Laser driven particle acceleration

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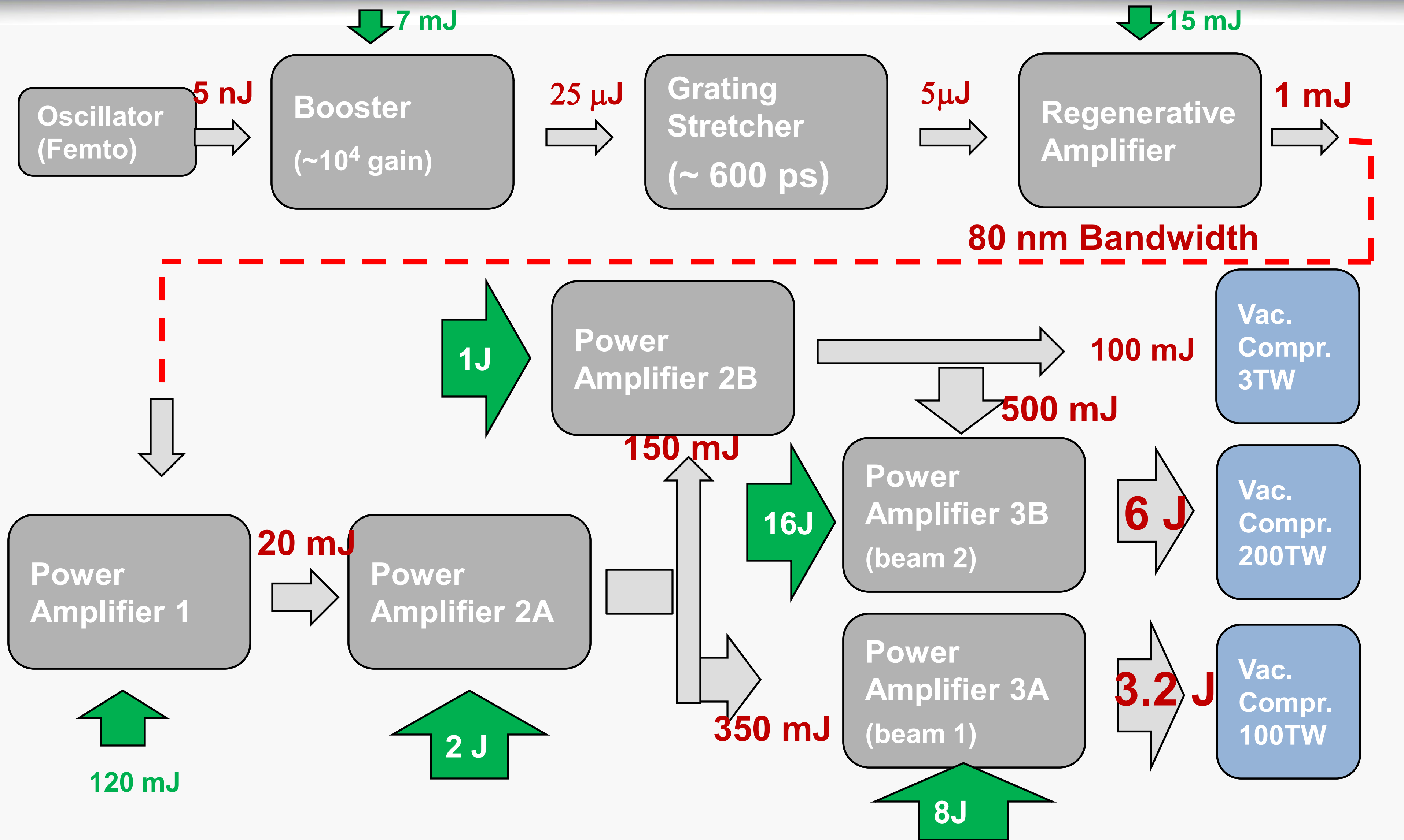
Outline

- Arcturus Laser Facility
- Motivation and objectives
- Applications
- Possibilities for open access

