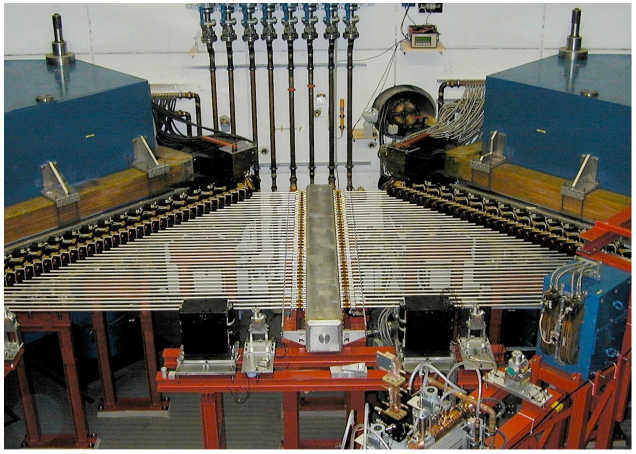
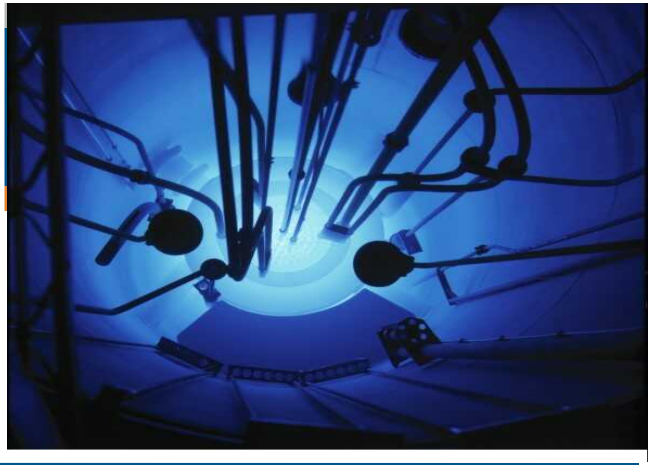




Electron cooler related R&D at Helmholtzinstitut Mainz (HIM)

Kurt Aulenbacher

Cool-15, Jefferson-Lab

2015, October,1

HELMHOLTZ ASSOCIATION

GSI

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

What is HIM ?

- **A joint venture between University Mainz & GSI**
- **Founded 2009…**
- **Scientific focus: Physics which can be performed at GSI& FAIR**
- **HIM-Sections: (1) Hadron-spectroscopy, (2)Hadron-structure (PANDA) (3)Theory (e.g. lattice QCD) (4,5)Super-Heavy Elements (two sections: chemistry&physics) (6)Matter & Antimatter**
- **And last but not least: (7)Accelerators and integrated detectors**

Objectives of HIM-section Accelerators and integrated detectors (ACID) (est. 2009)

1. **FAIR: HESR-Cooler support: Beyond 2MV:→4-8MV**
2. **Provide accelerator solutions for SHE research by GSI and JGU groups: low beta SRF ion accelerator cavities**

Mission…

- ACID cooler group does R&D on small, well defined aspects related to the design of relativistic magnetized coolers
- Such small scale research is well adapted to the possibilities of HIM (somewhat in between university research and „big science“)
- Ongoing projects: turbines as power generators for higher voltages >2MV and:
- Test set-ups for collector optimization & control , non invasive beam diagnostics,

Relativistic cooler - details to be covered

HIM/ACID tasks in HESR-cooler business: ... provide solutions for unresolved technical questions of relativistic cooling at HESR energies, corresponding to maximum cooler voltage of 8MV:

1. Beam magnetization: How to power solenoid channel & terminal ?→ main issue!
2. Energy recuperation effciency and control
3. Non invasive diagnostic of multi-megawatt beams

The power management issue:

- More cooling power needed due to stronger beam/target (PANDA) or beam/beam (ENC@FAIR) interactions→ Magnetization of beam required!
- Powering of continuous solenoid channel in d.c. acceleration stage
- Powering of terminal – electronics, source/collector
- Power requirement 50-150kW for supply floating at U>2MV

???transformer or insulating shaft technological limit???

The turbine approach

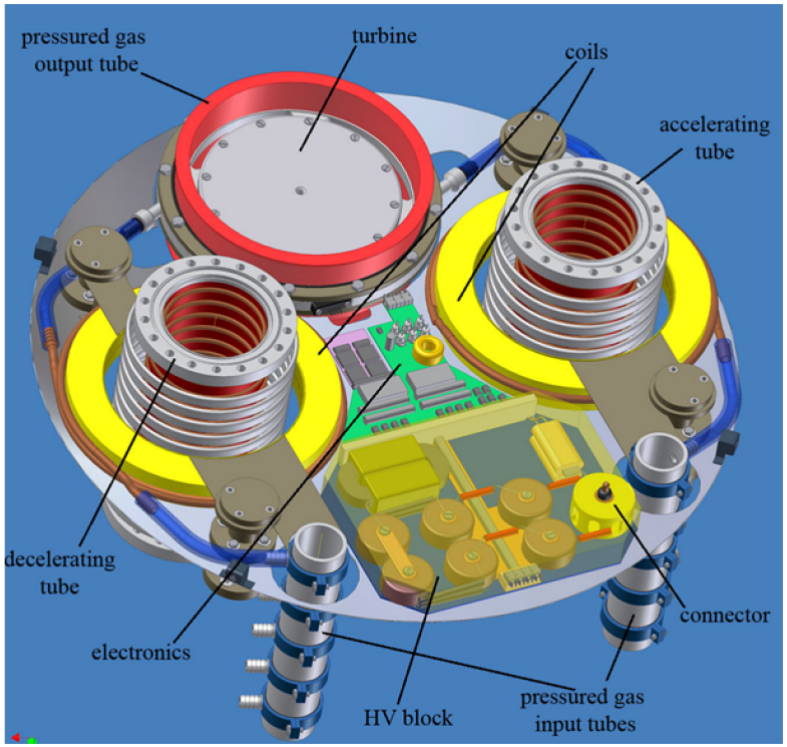
HESR cooler: solenoid channel problem & turbine concept

- Solenoids must be powered by floating power supply.
- Turbines for U>2MV → Suggestion of BINP-Novosibirsk: 60kV/Turbogen (400Watt)
- **Not realized** for Jülich 2MV-cooler…
- German company DEPRAG: Offers turbogenerators in the 5-50kW range - intended for use in the "green energy sector" but also potentially attractive for cooler application.

