# Towards a Self-modulation Experiment with long Electron Beams at PITZ

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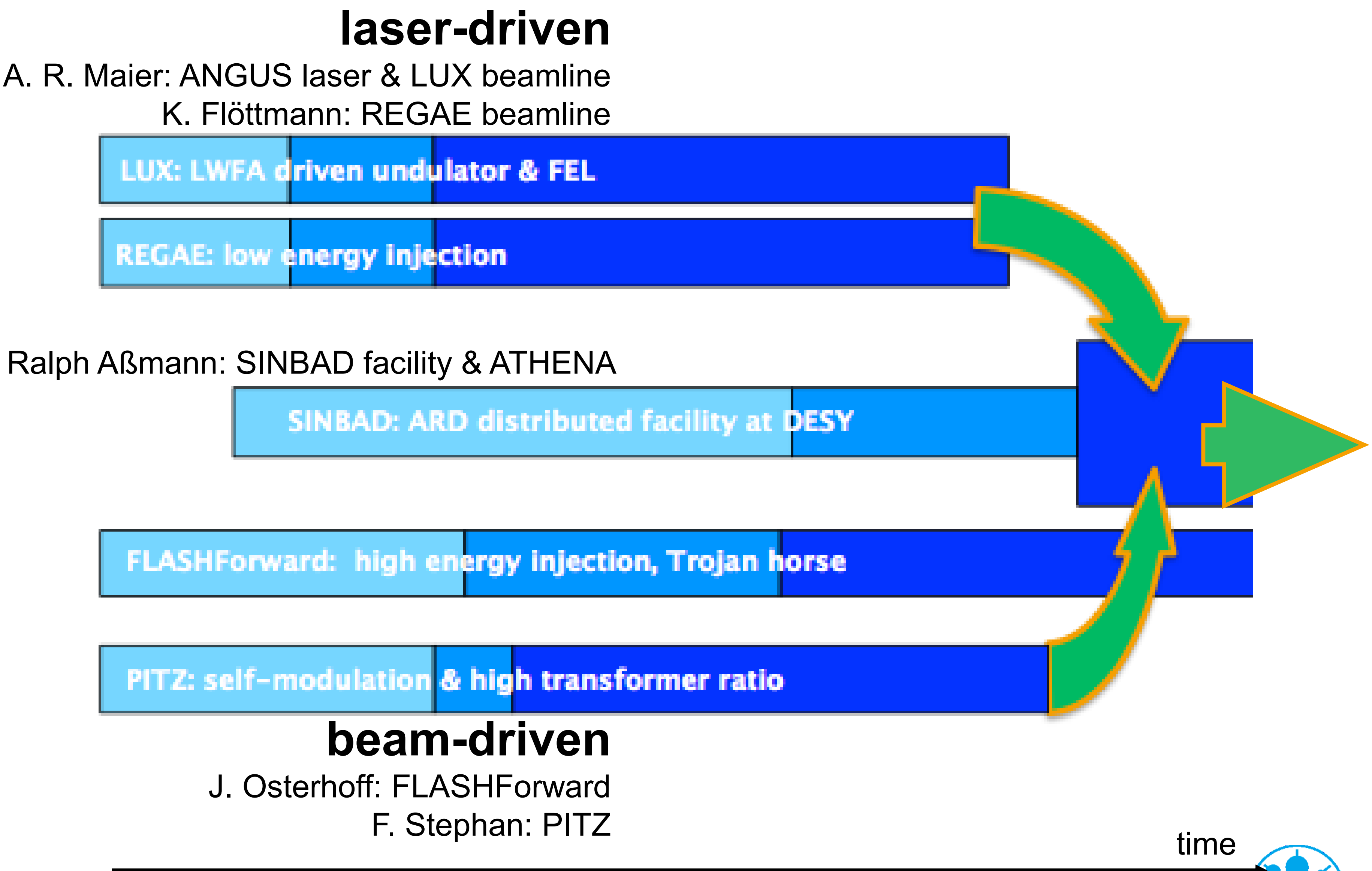
HELMHOLTZ ASSOCIATION

PITZ Photo Injector Test Facility Zeuthen

DESY

# Joint LAOLA Strategy



# Outline

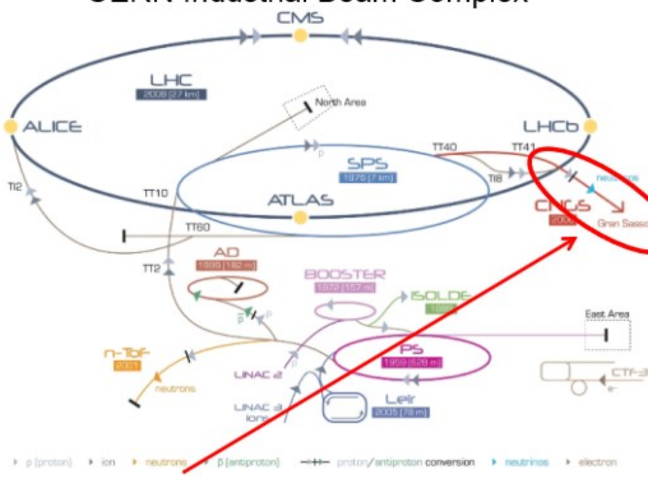
- Motivation
- Plasma Cell
- PITZ Beamline Remodeling
- Several experiments for preparation
  - 1) Beam dynamics (focusing into plasma cell)
  - 2) Electron beam – plasma cell interaction
  - 3) Electron beam scattering
- Current status