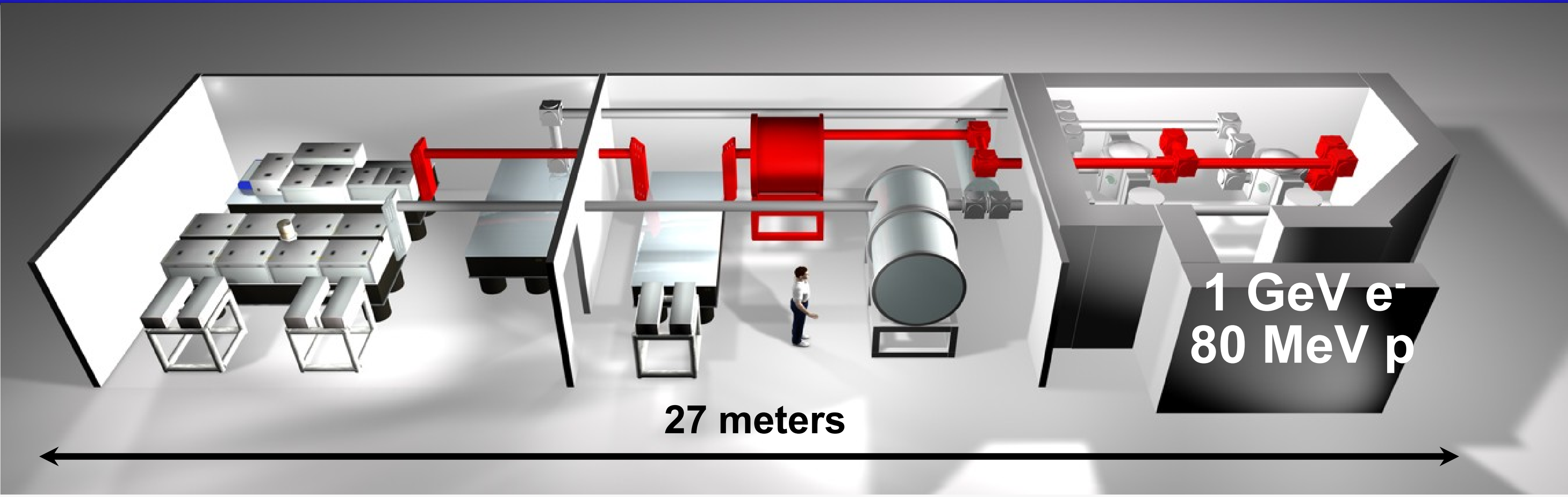
Present Arcturus Laser System

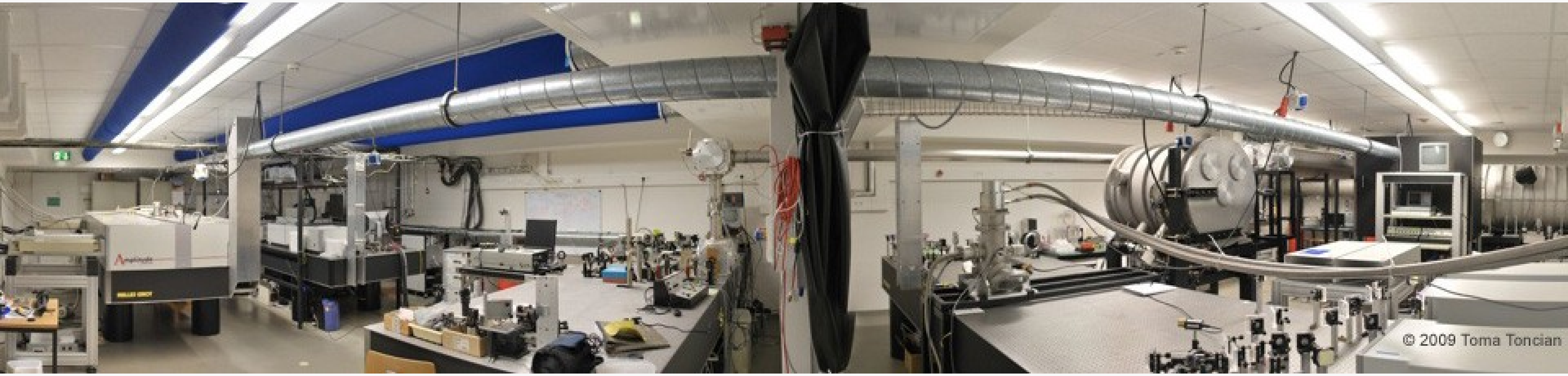


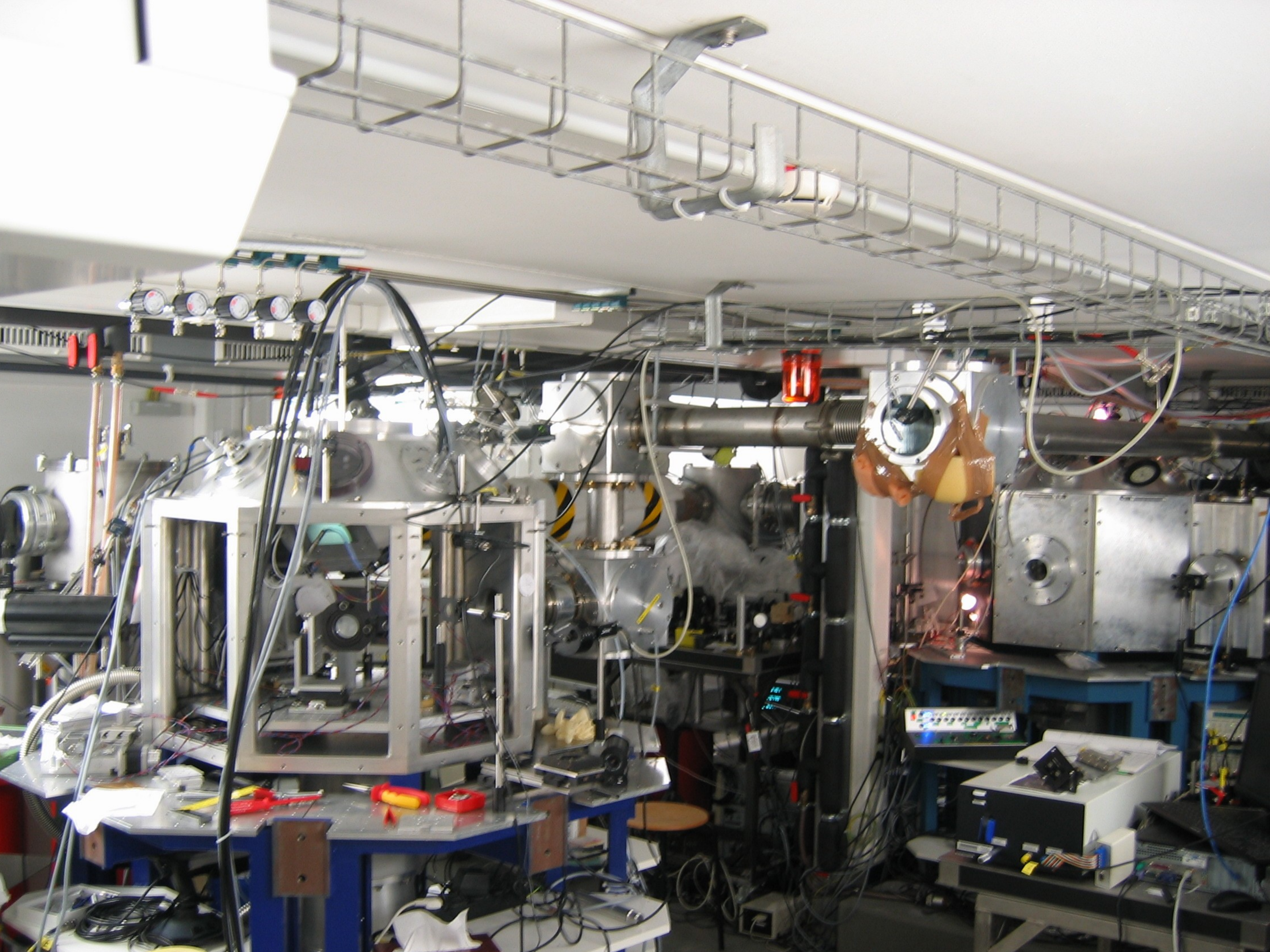
Present laser specifications

	Beam 1	Beam 2	Beam 3
Energy before compression	3.2 J	6 J	100 mJ
pulse duration is variable	>25 fs	>30 fs	>30 fs
Options	adaptive mirror plasma mirror 10Hz	adaptive mirror 10Hz	2ω 10Hz