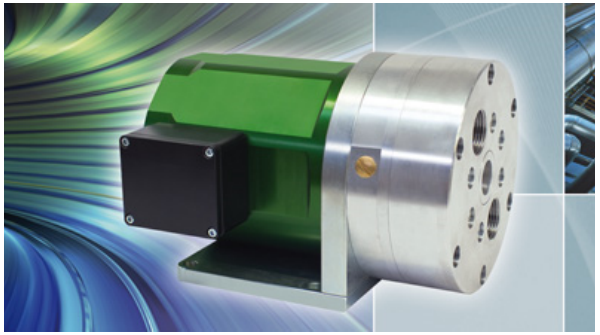
~40cm

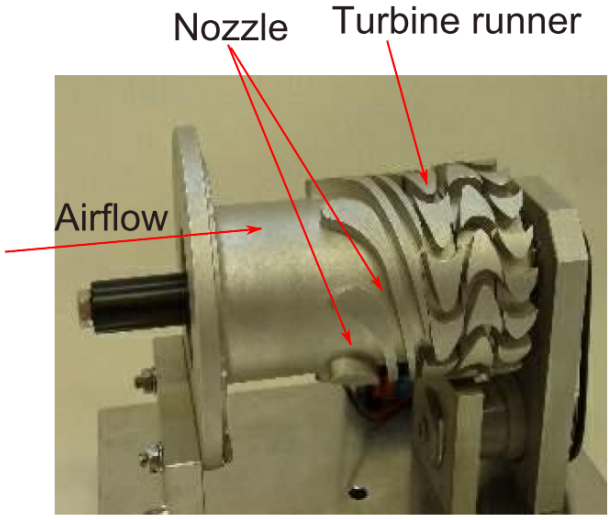
Poster by Andre Hofmann,, Monday

So far, two 5kW Turbogenerators have been purchased



First idea for Jülich Cooler ~600 W Turbogen. Powering 60kV + solenoids





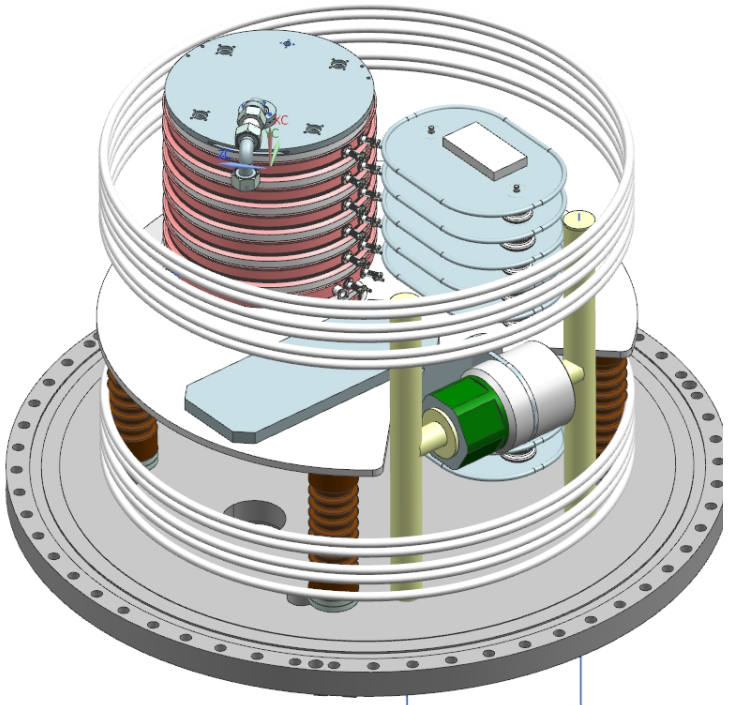
Runner of 5kW Turbine

HELMHOLTZ ASSOCIATION
Helmholtz Institute Mainz

HIM- BINP-collaboration for “turbine” driven 600kV stage with solenoid focussing

- BINP/HIM contract for fabrication of „prototype“ HV-Generator
- 5kW turbogen will be supplied by HIM
- First Option: Turbogen drives Cascade transformer
- Remaining parts similar to Jülich cooler
- Second option: turbine powers large solenoid and +/- 300kV d.c. Power supply
- The latter option selected for project.

Drawing: V. Reva, BINP



We believe that this scheme is **scalable**

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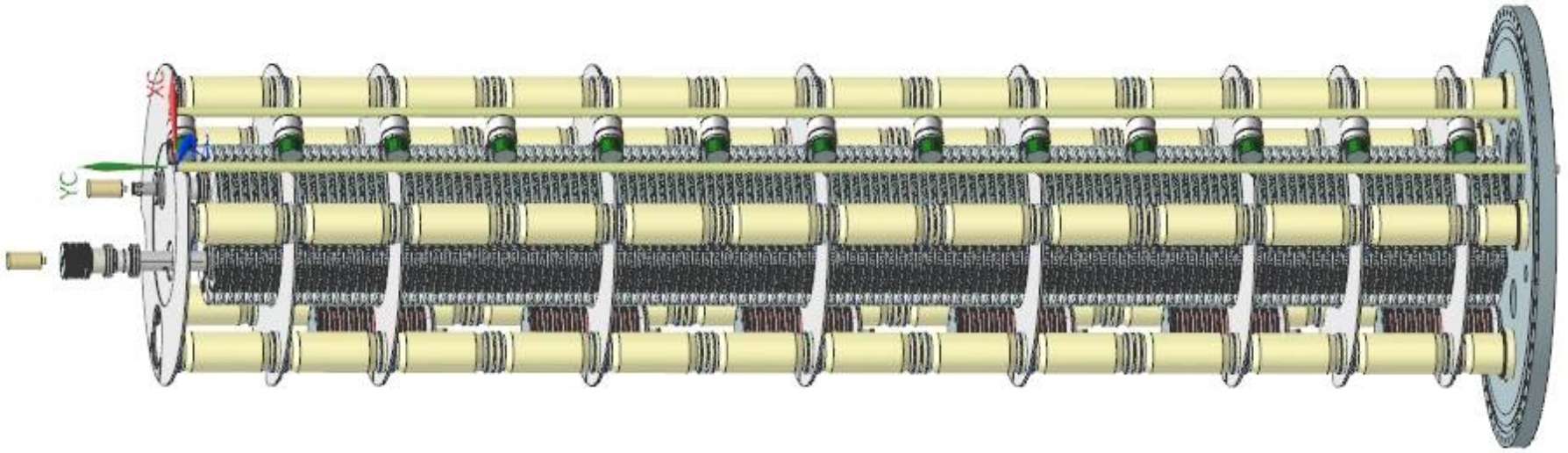
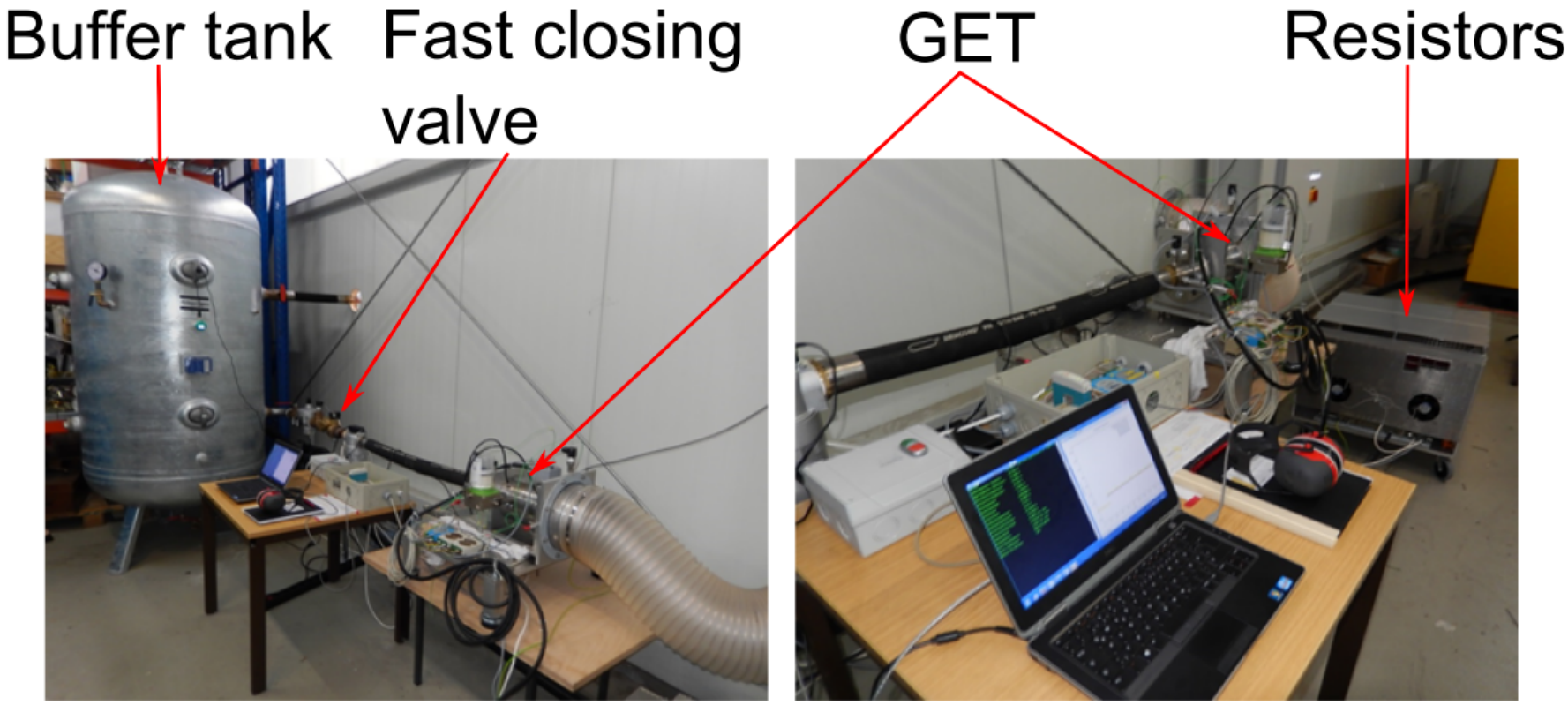
Goal. 2015-2018 turbine powered multi MV generator