# EAAC Workshop 2013: Patric Muggli, AWAKE: A Proton-Driven Plasma Wakefield Experiment at CERN

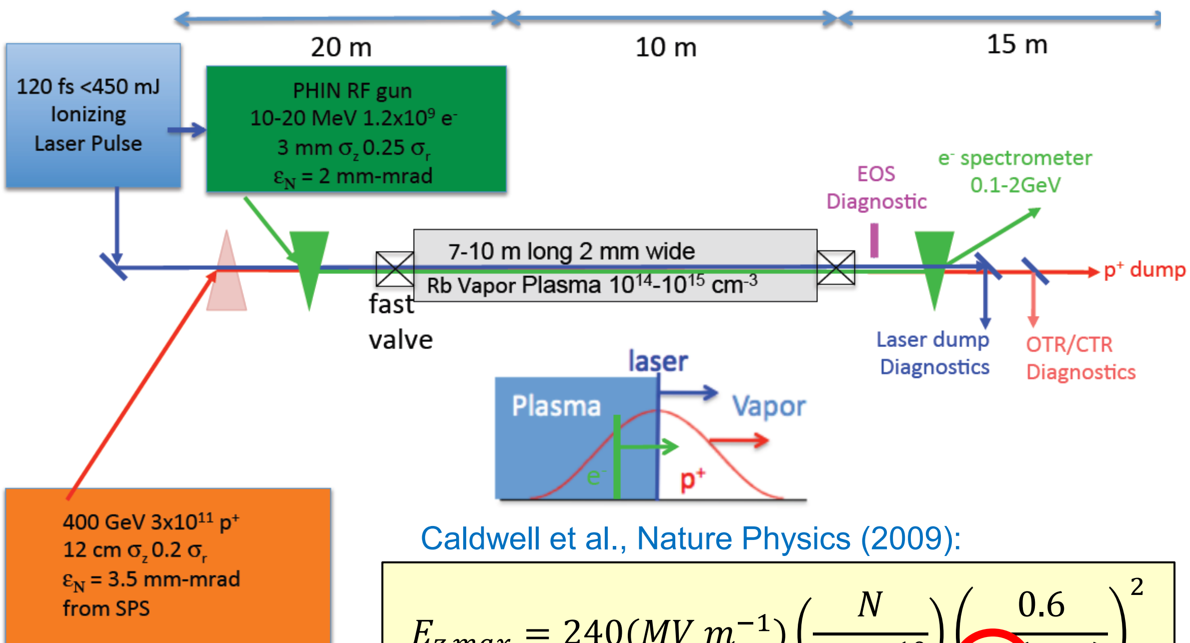
> Use high energy proton beams from SPS to drive plasma wave

> Convert proton beam energy to accelerate electron beam in single stage

CERN Industrial Beam Complex




CNGS experimental area




Caldwell et al., Nature Physics (2009):

$$E_{z,max} = 240(MV\ m^{-1})\left(\frac{N}{4x10^{10}}\right)\left(\frac{0.6}{\sigma_z(mm)}\right)^2$$

> High accelerating gradient requires **short** bunches ($\sigma_z$ less than 100µm)

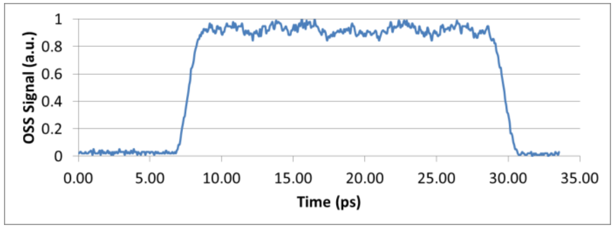
> Existing proton machines produce **long** bunches (10cm)

**Self-modulation!**

Courtesy:
Patric Muggli, Erdem Öz

# Why Experiments at the Photo Injector Test Facility at DESY, Zeuthen Site (PITZ)?

> Favorable circumstances




- Very high level photo injector test facility
- Worldwide unique laser system (pulse shaper)
- Well developed diagnostics (high resolution electron spectrometer, etc.); soon: transverse deflecting cavity + dispersive section for longitudinal phase space measurements
- High flexibility (Pure R&D facility)

> Possible contribution from PITZ:

- Self-modulation of electron beam (same principle as for proton beam!)
- Later: High transformer ratio (factor up to 8 possible)