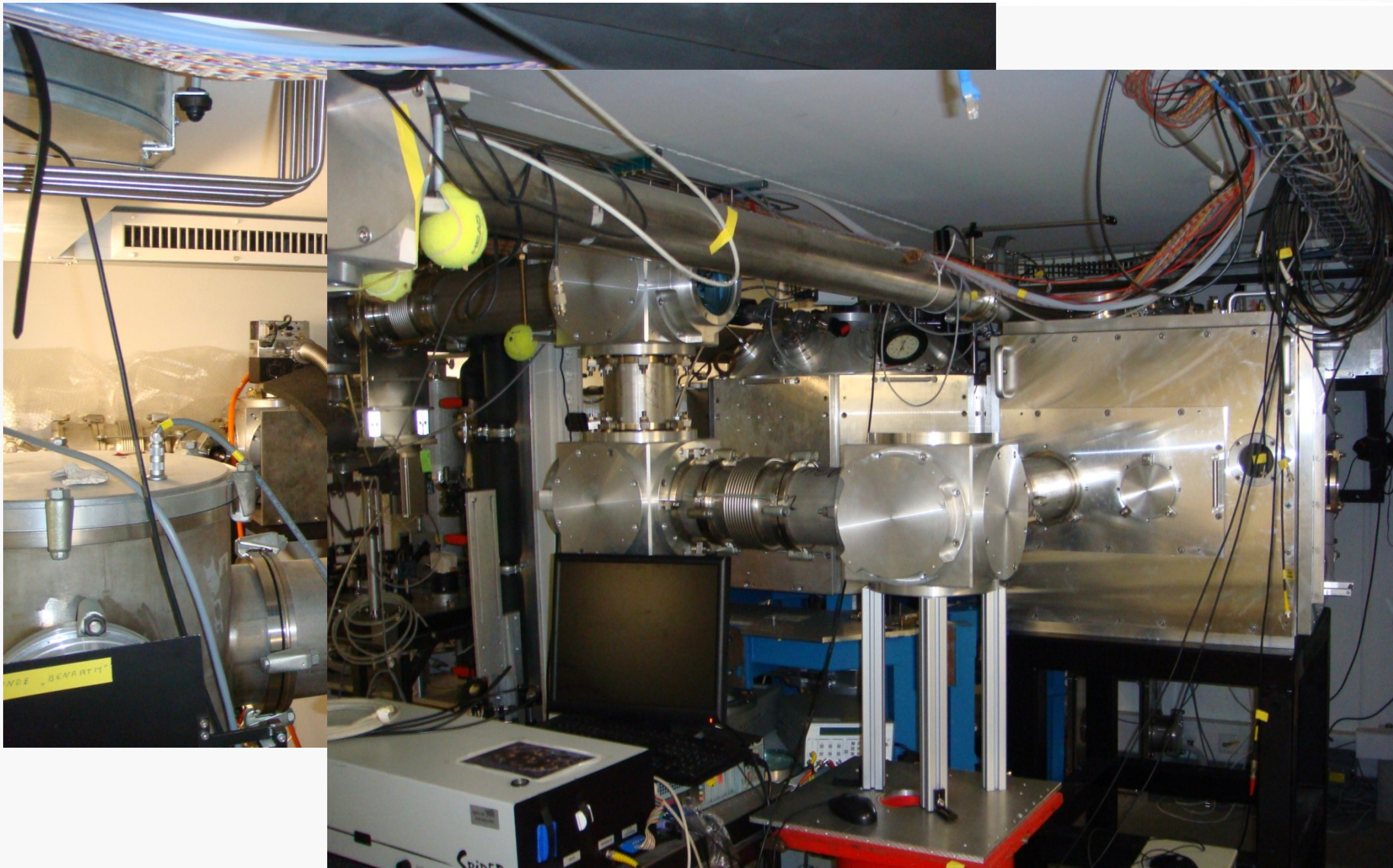
Düsseldorf Arcturus Laser Facility







Beamlines and target chambers



Laser specifications at the end of 2011

	Beam 1	Beam 2	Beam 3
Energy before compression	6 J	6 J	100 mJ
pulse duration is variable	>25 fs	>30 fs	>30 fs
Options	adaptive mirror plasma mirror	adaptive mirror	2ω
Power	200 TW	200 TW	3 TW
XPW system	for contrast	enhancement	

Topics investigated using the Arcturus laser

- HHG – Behmke et. al., PRL (2011)
- Proton acceleration dependent on target size – Toncian et al., PoP (2011)
- Spin polarisation of protons – Büscher et al., SPIN Physics Symposium, (2010)
- Channel formation – Willi et al. Plasma Phys. Control. Fusion (2009)
- Absorption measaurements on sturctured tsrgets – Cerchez et al., to be published
- Electron acceleration

Topics investigated at national and international facilities

- **National collaborations (MBI group in Berlin)**

  Ion acceleration from microspheres: T. Sokollik et al., PRL (2009) - cover page of PRL

- **International collaborations (M. Borghesi (Belfast) and J. Fuchs (LULI))**

  - Laser beam filamentation: G. Sarri et al., PRL (2011)
  - Magnetized soliton remnants: L. Romagnani et al., PRL (2010)
  - Proton production: S. Buffechoux et al., PRL (2010)
  - Laser-driven ultrafast field propagation: K. Quinn et al., PRL (2009)
  - Plasma jets: S. Kar et al., PRL (2008)
  - Observation of collisionless shocks: L. Romagnani et al., PRL (2008)
  - Laser driven micro-lens: T. Toncian et al., Science (2006)

Motivation and goals for electron acceleration

In progress

- Optimization of laser parameters for LWFA (small energy bandwidth, stability, divergence etc.)
- experimental validation of scaling laws

