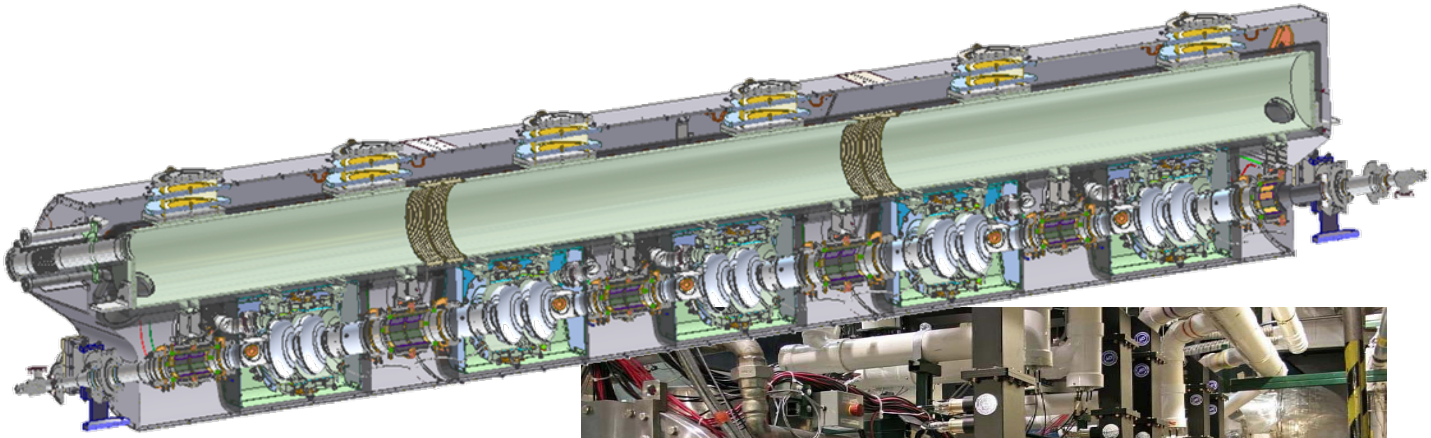
DESY

BROOKHAVEN NATIONAL LABORATORY

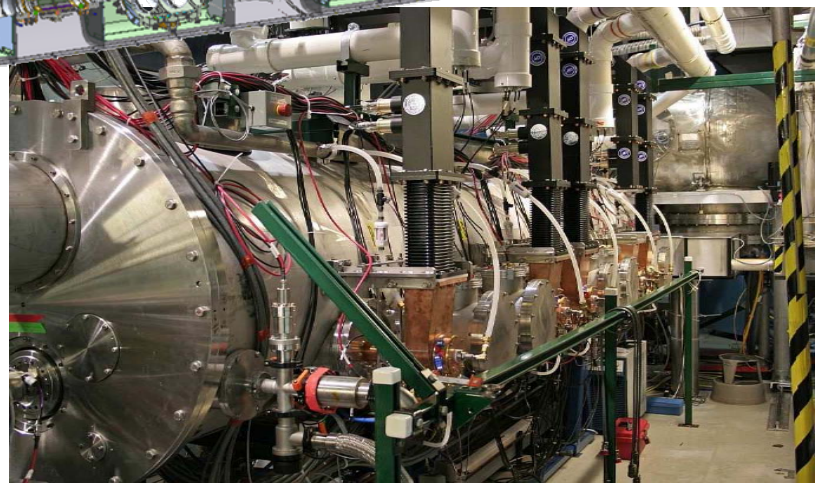
Jefferson Lab Thomas Jefferson National Accelerator Facility

MAX-BORN-INSTITUT

BERLinPro: SRF booster + Linac cavities



booster
+ sc rf



Transfer of booster technology from Cornell University under way.
Consultant agreement signed, technical drawings received.