# Simulated Self-modulation Experiment

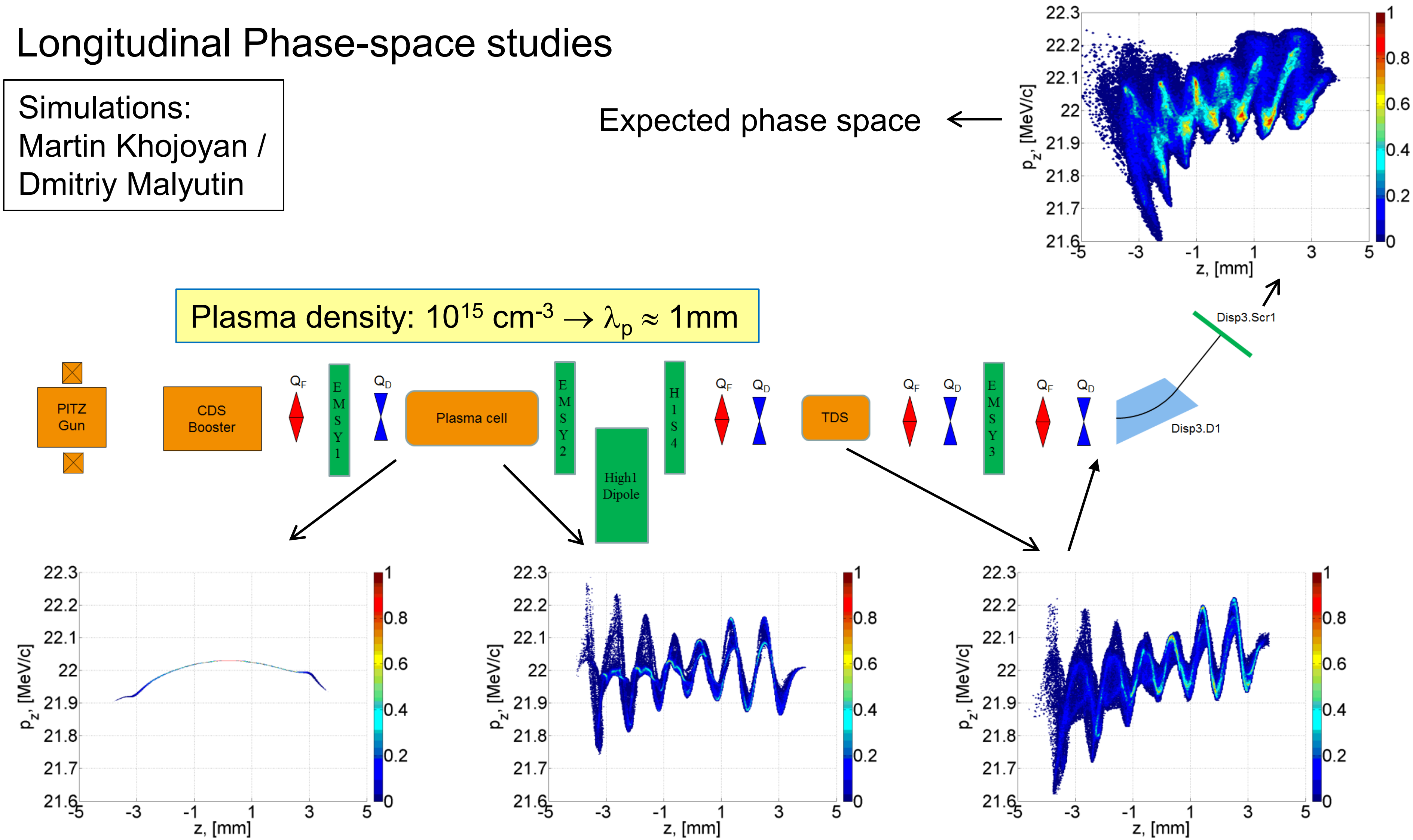
Not fully optimized

## Longitudinal Phase-space studies

Simulations:
Martin Khojoyan /
Dmitriy Malyutin

Expected phase space

Plasma density: $10^{15}$ cm$^{-3}$ $\rightarrow \lambda_p \approx$ 1mm



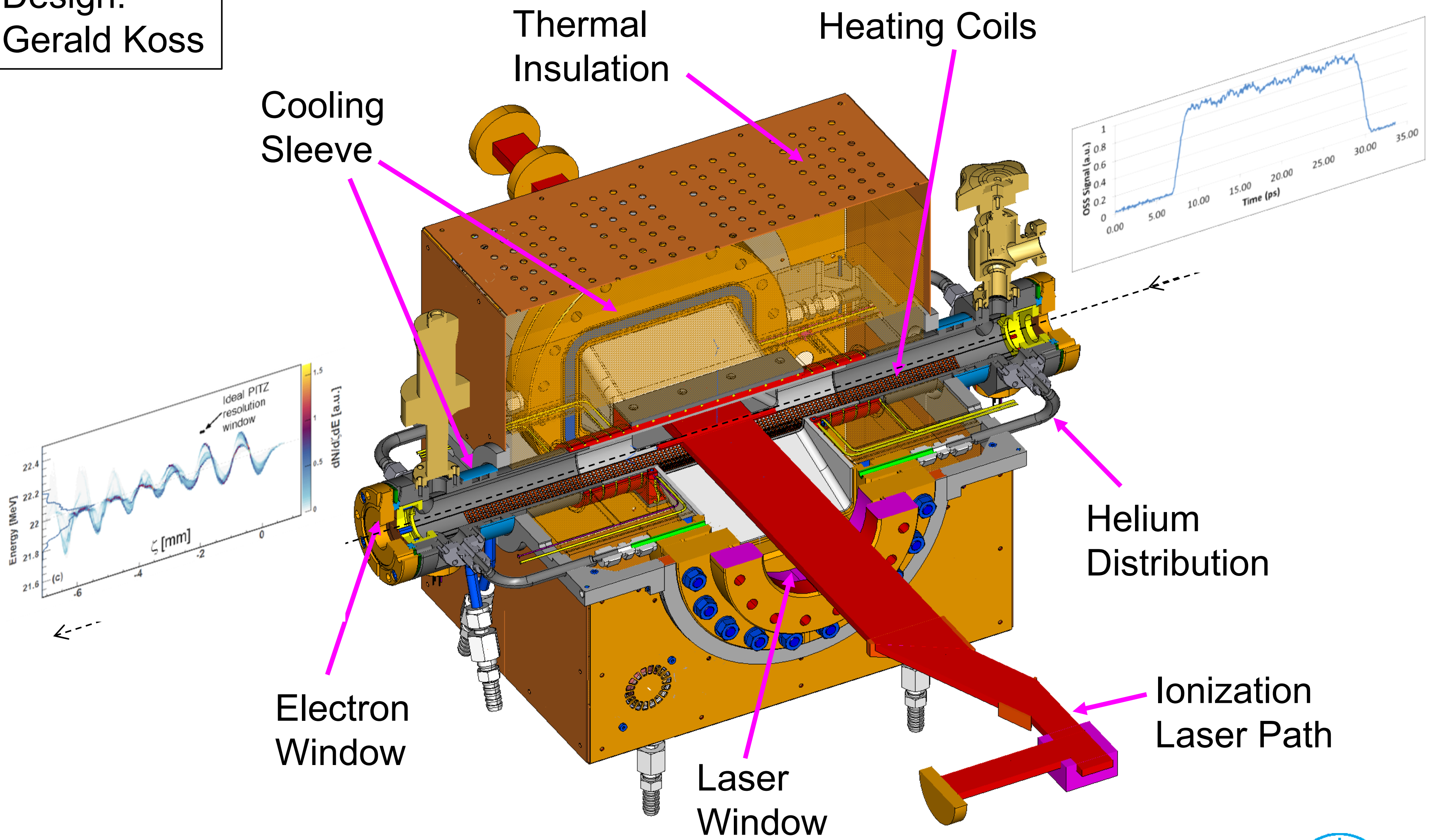

In front of plasma cell

After plasma cell
(assuming zero initial energy spread)