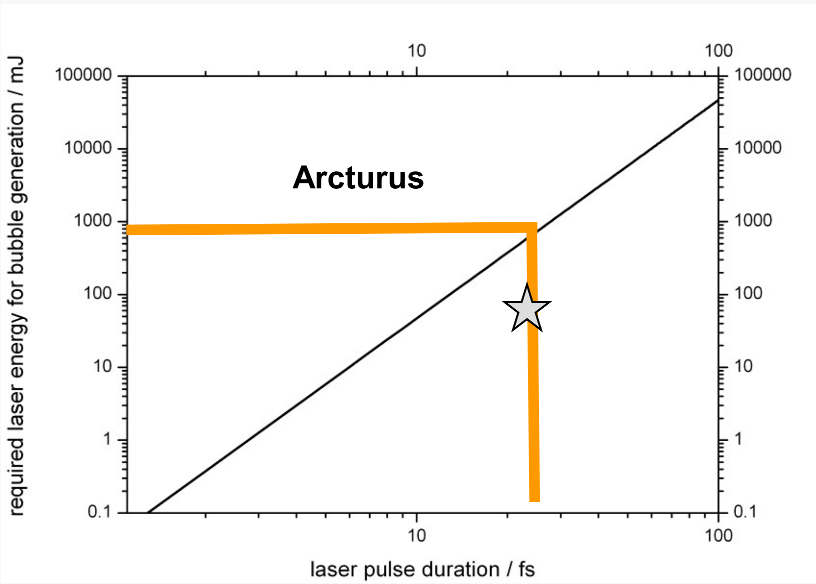
Longer term

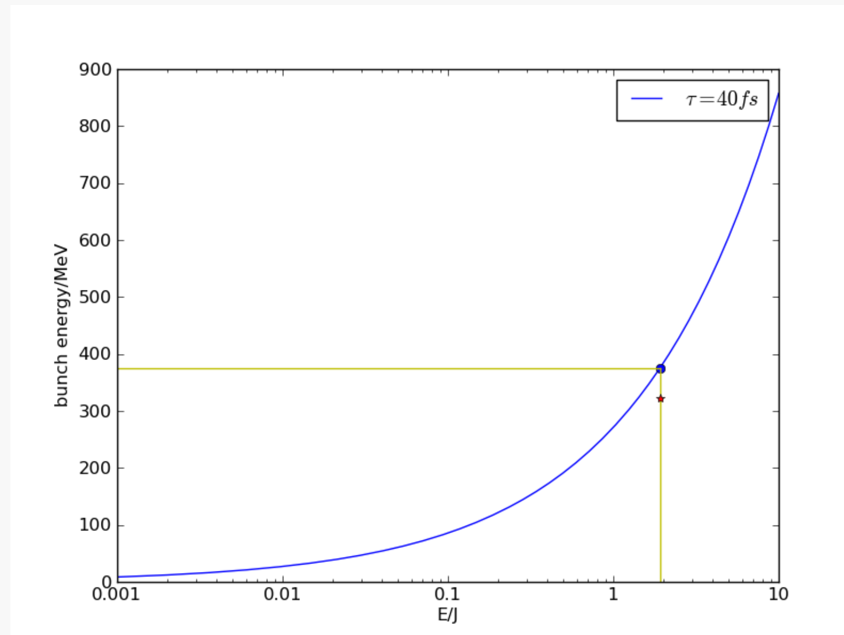
- multi-beam applications: multi-stage acceleration (B. Hidding et al., PRL 104, (2010))
- e- beams as seeder for classical accelerators
- beam driven wakefields with unique features due to short e-bunches
- Thomson scattering

The bubble regime

Pukhov, Meyer-ter-Vehn 2002

Directly accessible for our parameters:





→ **Well above bubble threshold!**

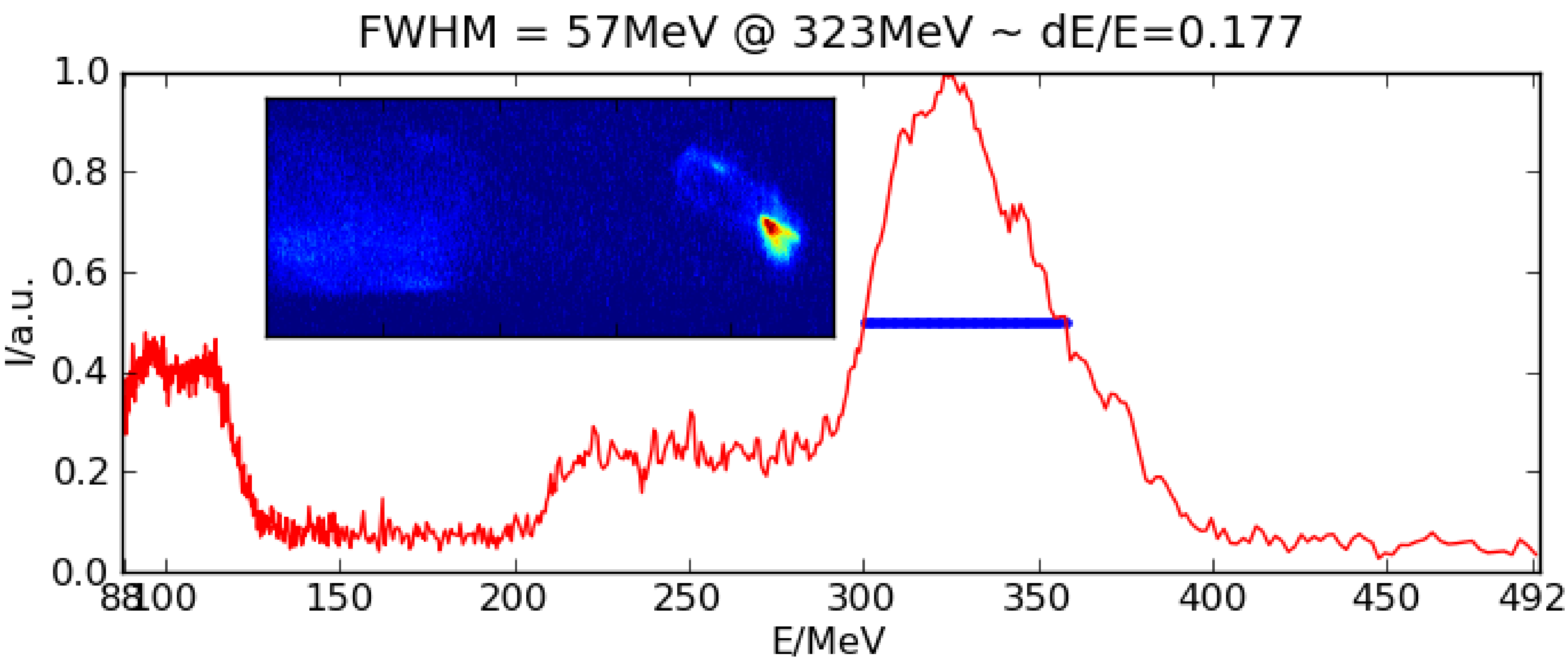
Bubble scaling predictions:
Gordienko/Pukhov, PoP 12 (2005)

if $$P > P_{\rm crit} \approx \left(\frac{\tau[\rm fs]}{\lambda[\mu \rm m]}\right)^2 \times 30\,\rm GW$$ **= 30 TW**

then $$E_{\rm mono} \approx \sqrt{\frac{P_{\rm laser}}{8.5\,\rm GW}} \times \frac{\tau[\rm fs]}{\lambda[\mu \rm m]} \times 0.1\,\rm MeV$$