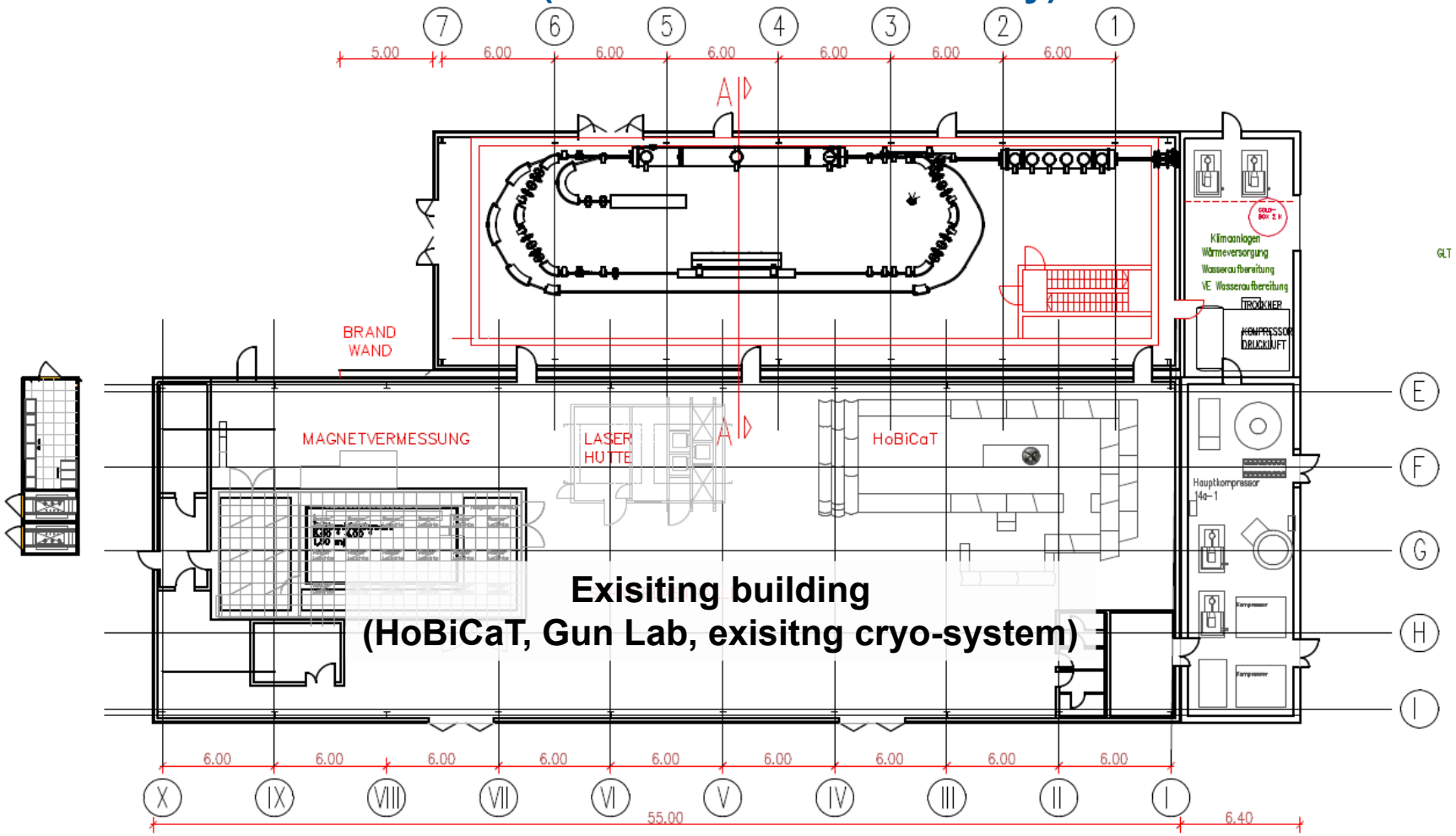
High current linac cavity development together with:
Aiming for waveguide HOM absorbers combined with ferrite ring on beam pipe (for higher modes).

Universität Rostock Traditio et Innovatio

technische universität dortmund

DESY

Due to radiation protection reasons
(take in mind: BERLinPro is a cw machine)
machine hall most likely will be underground !
(cost estimates under way)



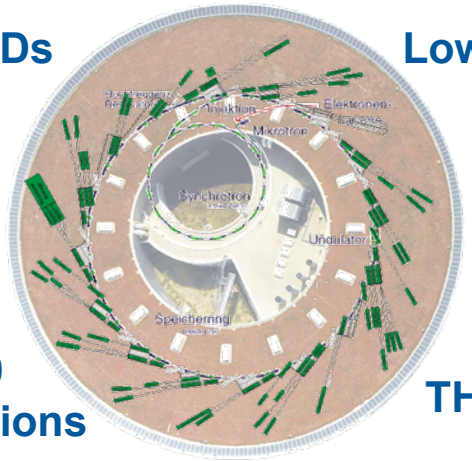
Exisiting building
(HoBiCaT, Gun Lab, exisitng cryo-system)