In front of dipole

# Plasma Cell Design

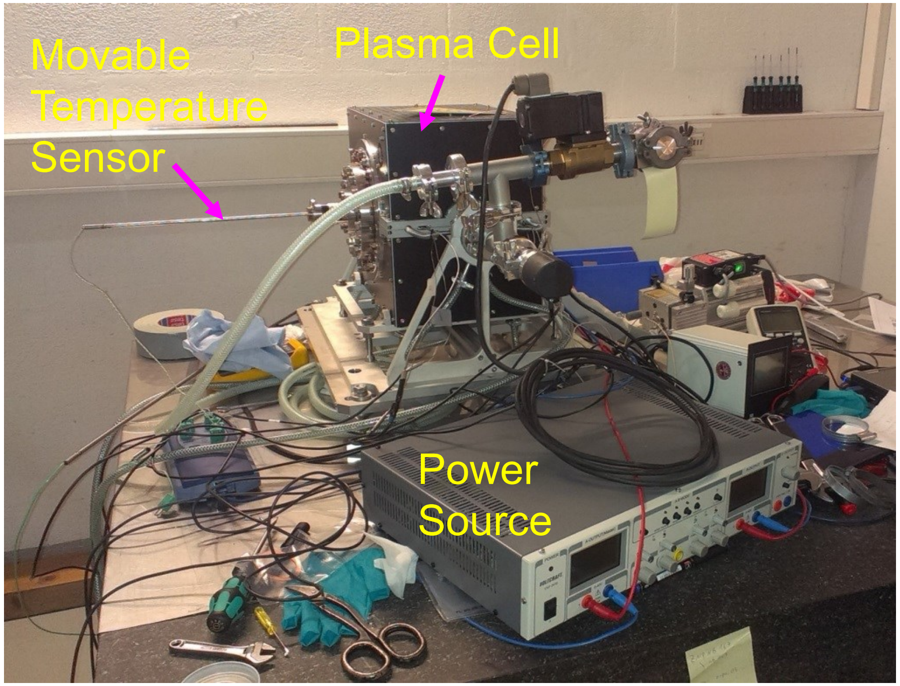
Design:
Gerald Koss

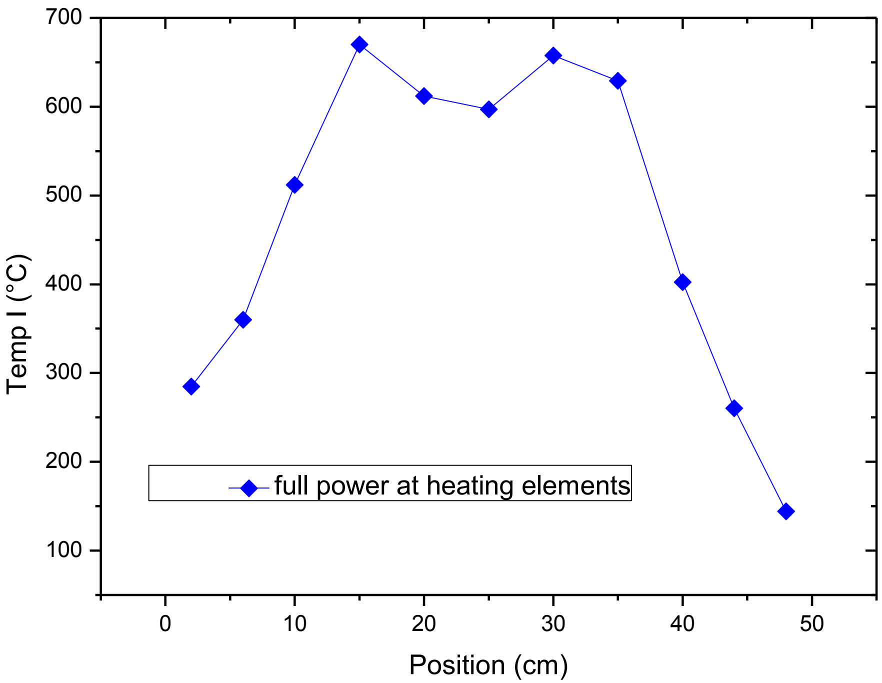


# Commissioning of PITZ Plasma Cell

## Measurement of longitudinal temperature profile

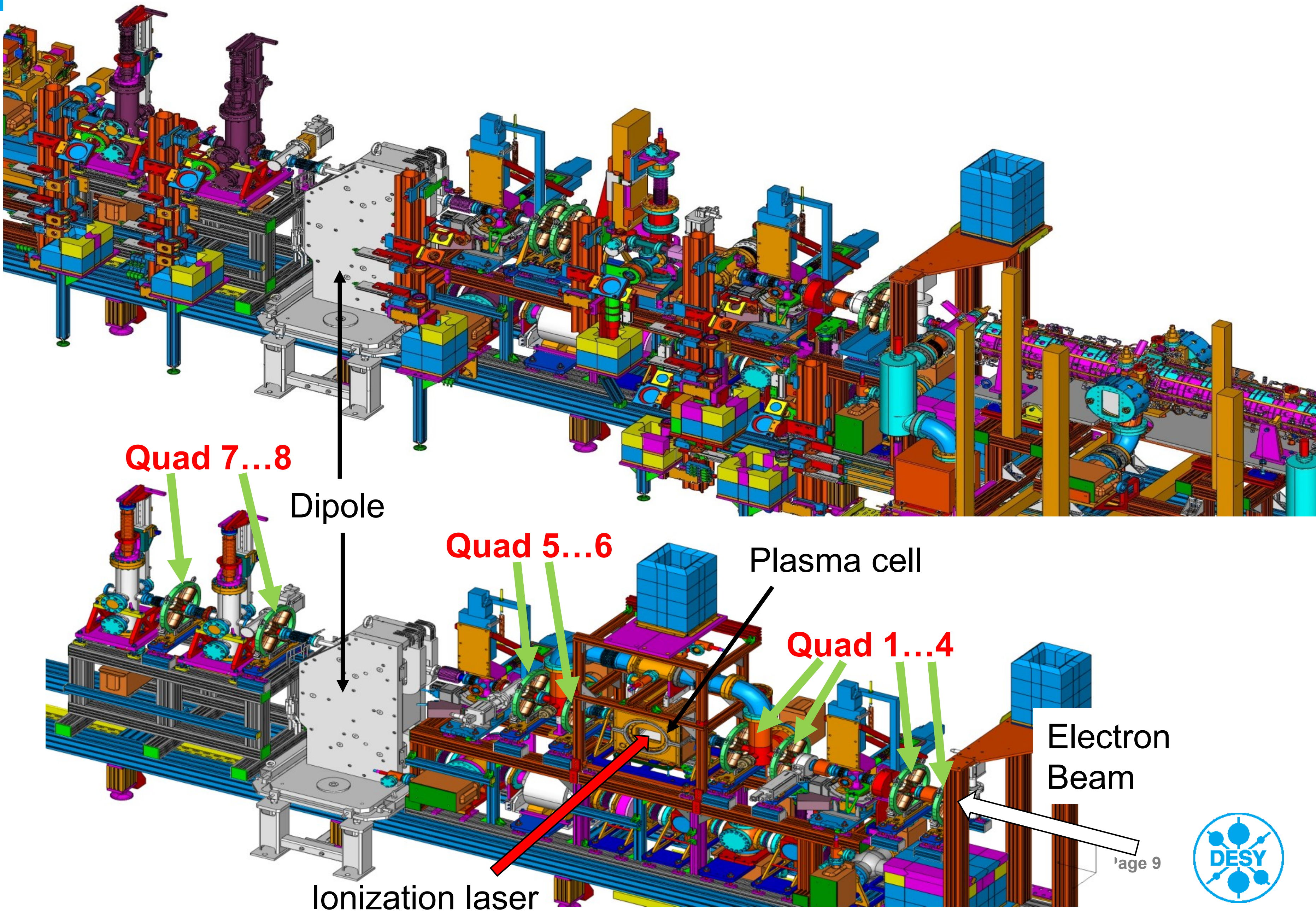