Electron acceleration with Arcturus laser:
1.9J, 40fs

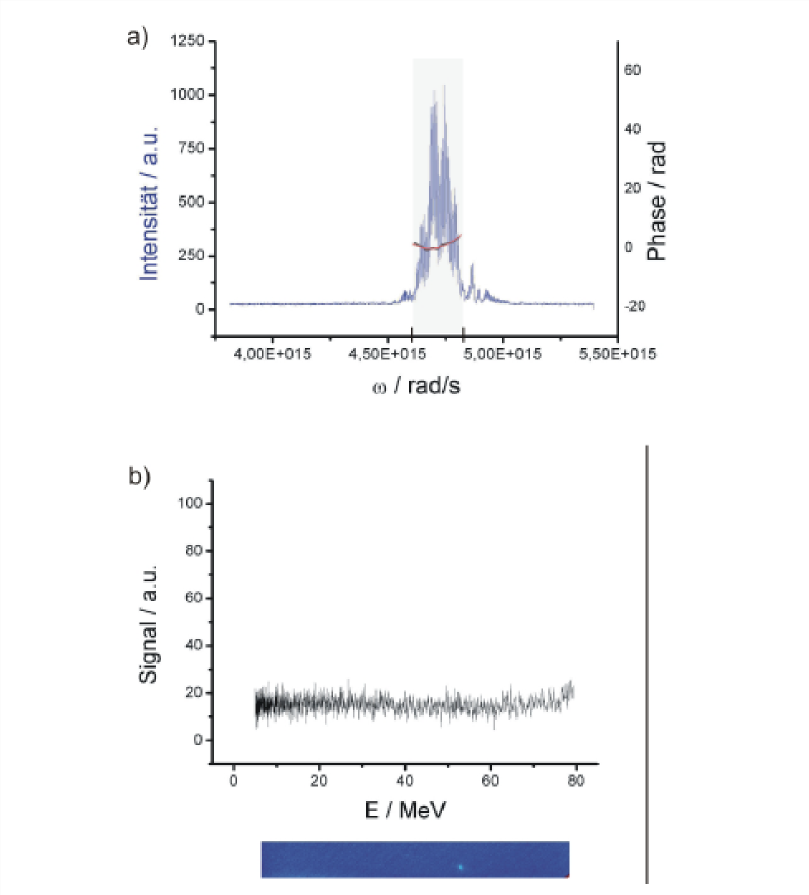
$\tau = 40\ fs,\ \rho_e = 1.64e+019\ cm^{-3},\ \lambda_{Plasma} = 8.24\ \mu m,\ \tau c = 11.99\ \mu m$



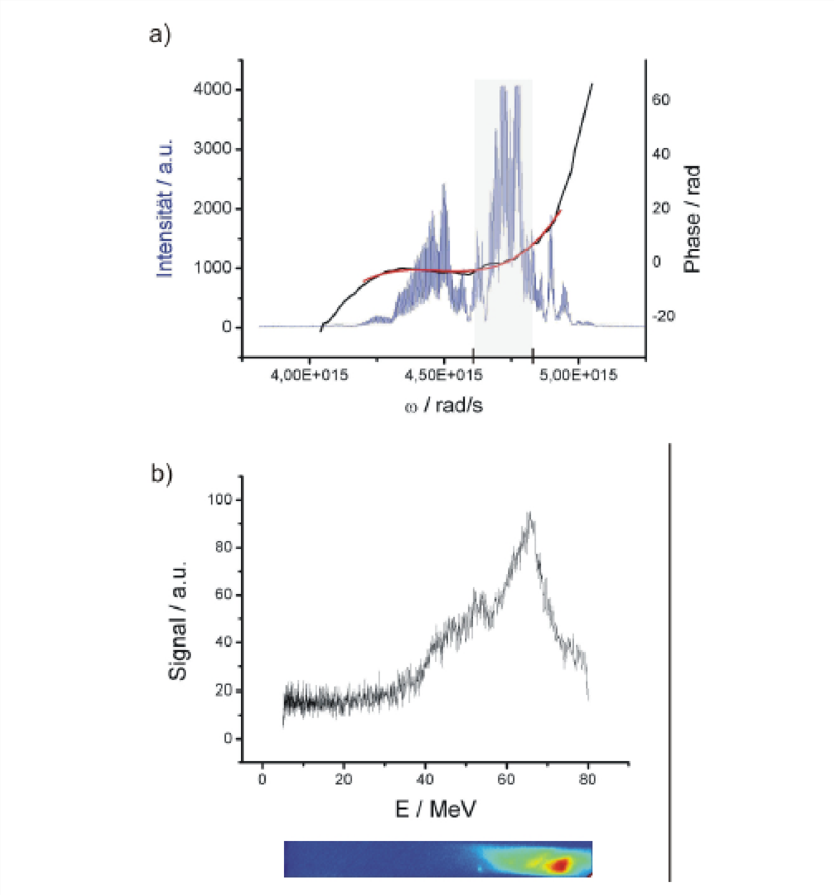
Theor. prediction using Pukhov's scaling law (Gordienko/Pukhov, PoP (2005)): 375MeV

Simultaneous SPIDER / electron measurements

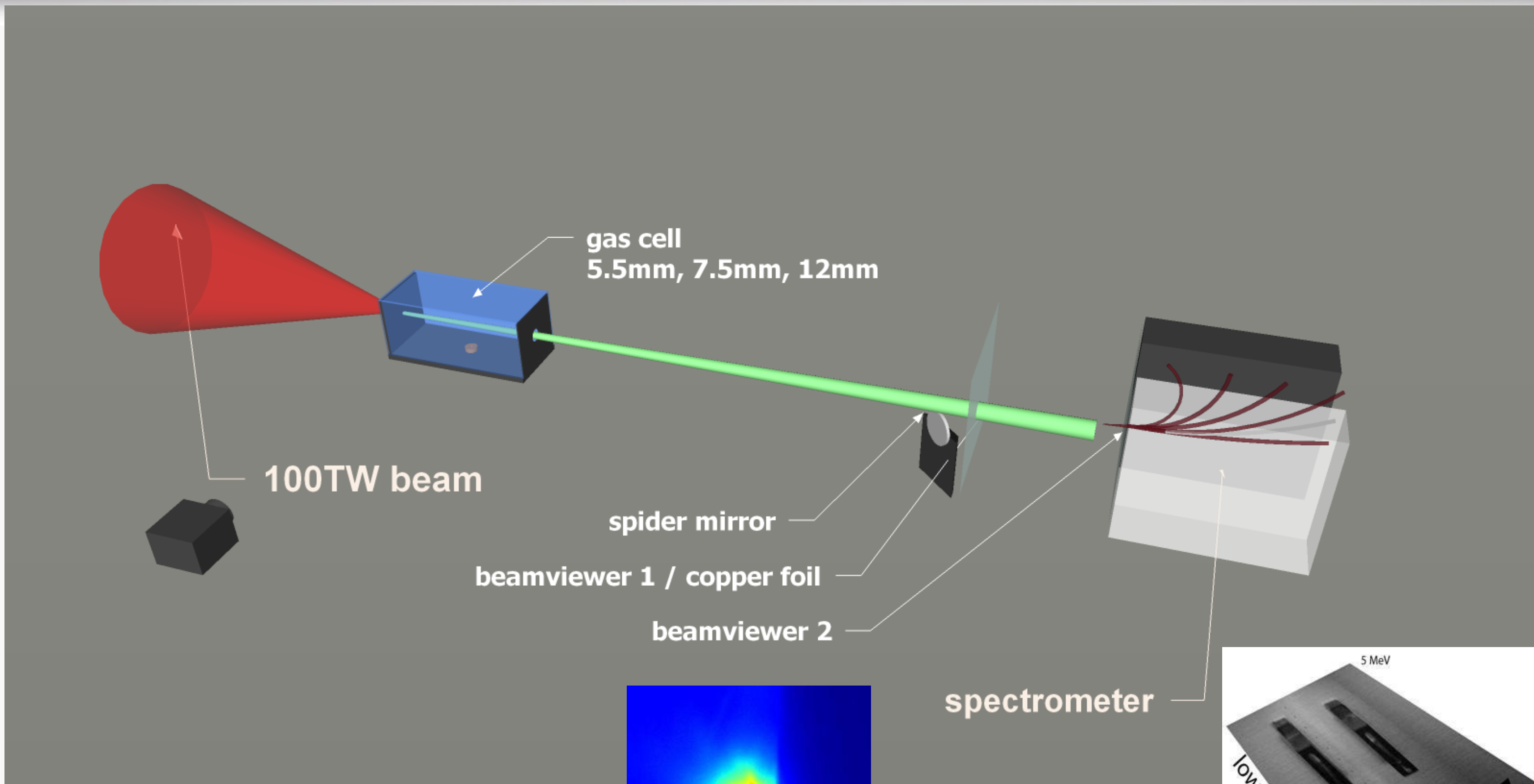
Focus 300µm in front of gas jet entrance