BESSY II perspectives

1998 Start → 2010 today → BESSY II perspective → 2025

16 IDs

Low-α

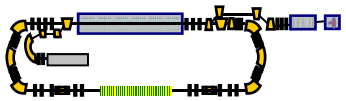


Femto-Slicing

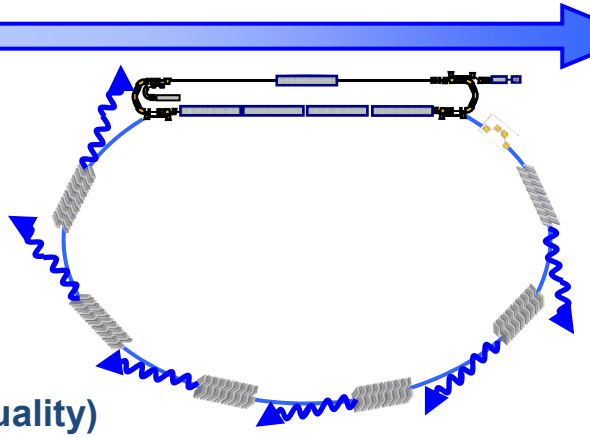
~50 endstations

THz

BERLinPro



~ 2020 Decision on a future facility



Preservation
(continuous replacement of exhausted and obsolete components, e.g. standard power supplies, control hardware, ...)

Modernisation (better than only preservation)
(e.g. new solid state rf-transmitters replacing old klystron systems → much higher reliability, lower phase noise = higher beam quality)

Up-Grade = Providing new and unique capabilities

BESSY II perspectives: Preservation with Modernisation

- **new EU HOM damped cavities (~1500k€)**
  - replacement of the old (30a) DORIS cavities with their suspicious mode damper fingers (only few spare parts still available) limiting single bunch currents
  - presently the last spare was installed in BESSY
  - two of four cavities at BESSY are suspicious

  → extraction more HOM power, more stable beam conditions at high currents

  → no problems with higher single bunch currents

- **new solid state rf-transmitters (~2500k€)**
  - ever increasing problems with purchasing of klystrons and IOTs
  - three of four operational klystrons are near to the end of their lifetime
  - only three spare klystrons in house; spare parts only from single source

  → due to modularisation higher redundancy and reliability

  → modern LLRF systems with lower phase noise resulting in more stable beam conditions, especially in low-α mode

- **new IGP (vacuum pump) power supplies (with pressure dependent HV) (~700k€)**
  - old power supplies not longer reliable

  → reduction of average vacuum pressure expected → increasing beam lifetime

- **new digital transverse and longitudinal feedback system (~250k€)**
  - transverse system is only analogue; longitudinal system is not operational

  → new diagnostic possibilities

  → operational headroom

BESSY II perspectives: Preservation with Modernisation

- **refurbishment of extraction and injection elements of booster and storage ring (solid state pulser) (~500k€)**
  - present system maybe will not withstand permanent Top-Up operation
  → better timing accuracy, more stable beam (Top-Up Phase II)
  → guaranteeing operational reliability

- **refurbishment of MP-WLS and WLS (3) (~600k€)**
  - MPW will not withstand operation of one week with Top-Up (TopUp requires operation for as long as possible)
  - cryogenic cold heads needs to be refurbished at three WLS

→ longer permanent operation
→ less maintenance (frees man power for BERLinPro and saves costs)

- **new quadrupole power supplies (~830k€)**
  - old power supplies not longer reliable; lots of permanent maintenance

- **new central control room for BESSYII and MLS (~800k€)**
  - present control room is not suited to be permanently manned (noise, ergonomics)
  - need new hardware for display of machine states, remote control, ...

Over the next 3 to 5 years (2011 – 2015) this program needs an total investment of 8200 k€

BESSY II perspectives: Up-Grade

- **Fast Orbit Feedback Phase II (~1500k€)**
  (full digital, higher precision beam position monitor systems, new data distribution (network)
  → better suited to maintain beam with highest stability
  → allows for more sophisticated beam optics modelling which results in a more accurate machine model and easier ad to new requirements of experiment

- **sc Overvoltage cavity system (~3000k€)**
  (multi-cell HOM damped cavity module at third harmonic, similar to ERL)
  → would allow low-α mode (bunch length ~ 1ps) with 40mA average current (two order of magnitude higher than presently available)

needs detailed beam dynamics studies and srf-developments prior to a possible implementation

- **... maybe lots of other ideas! One needs to start a process to define the future!**

A BESSYII upgrade program needs a careful preparation phase (1 – 2a) and one would estimate necessary investments in the order of 2 to 3 Mio€ / a over 5 years.

Nothing of that is funded yet.
Management needs to be convinced.
Priorities needs to be defined.