- Preliminary results



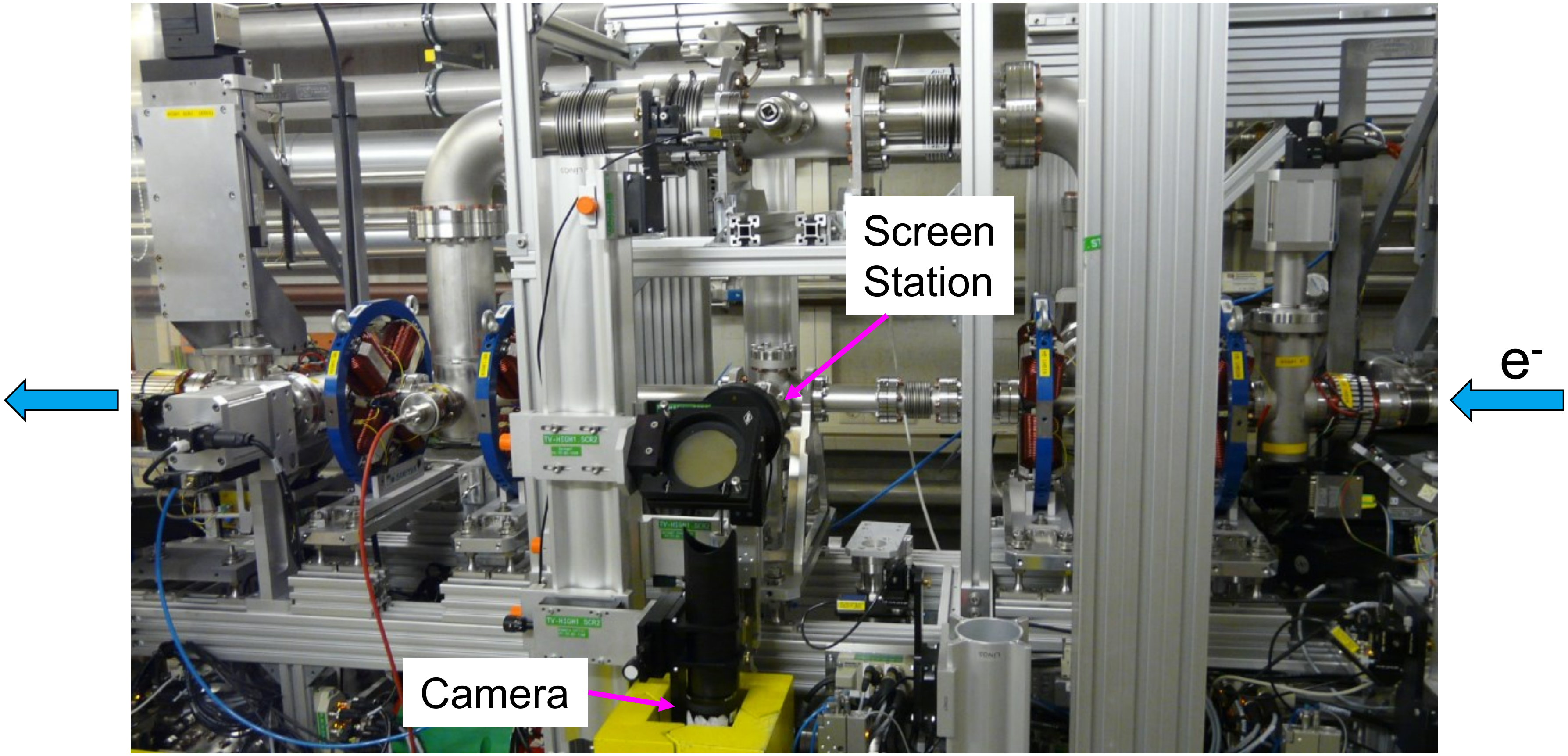

- Maximal temperature ≈700°C → enough to reach Li gas density of ≈$10^{16}$ cm$^{-3}$
- Temperature dip: influence of cross-shaped plasma cell