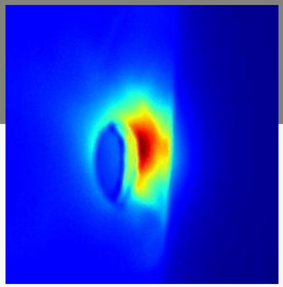


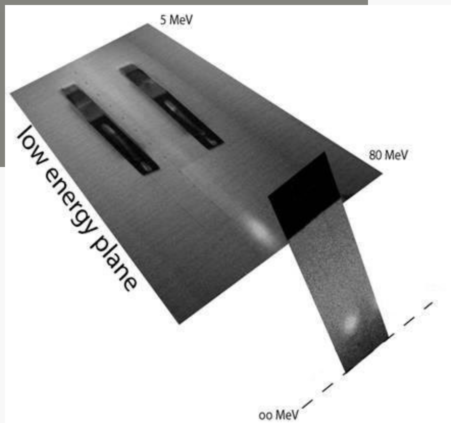
Focus directly on gas jet entrance



Gas cell setup

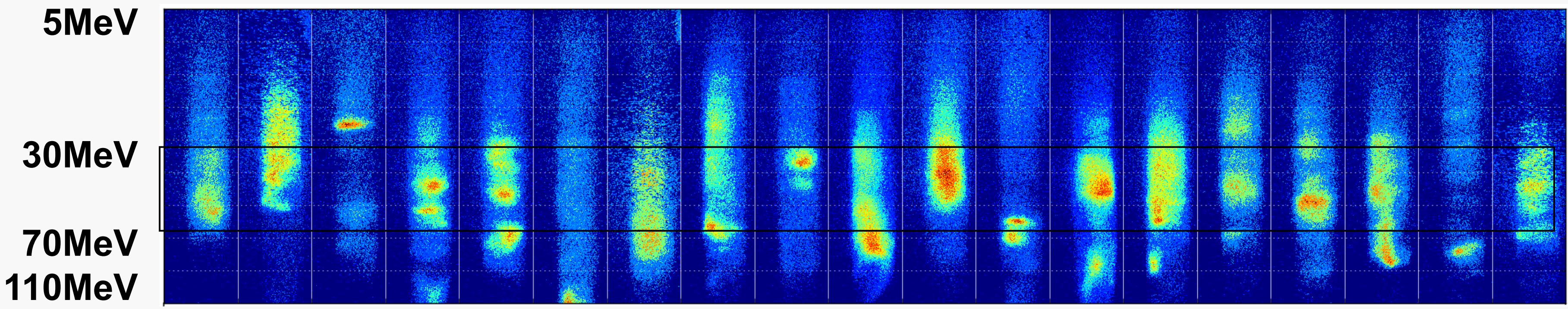


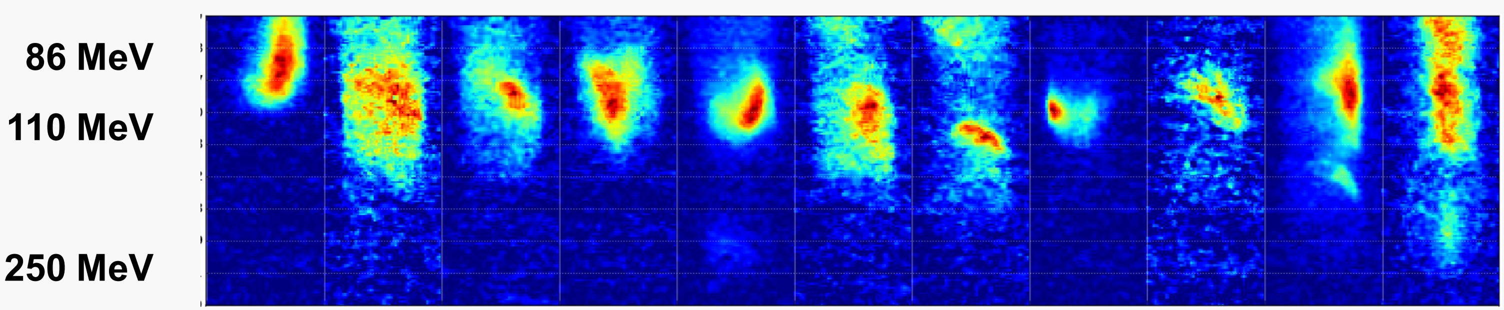




Reproducibility studies using Arcturus

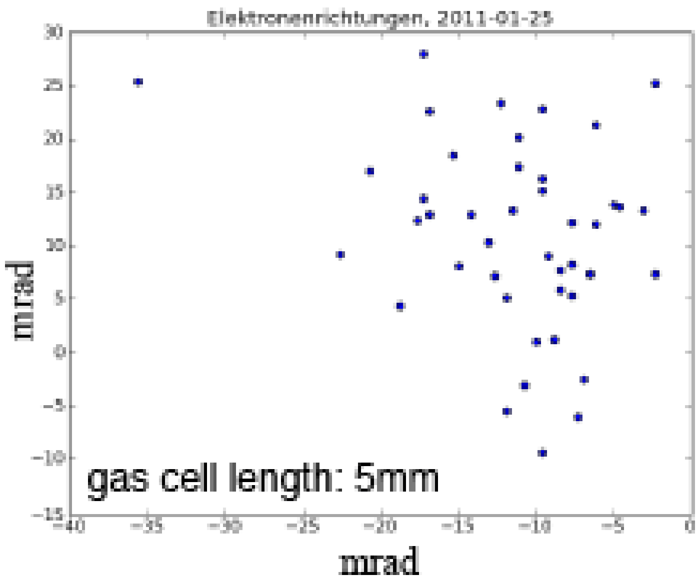
Sample shot collection on the gas cell (non consecutive, 50% of shots hit the aperture)