12*700 kV device….(Drawing by V. Reva)



Are turbines really reliable?

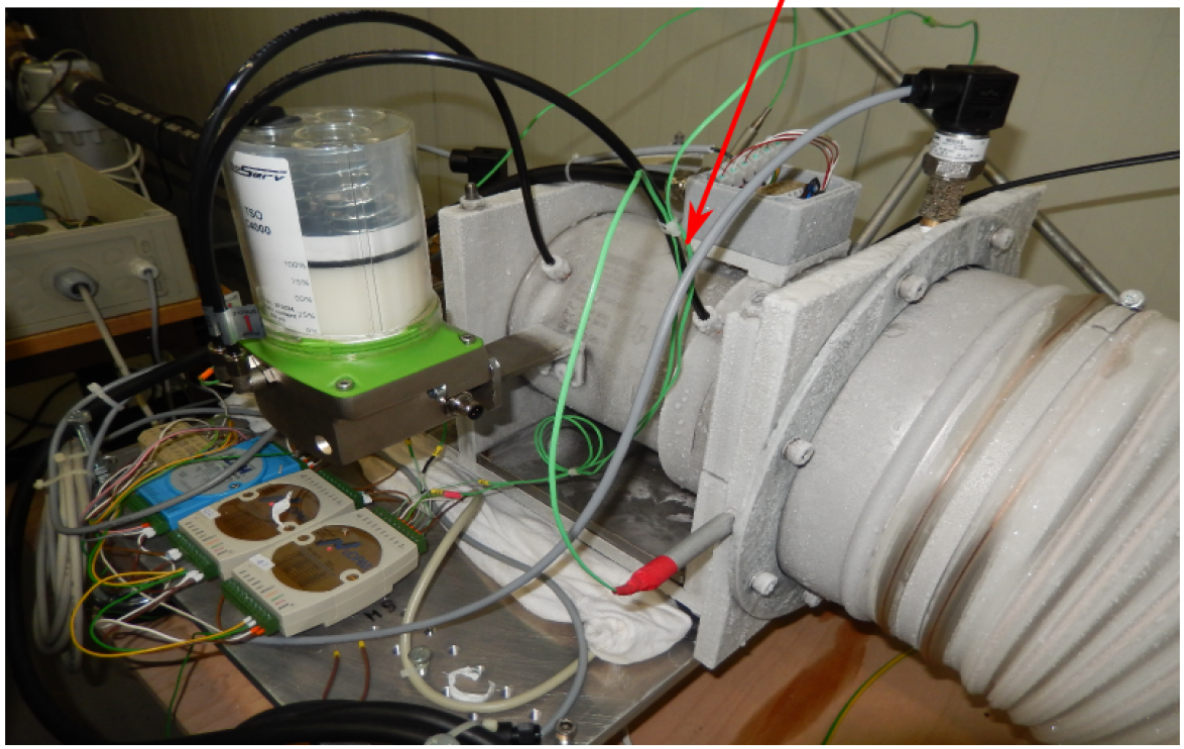
Test set –up for long term operation at HIM/Mainz



Poster by Andre Hofmann,, Monday

Input power of the compressor (outside of the hall): 40 kW

GET



Two obvious features:

- Lubrication needed
- Exhaust air is very cold if room temperature air is let in

Poster by Andre Hofmann,, Monday

Some thermal considerations

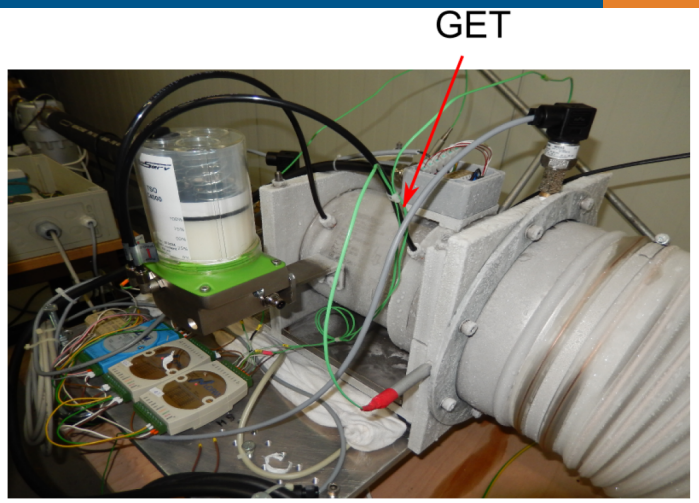
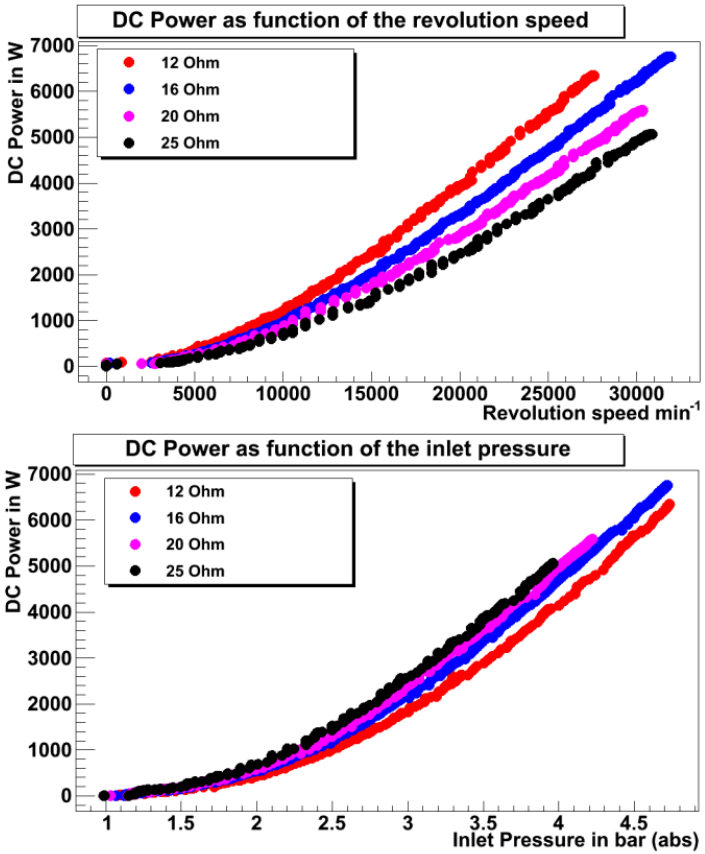