# Beam Line Remodeling



# Pre-experiment #1: Screen station

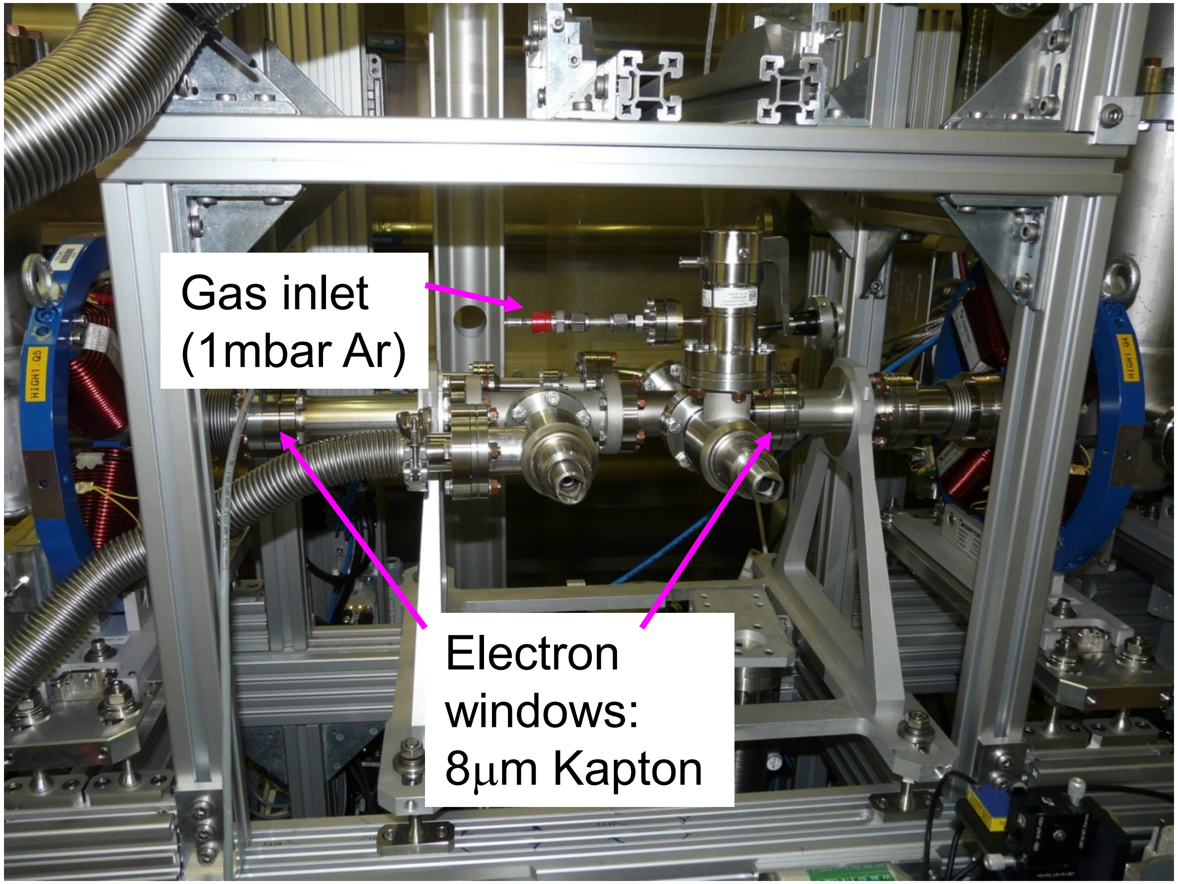
- Purpose: Find quadrupole settings for best focusing




- Best result: <100µm spot size (100 pC bunch charge; 22 MeV; no scattering foil)

# Pre-experiment #2: Dummy Plasma Cell

- Purpose: test of interaction electron beam ↔ electron window foils

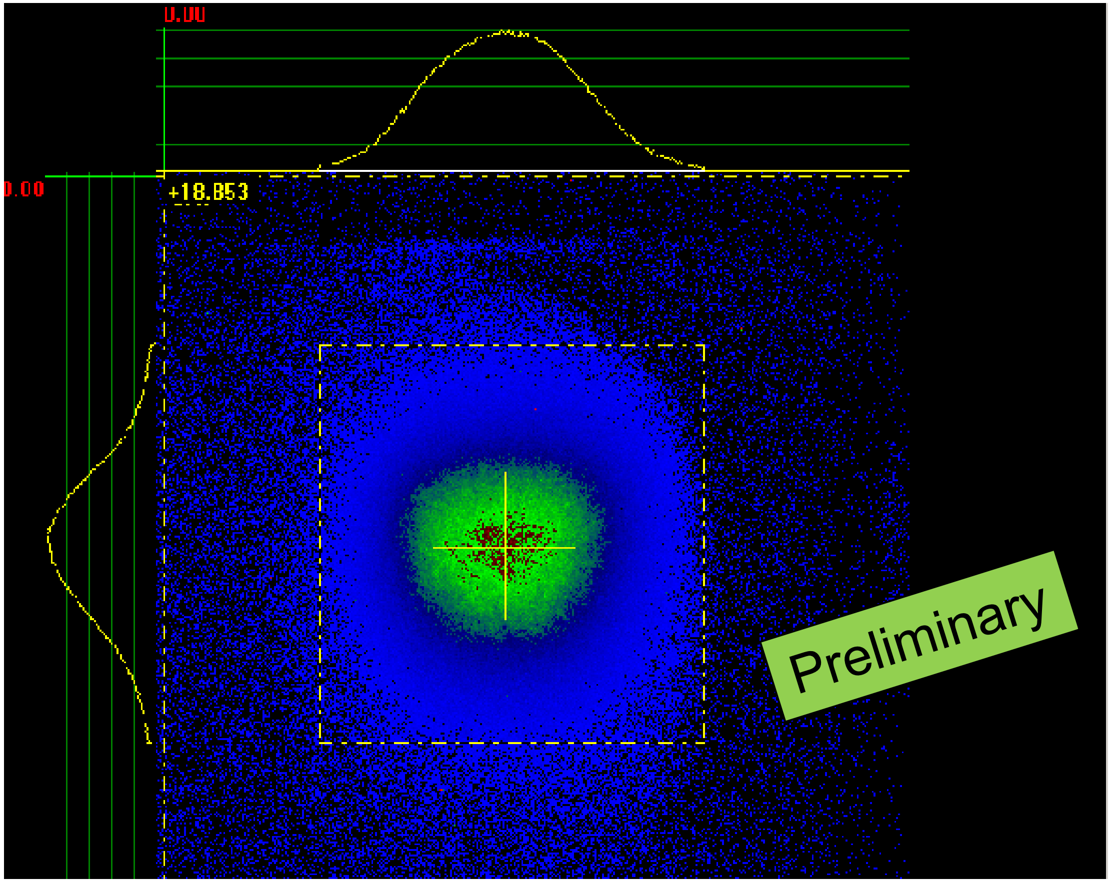



$e^-$

- 1) No damage after several hours of continuous run (nominal conditions and factor 100 more); negligible gas diffusion