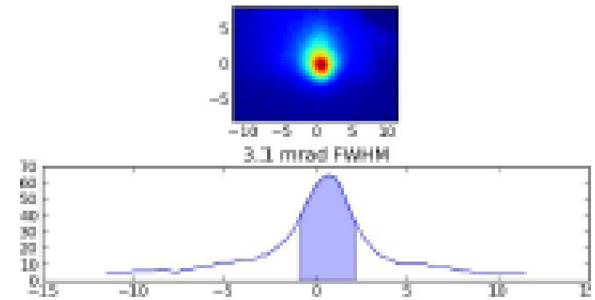
Pointing stability and beam divergence

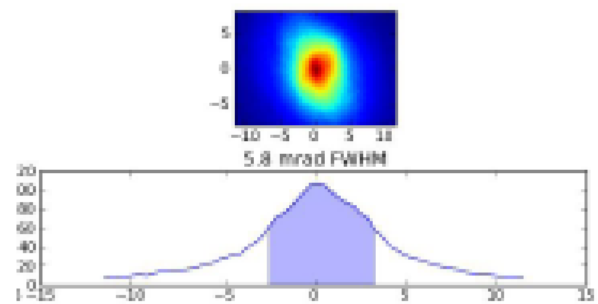
- Pointing Stability



- 8.5mrad x 14.8mrad (RMS)

- Beam Divergence

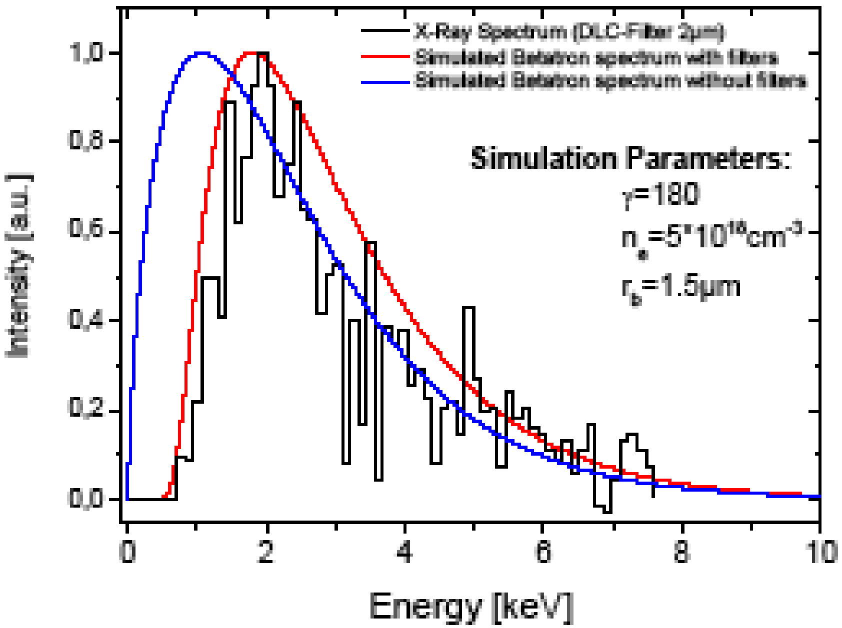


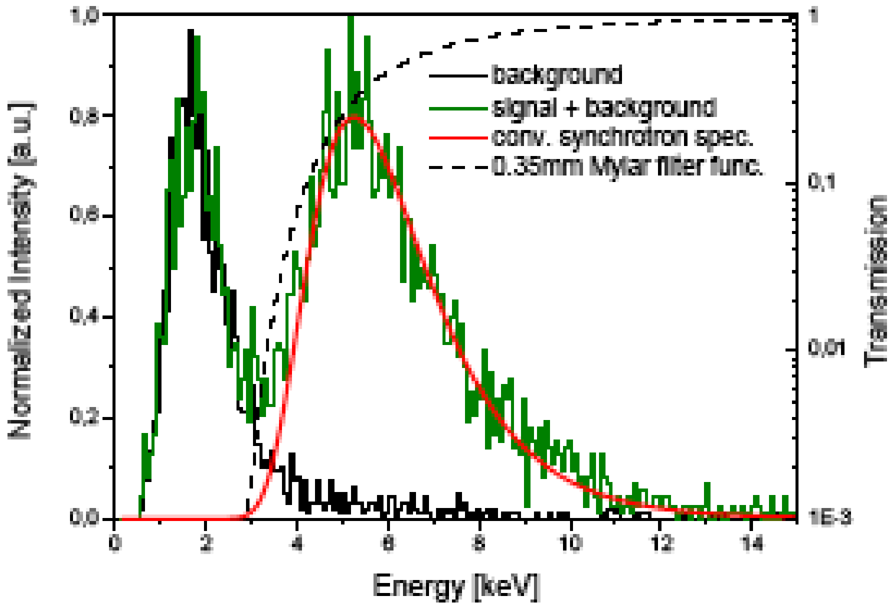


→ Increased pointing stability and divergence compared to gas-jet

Betatron radiation: Spectral characterisation

- **Single photon counting mode**
  - Düsseldorf
  - Jena

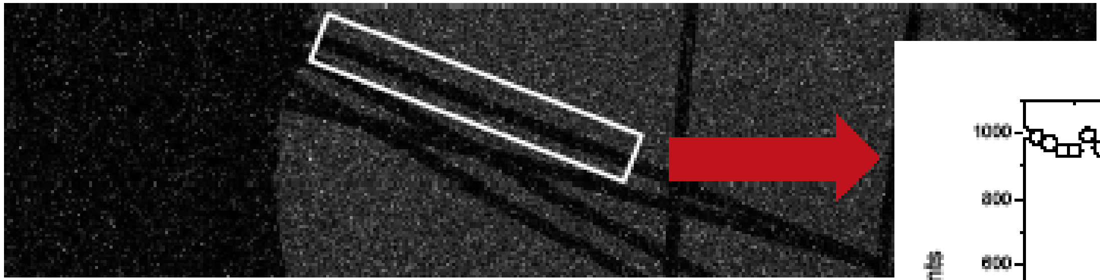


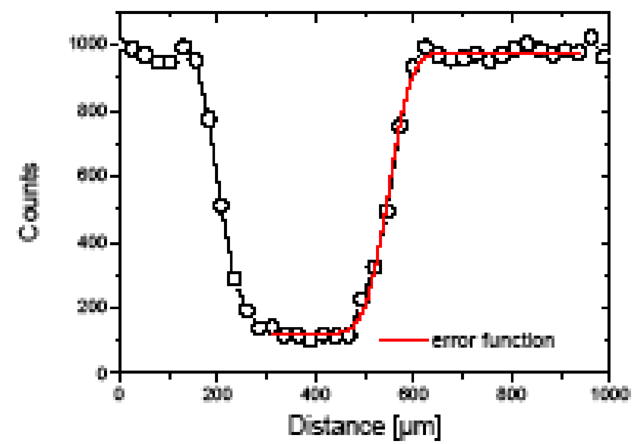


- **E_{max} = 1070eV**

Betatron radiation: Source size

- "Knife Edge" Technique
- Backlighting of tungsten wire (Ø = 100μm)





