Electron windows studies for Self-Modulation Experiments at PITZ

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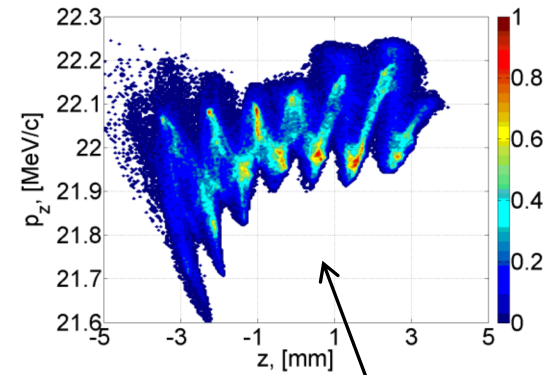
Simulated Self-modulation Experiment

Not fully optimized

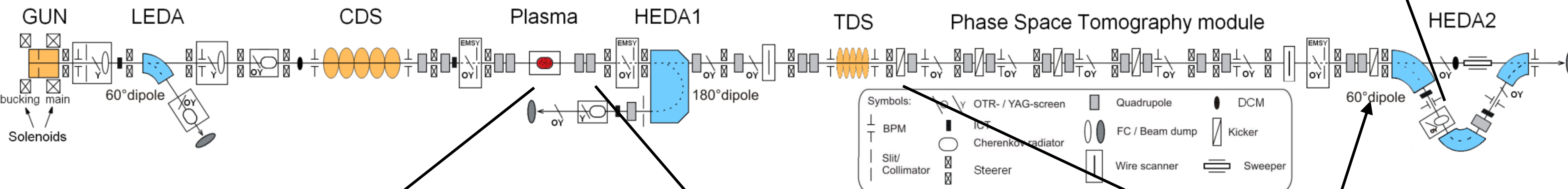
Longitudinal Phase-space studies

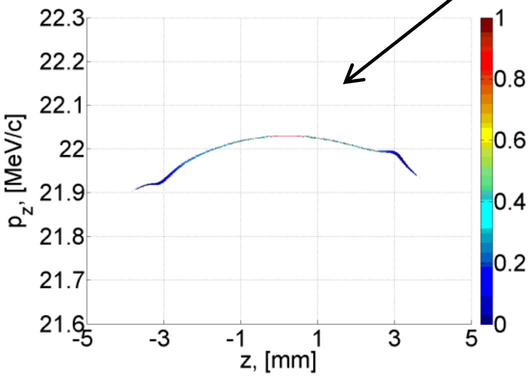
Simulations:
Martin Khojoyan /
Dmitriy Malyutin