# Pre-experiment #2: Dummy Plasma Cell

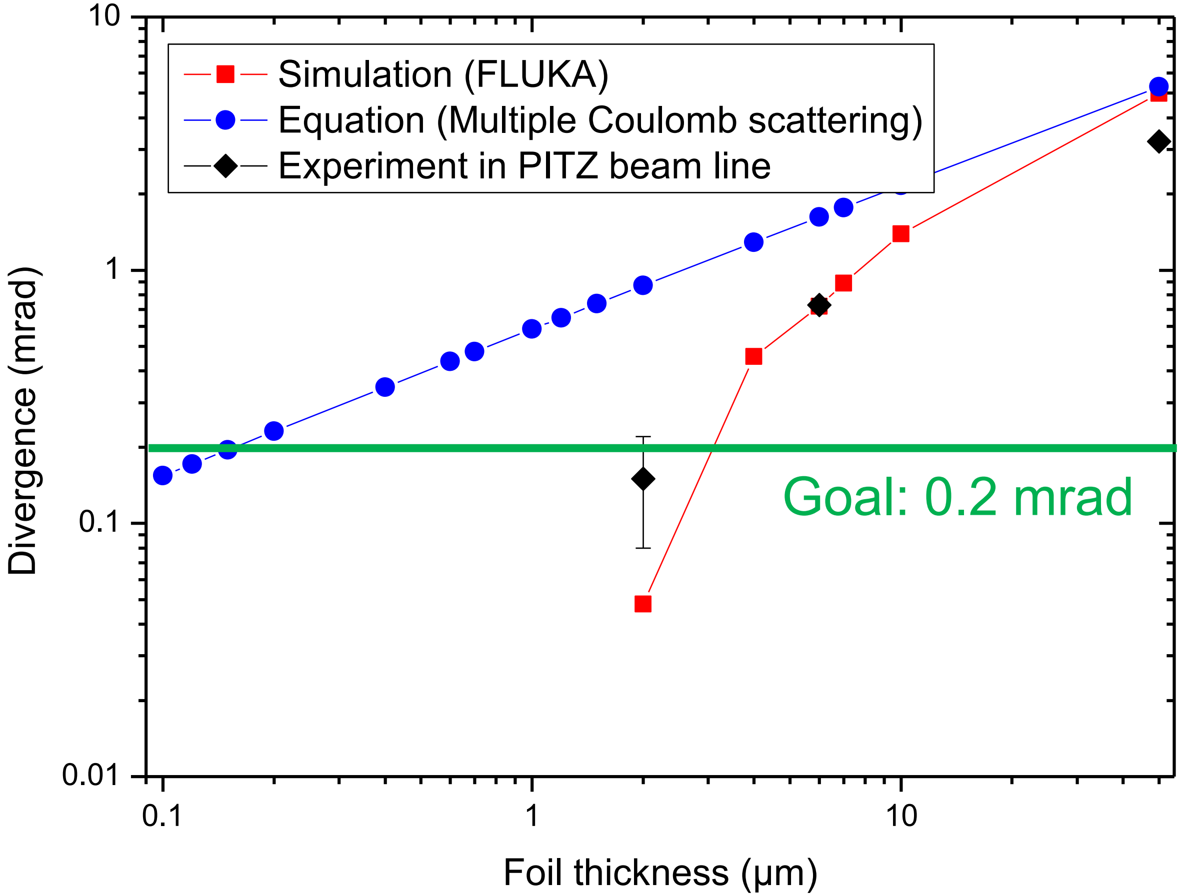
- Purpose: test of interaction electron beam $\leftrightarrow$ electron window foils




- 2) Capturing of tightly focused beam behind plasma cell (at that time only 2 Quads available for beam capturing)