Table 2: Properties of the GET

Property	Value
Power	5 kW
Revolution speed	35000 min^{-1}
Pressure (in)	4 bar
Pressure (out)	1 bar
Mass Flow	4 $\frac{\mathrm{m}^3}{\mathrm{min}}$
Pressure condensation point	–20°C
Voltage phase to phase	263 V
Current	12 A
Norminal frequency	583 Hz

- Exhaust medium is strongly coooled due to adiabatic (isentropic) expansion
- Gives options for thermal managment of heat generated by loads inside tank



Results & conclusions

- Turbine operated > 1000 hours without failure at 5kW
- Lubrication of bearings is needed, but minimal
- Lubrication unit has been modified for 10bar external preesure → test of turbine in pressurized vessel in autumn 2015
- Closed cycle operation with dry Nitrogen seems favorable → test next year
- Turbine with gas bearings currently developed by DEPRAG
- Turbine powered prototype under construction at BINP.
- Demonstration of 600kV Turbo-HV-Genarator+Solenoid → next COOL?

What can we learn from a „cooler-test stand“?

Investigation of critical cooler issues at HIM/KPH:

2.2 System Overview

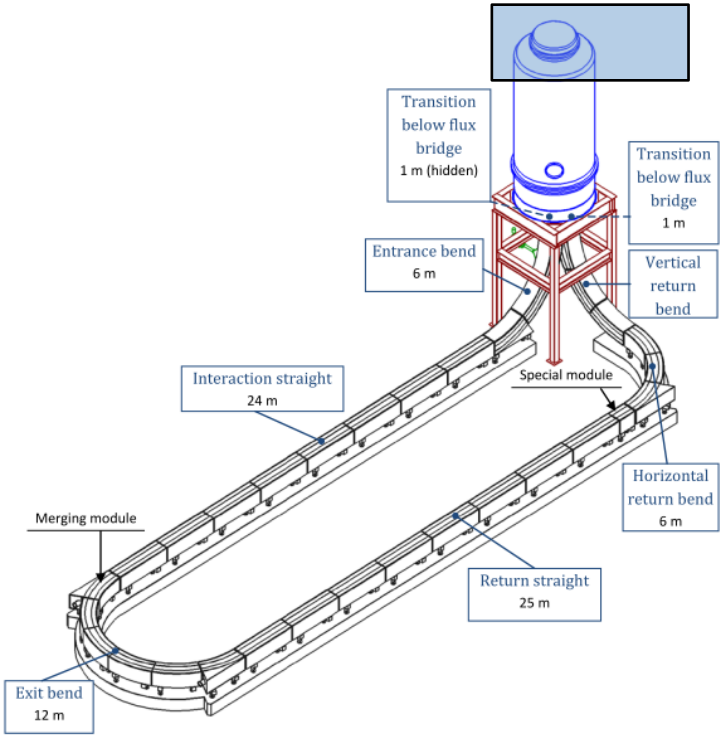


Figure 2-1: Layout of the HESR Electron Cooler

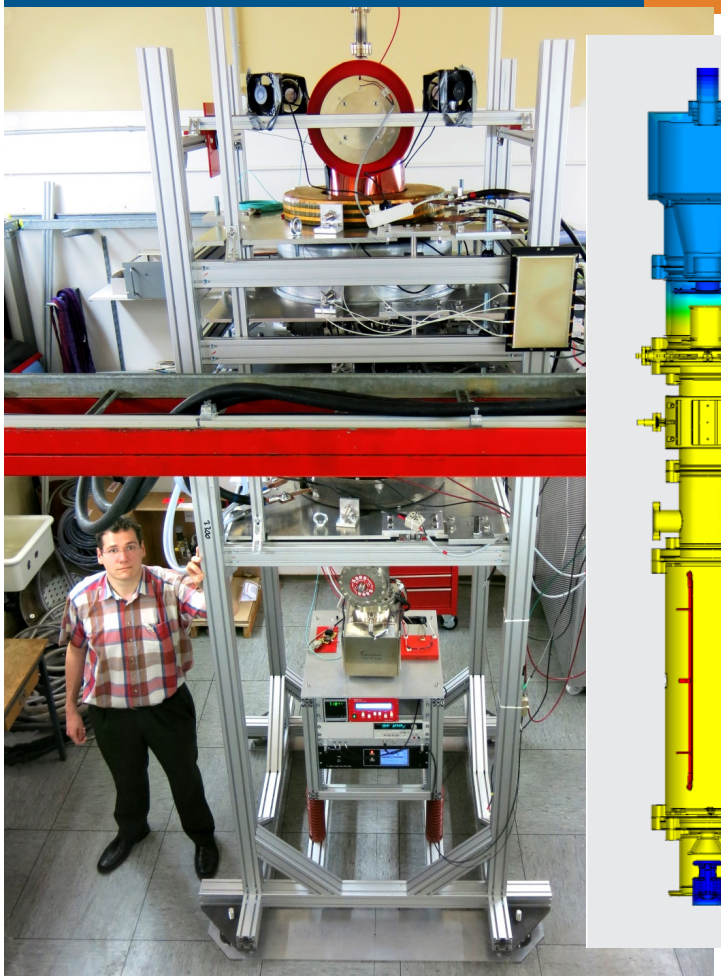
Idea:

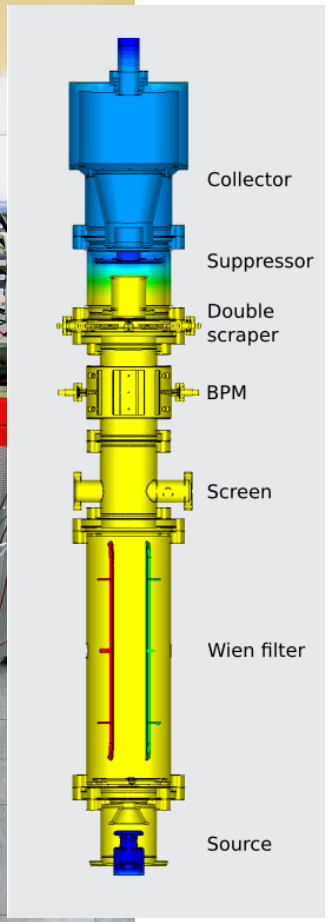
- Investigate source/collector system in order to define expected operation conditions at 8MV!