- Width of error function is proportional to source size

→ **Source Size ≤14μm**

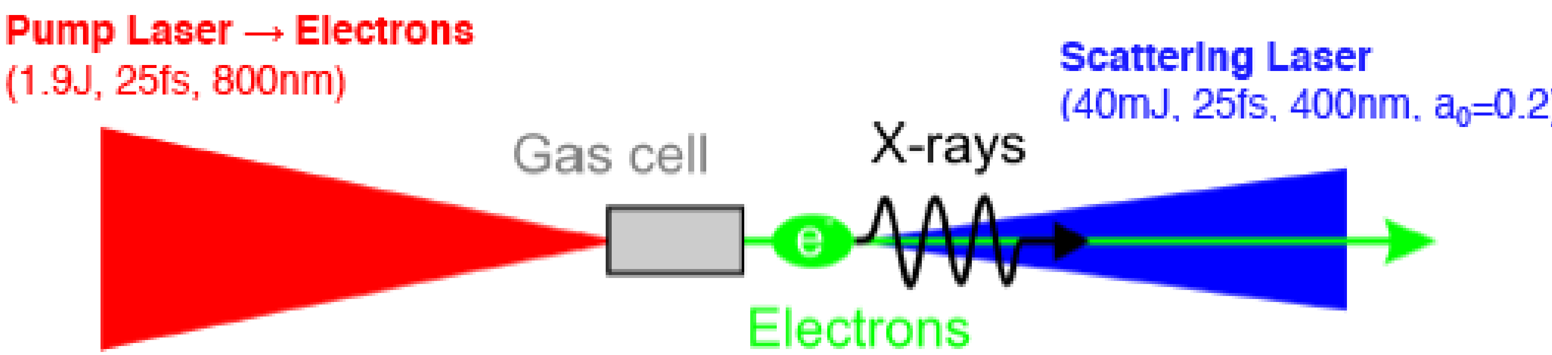
Applications

- **Generation ultra-short X-ray sources: Thomson scattering**

- **Space radiation studies**

Thomson scattering

- Head-on (180°) geometry
- Counterpropagating laser field



→ **Ultrashort narrowband x-rays**

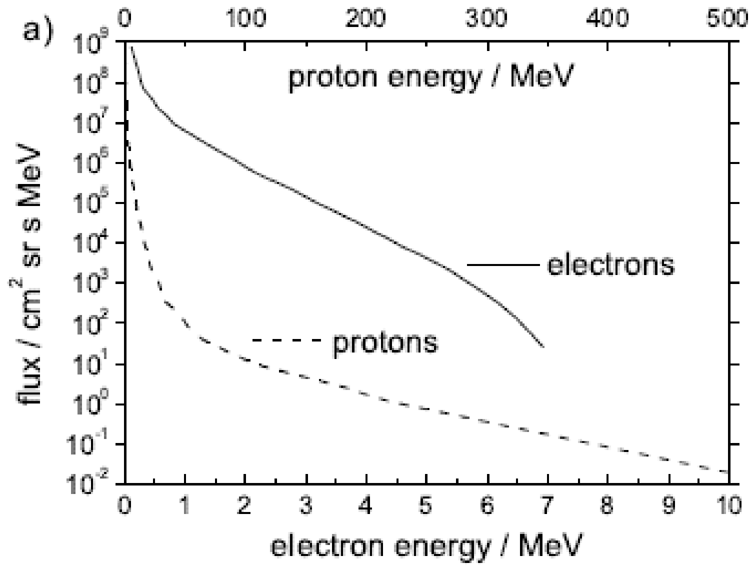
$$\lambda = \frac{\lambda_0}{4\gamma^2}\left(1 + \frac{a^2}{2} + \gamma^2\theta^2\right)$$

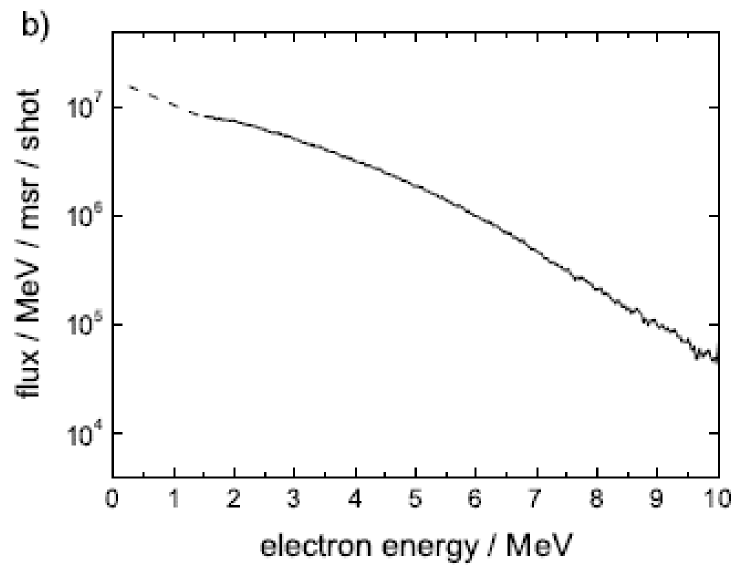
Flying mirror on thin foil targets

Space radiation studies

Typical e- flux in the van-Allen belt

Easily producible thermal spectrum from an LPA (simulation)





ESA and university funding – B. Hidding

B. Hidding, et al., Deutsche Patentanmeldung 10 2010010716.6 (2010)

B. Hidding, et al. NIMPR 636, 31 (2011)

Possibilities for open access

- As an university we can offer time at the facility at any time
- Experiments should however be carried out on a collaborative basis

Funding and networks

- **Transregional Collaborative Research Centre SFB/TR18 (DFG)**
  (Düsseldorf, Jena, LMU, MPQ and MBI)
  (It is a 12 year programme which started in 2004 and is assessed after every 4 years)
- **Graduate school GRK1203 (DFG)**
  (Düsseldorf and Jülich)
  (It is a 9 year programme with one assessment)
- **Graduate school HITEC (HG)**