# Pre-experiment #3: Electron Beam Scattering

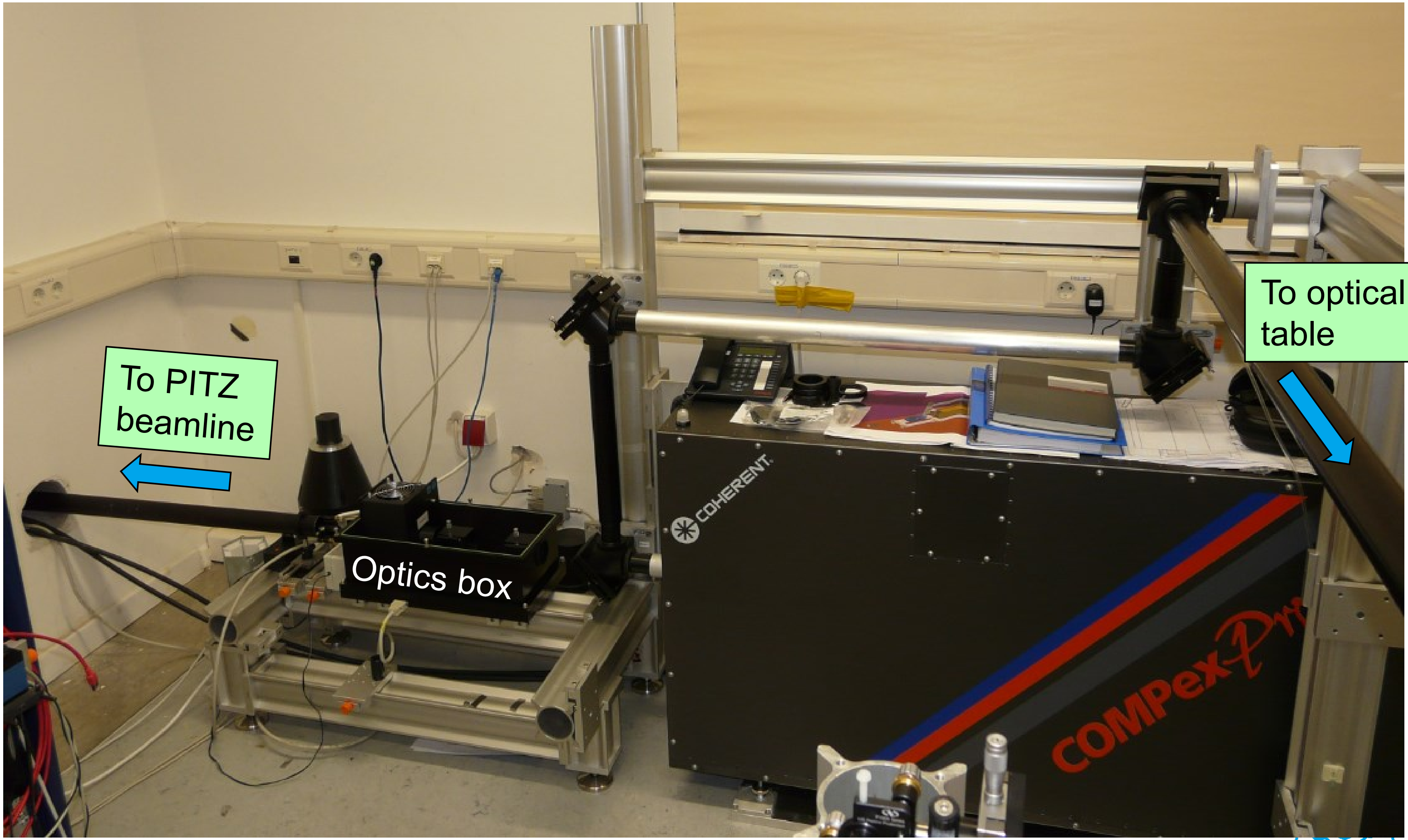
- Purpose: Find maximal allowable window foil thickness




- Result: ≈3µm (to be checked: gas diffusion)

# Ionization Laser (ArF Excimer Laser; 193 nm)

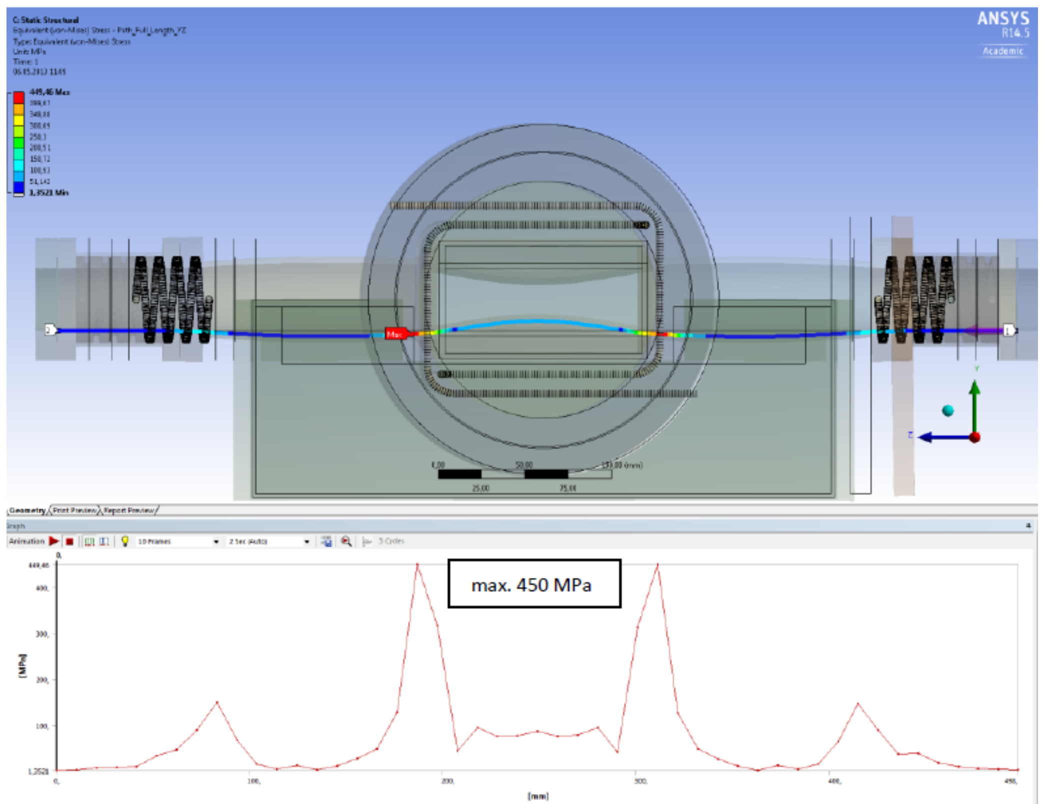
- Coherent COMPexPro 201: up to 400 mJ / pulse; 10 Hz



# Everything ready to go, BUT…

- After last test sequences a small vacuum leak was found at the cell
- Plasma cell central body is made out of 1.4828 heat resistant steel (up to 1000°C in air) - 5 pieces welded together
- Leak search and repairs are under way

ANSYS Simulations of Mechanical Stress (Side view)



# Summary

- Self-modulation experiments are in preparation
- PITZ plasma cell
  - Designed and fabricated
  - Commissioning mainly done (next step: Lithium vaporization, ionization)
- PITZ beamline was remodeled
- Ionization laser is set up (beam line almost completed)
- Several preparatory experiments have been performed
  - 1) Beam dynamics: <100μm focusing into plasma cell was achieved
  - 2) Electron beam – plasma cell interaction: 8μm Kapton foil could be used for first experiments
  - 3) Electron beam scattering: Simulation and Experiment show goal of 3μm window thickness
- Current status: leaky plasma cell is being repaired