- Only the blue part
  –source and collector –
  has to be build for these investigations
  (no MV part is needed)

→ Build cooler test stand at HIM

Test-stand

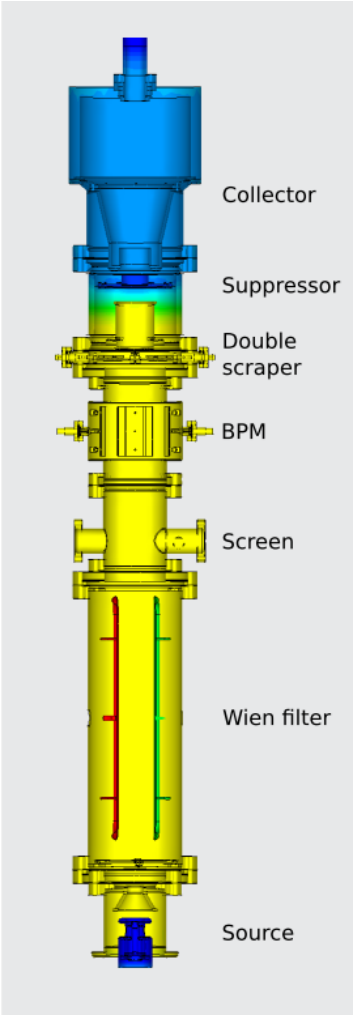


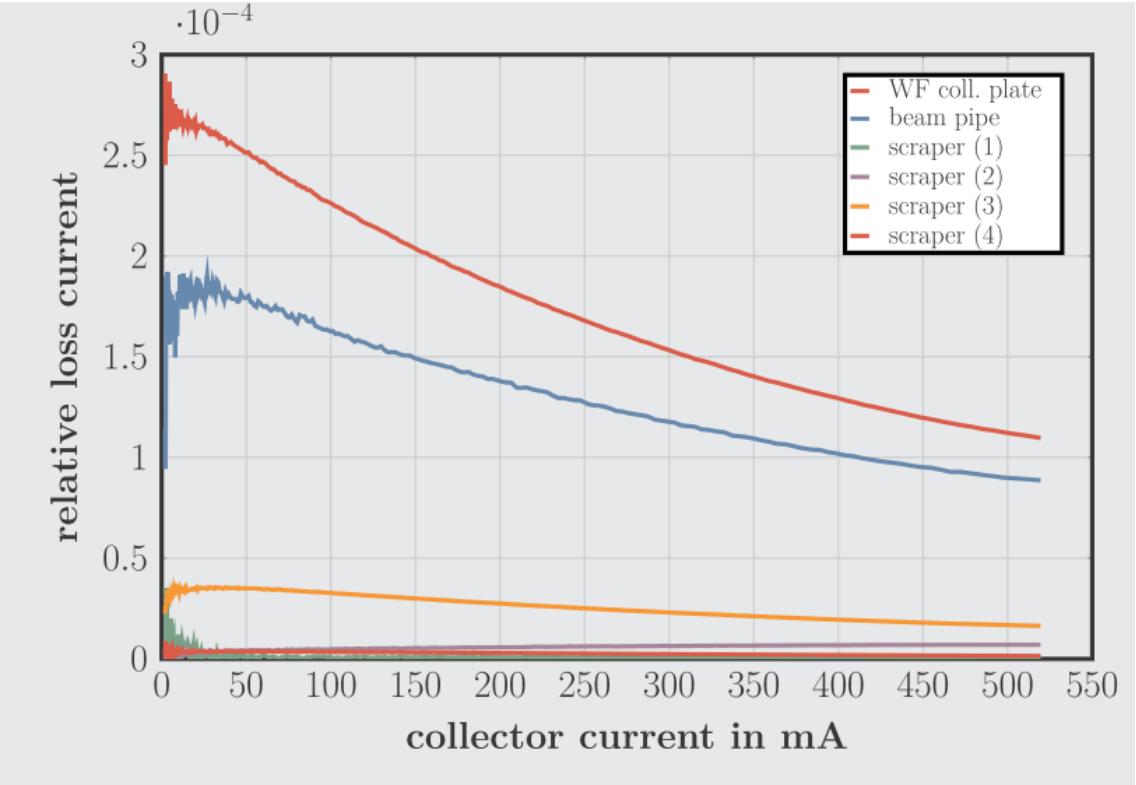


Selected results

- Long term stable operation with magnetized beam
- No significant vacuum increase due to desorption in collector
- Demonstration of effective capture of backstreaming electrons from collector
- Investigation of magnetron like discharges (due to unsuitable geometry in gun region)

Poster by Max Bruker , Monday



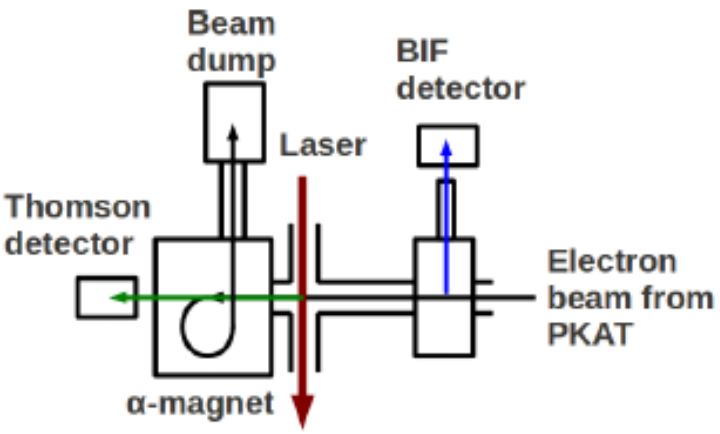


Poster by Max Bruker , Monday

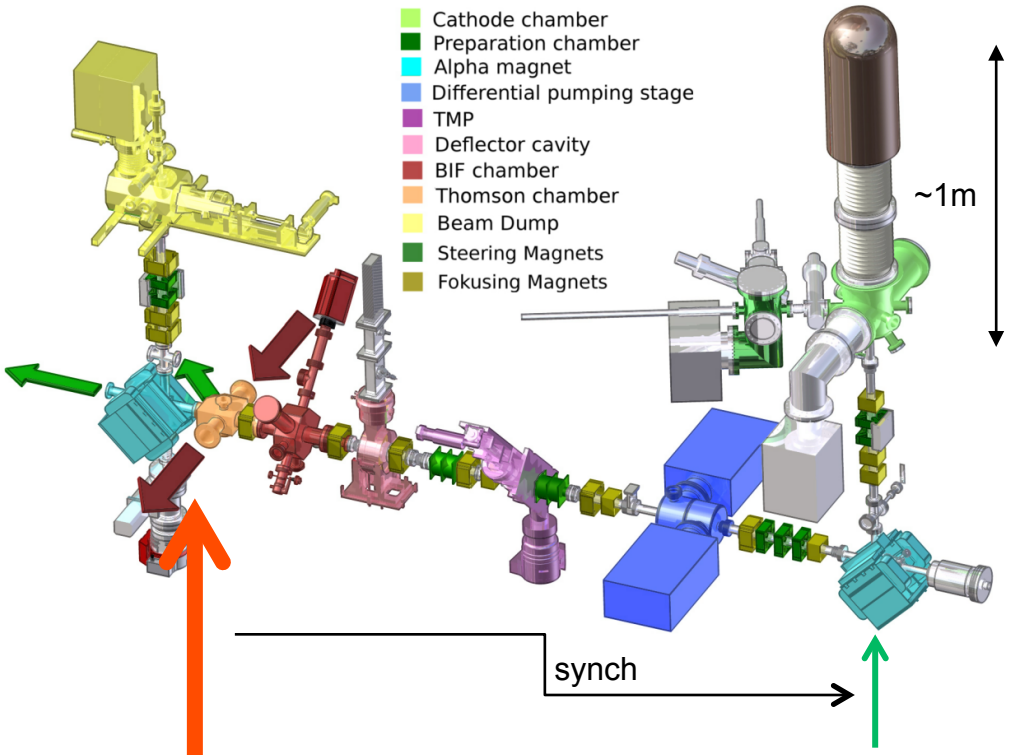
Loss is believed to be due to scraping of secondary beam on aperture at collector entrance (ground potential)
After modifaction „true“ loss could be measured with nA resolution