Expected phase space ←

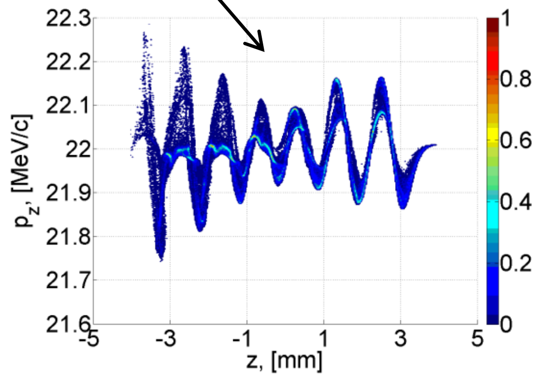


Plasma density: 10^{15} cm^{-3} → $\lambda_p \approx$ 1mm

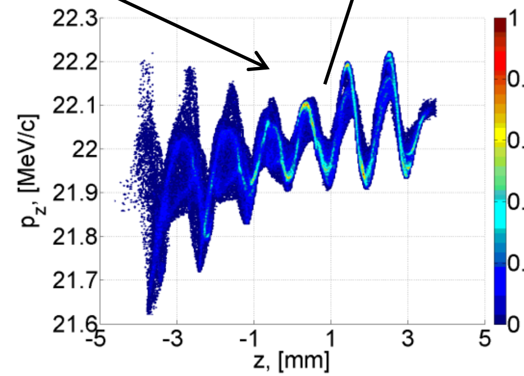




In front of plasma cell

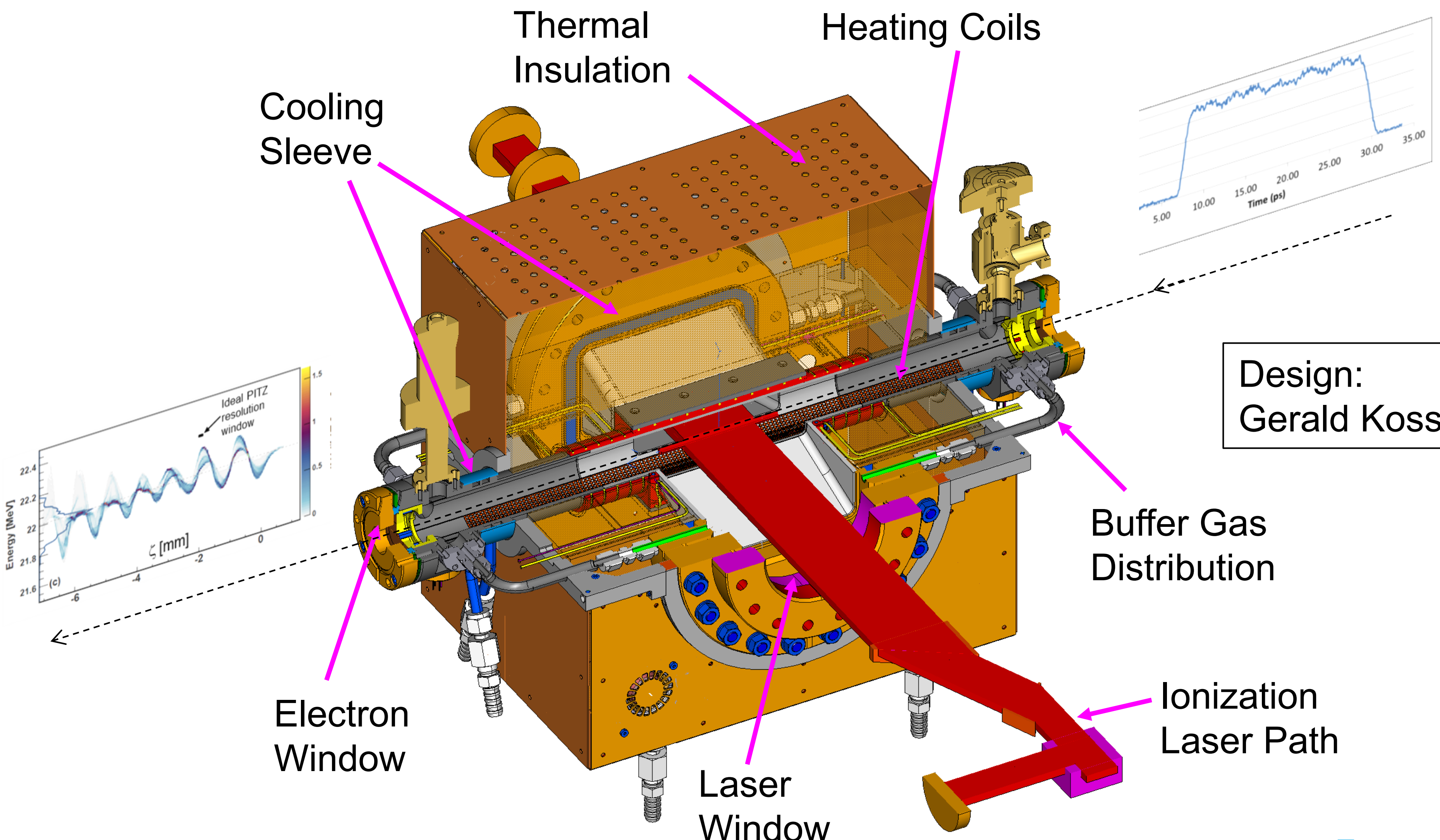


After plasma cell
(assuming zero initial energy spread)