„minimal invasive“ Beam diagnostics

Non-invasive diagnostics for relativistic coolers (PhD T. Weilbach)
Thomson Laser Scanner (TLS)



PhD work Tobias Weilbach !



$$\lambda_{SC} = \lambda_{Laser}\frac{1+\beta\cos(\Theta_{Sc})}{1+\beta\cos(\theta_L)}$$

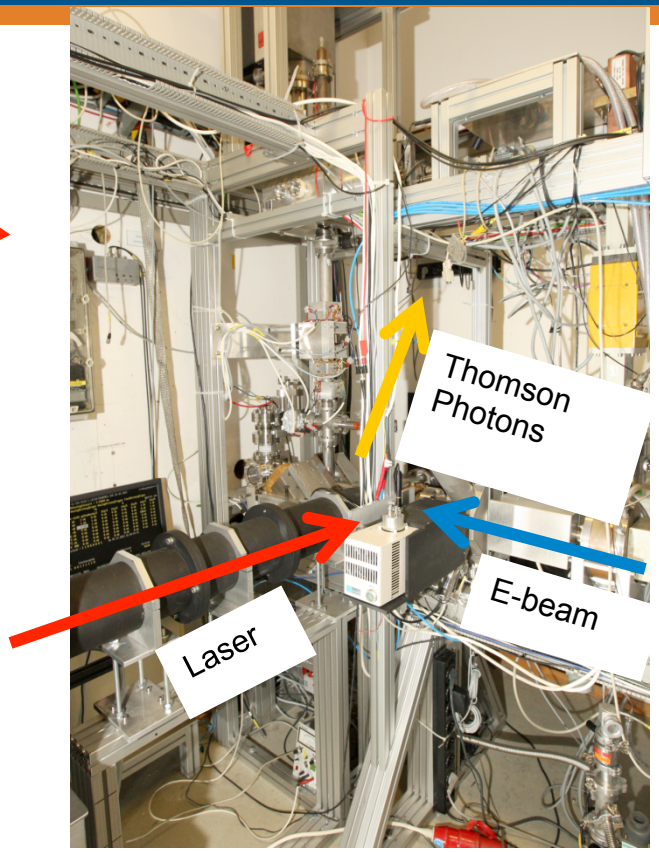
$$\lambda_L = 1.05\mu m \Rightarrow \lambda_{SC} = 0.61\mu m$$

Thomson Laser 150 Watt c.w.
(150kHz, 20ns),

Laser Wire geometry: q_{laser}=p/2
Scattered photon: q_{sc}=3p/2

Source laser <10W c.w.
150kHz, 20ns
→I_{peak} ~60mA @100kV

Thomson diagnostics



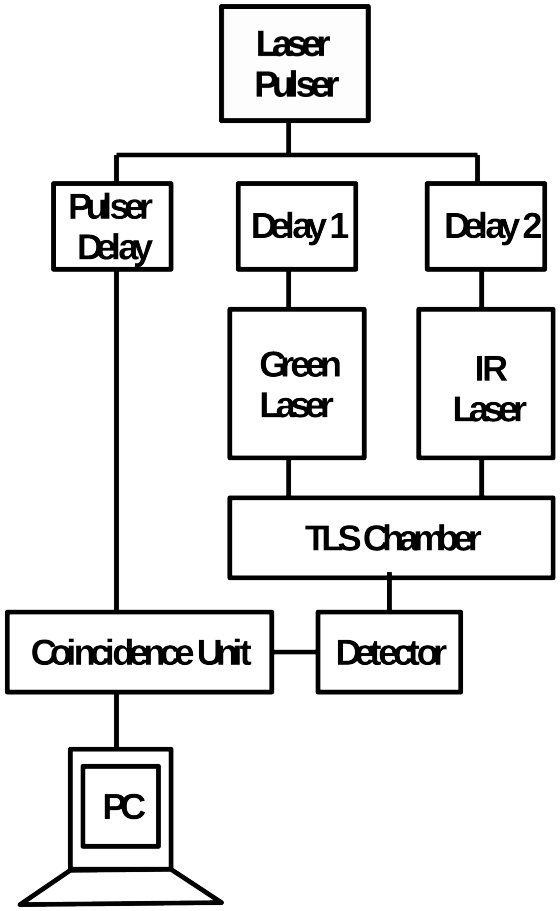
Thomson scattering on medium relativistic beam was demonstrated by Habfast et al.

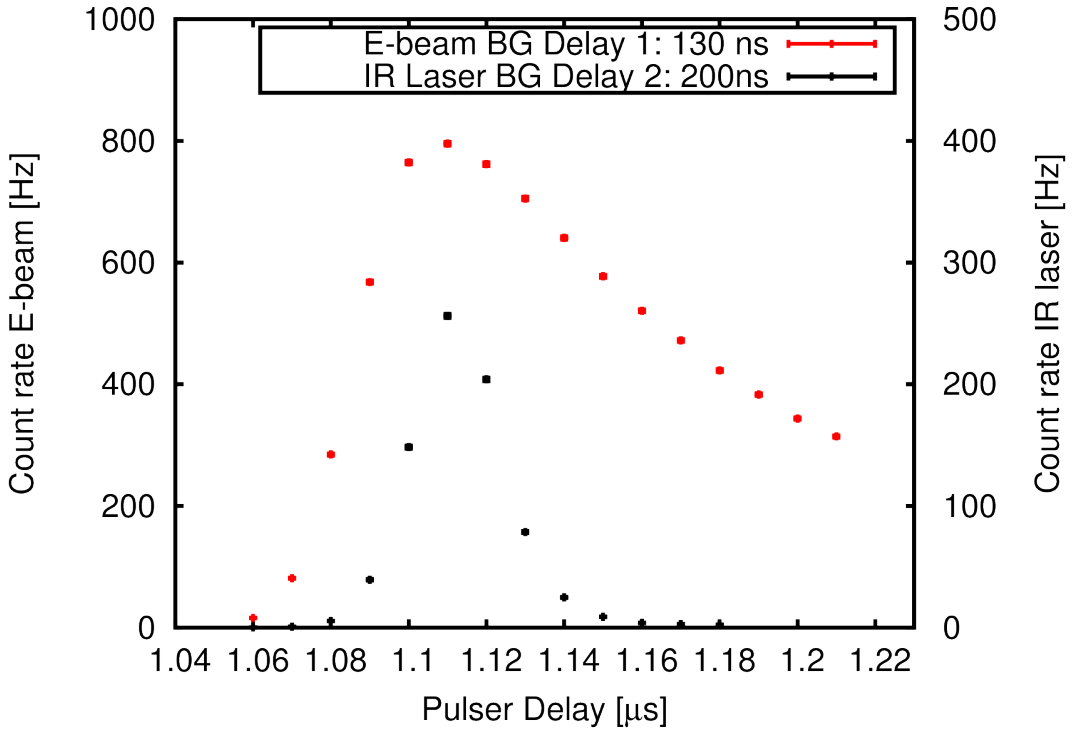
- Advantage of Habfast et al: longitudinal interaction region and higher Electron density → 5 Orders of magnitude higher rate per power!

- Our case: 2 Orders of magnitude higher laser power! + larger solid angle
- Relativistic cooler case: several order of magnitude due to C02 laser + higher density

Thomson diagnostic: timing adjustments

PhD work Tobias Weilbach !

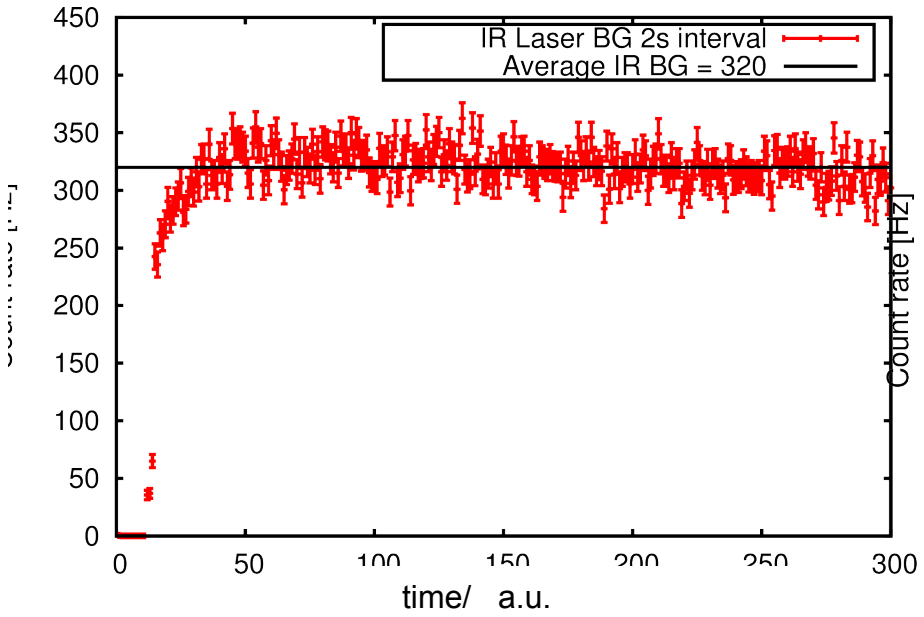


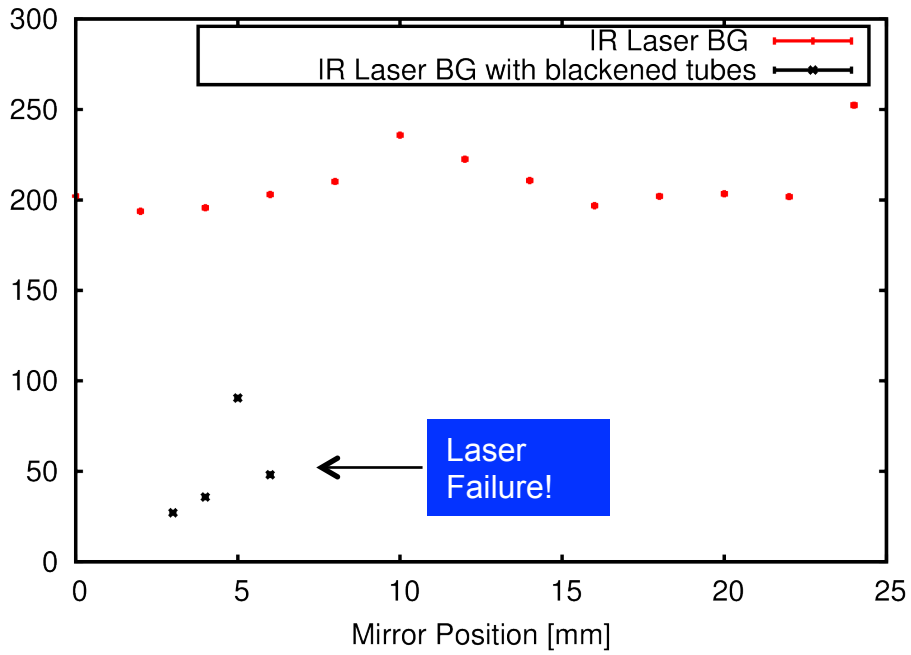


Beam pulses are ~20ns, 100kHz

Background events can be used to adjust timing for the interaction

Thomson diagnostic: backgrounds

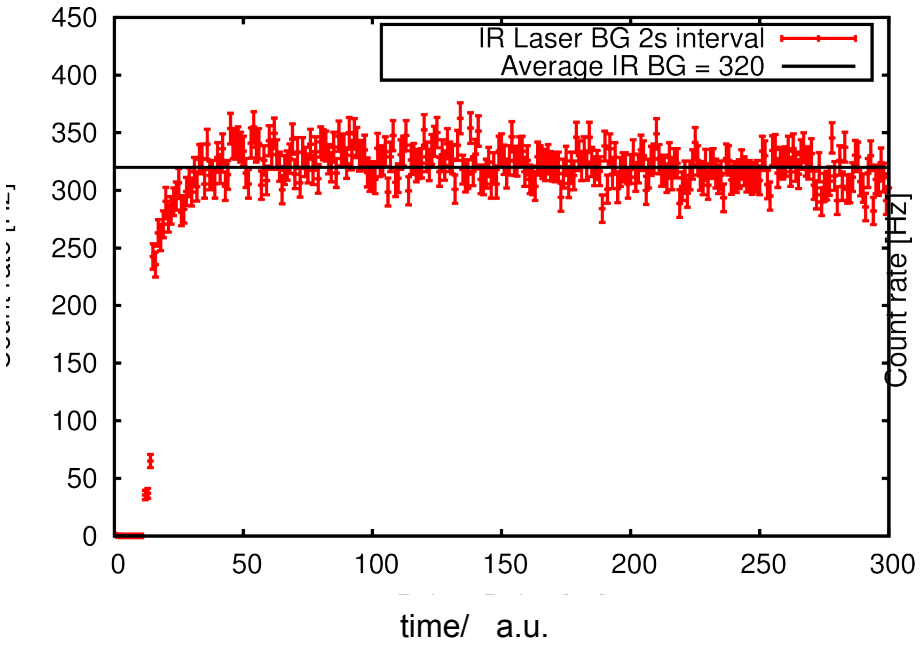


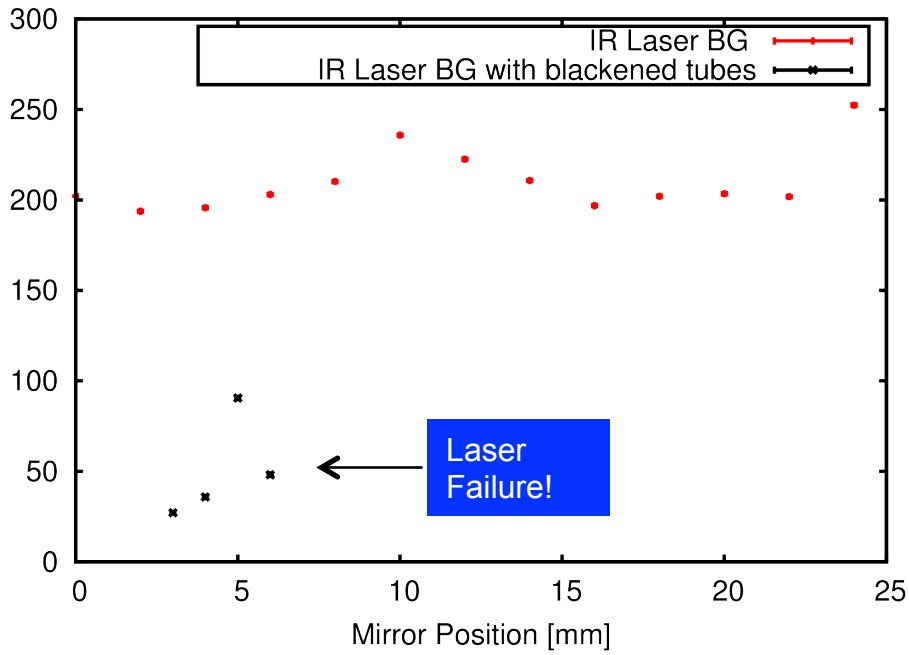


Background Signals in right plot are generated by 110 Watt (50kW peak) IR radiation superimposed on 40mA (20mA peak) Electron beam.