In front of dipole

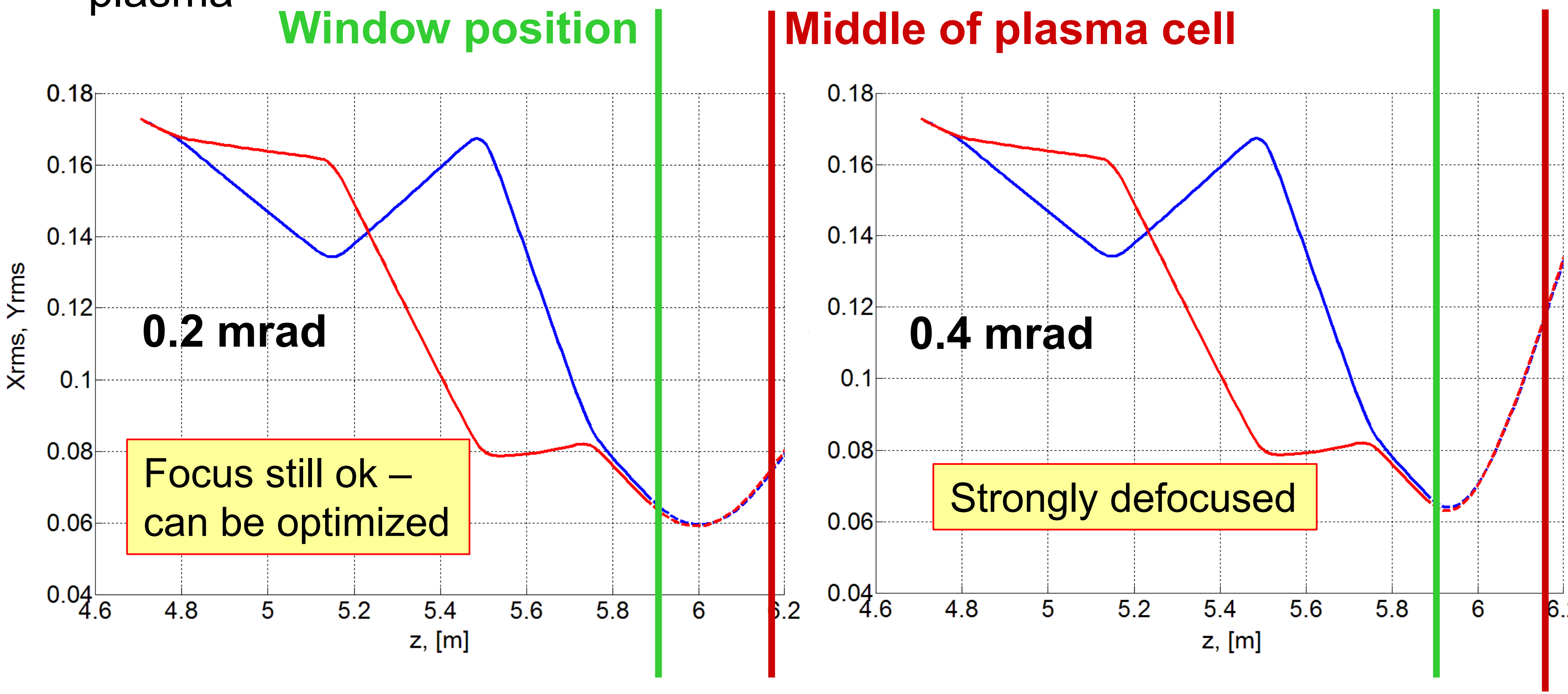
Plasma cell design



Design:
Gerald Koss

Maximum acceptable scattering

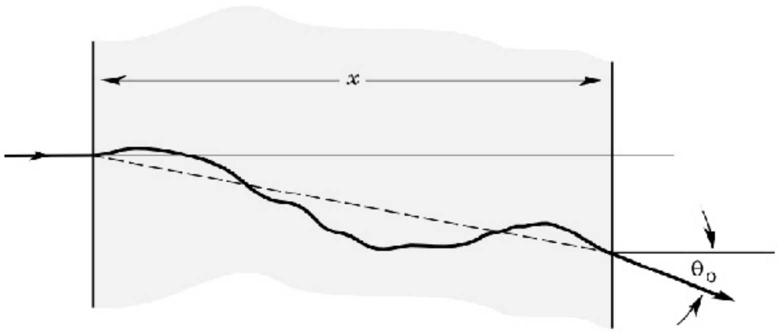
- ASTRA simulations: electron beam scattering impedes focusing into the plasma