Background completely dominated by Laser (almost 10^{21} photons per second!)

Thomson diagnostic: backgrounds





Reducing the reflectivity of the vacuum chamber walls yields (estimated) S/N ~ 0.01.

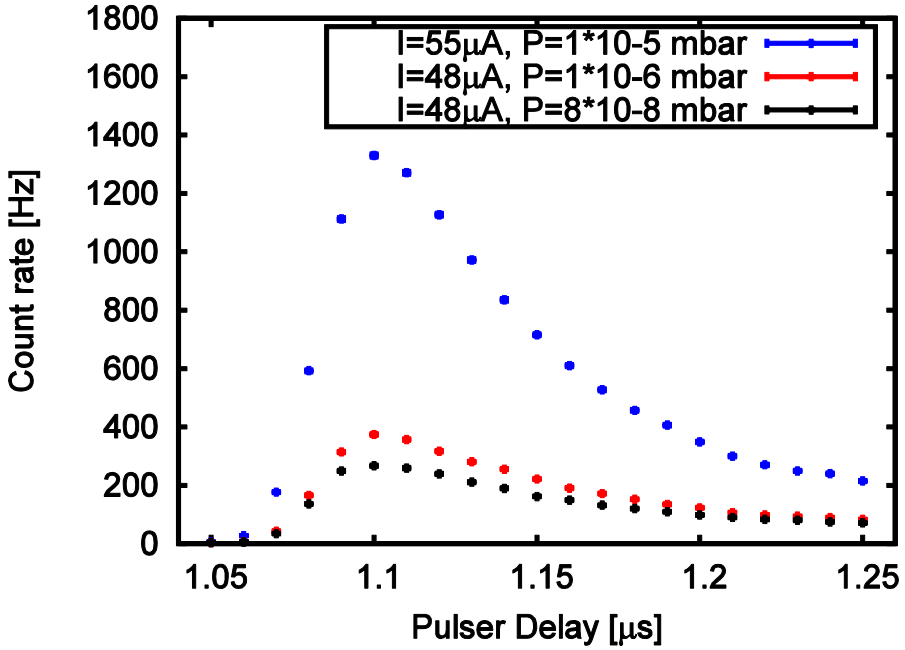
→3-4 order of magniutde more signal in real cooler
→ background estimation for real cooler is on better footing now !

Conclusion and outlook

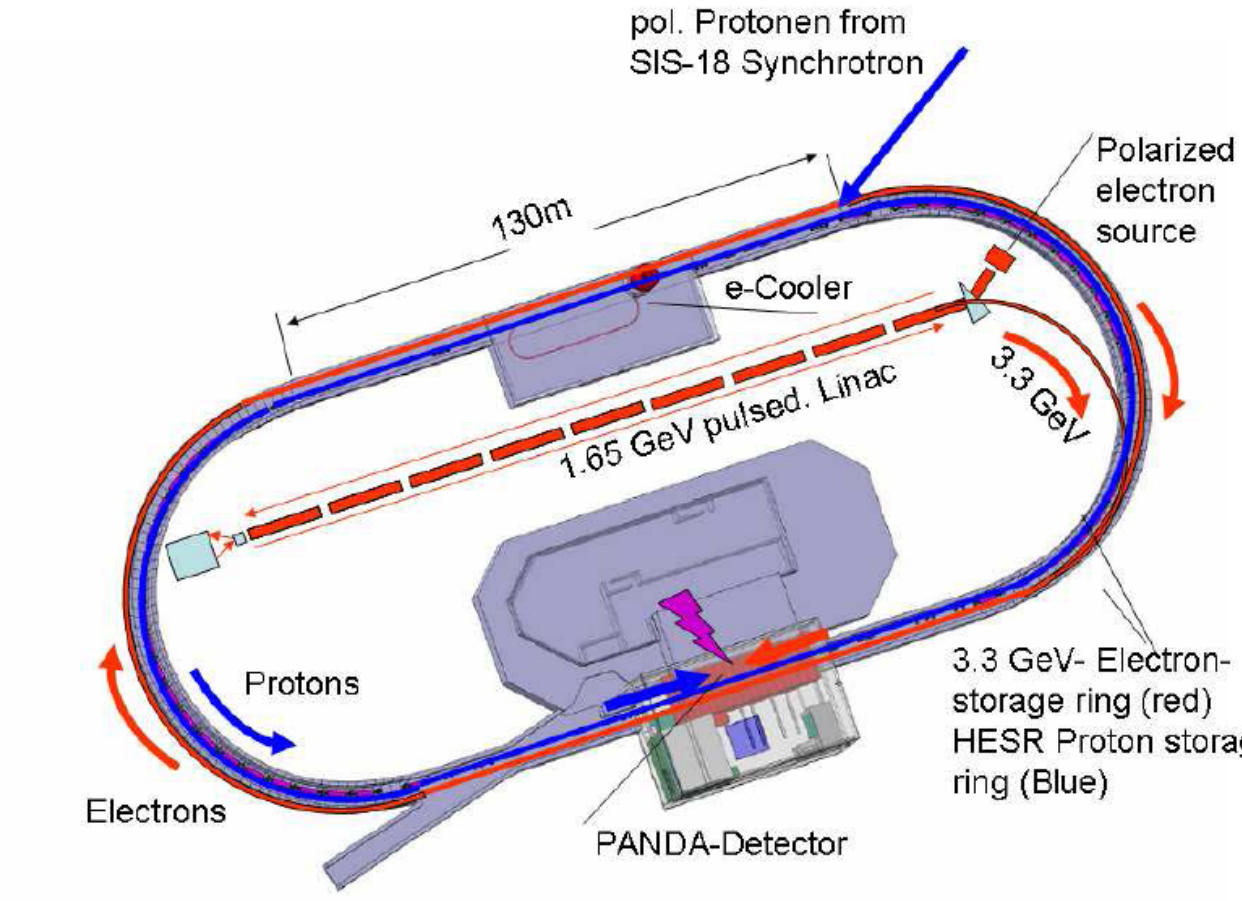
- Potential of Turbine powering will be clarified in foreseeable future
- Together with results from the other activites this will provide a part of input for a TDR....
- TDR could be joint approach (HZJ, BINP, GSI, HIM,...) „An 8MV cooler for HESRatFAIR“

Conclusion and outlook

THANK YOU


I=55µA, P=1*10-5 mbar
I=48µA, P=1*10-6 mbar
I=48µA, P=8*10-8 mbar
Count rate [Hz]
Pulser Delay [µs]
0
200
400
600
800
1000
1200
1400
1600
1800
1.05
1.1
1.15
1.2
1.25

Double polarized collider ENC:



Cooler device is quite common
to the needs of pbar at HESR/FAIR and (later) ENC!!