- Maximal agreeable scattering angle: 0.2 mrad

FLUKA: a Monte Carlo simulation package

> Multiple scattering
  - a particle undergoes a number of scatterings per each step, resulting a small deviation from initial trajectory
  - Valid only if number of elementary scatterings per step is large enough

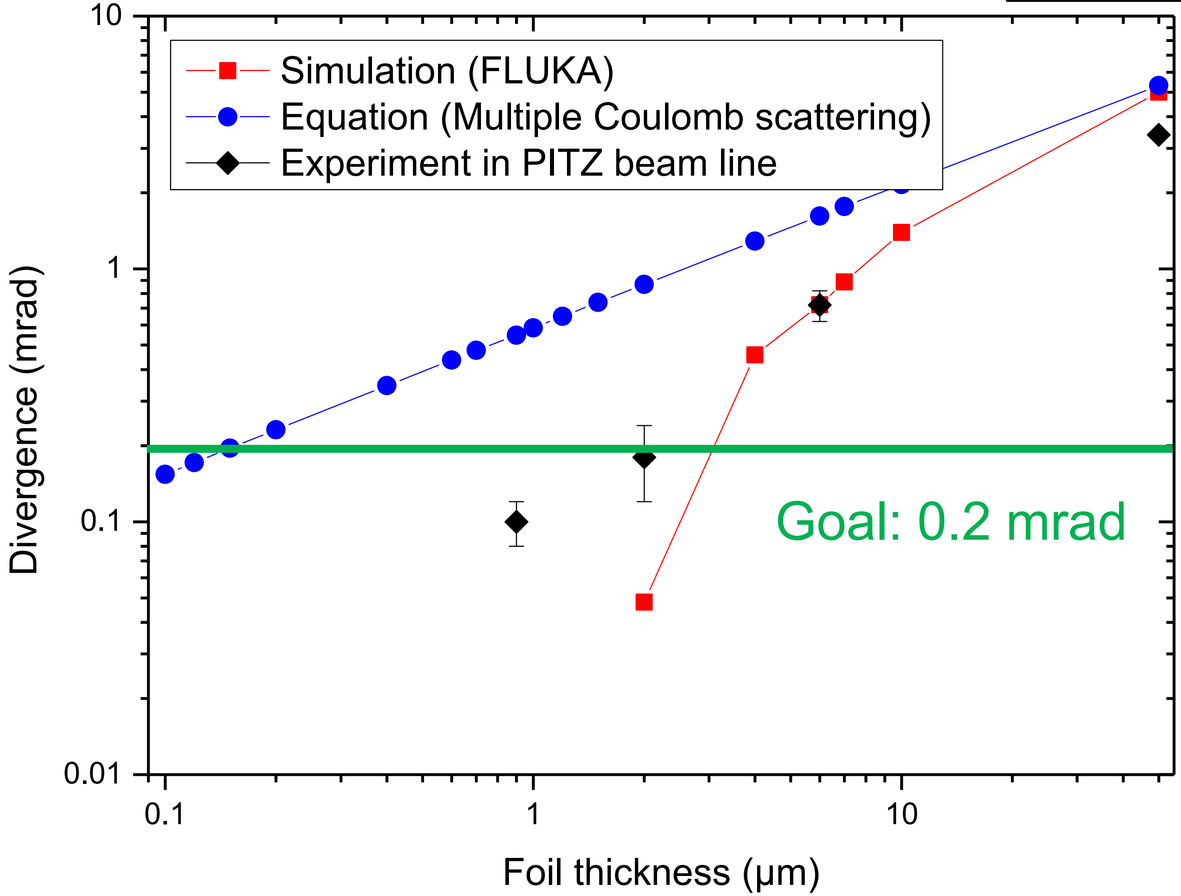


> Single scattering
  - based on the Rutherford formula
  - Every interaction is a separate step ->demands much more CPU time compared to multiple scattering

"FLUKA: a multi-particle transport code"
A. Ferrari, P.R. Sala, A. Fasso`, and J. Ranft,
CERN-2005-10 (2005), INFN/TC_05/11, SLAC-R-773

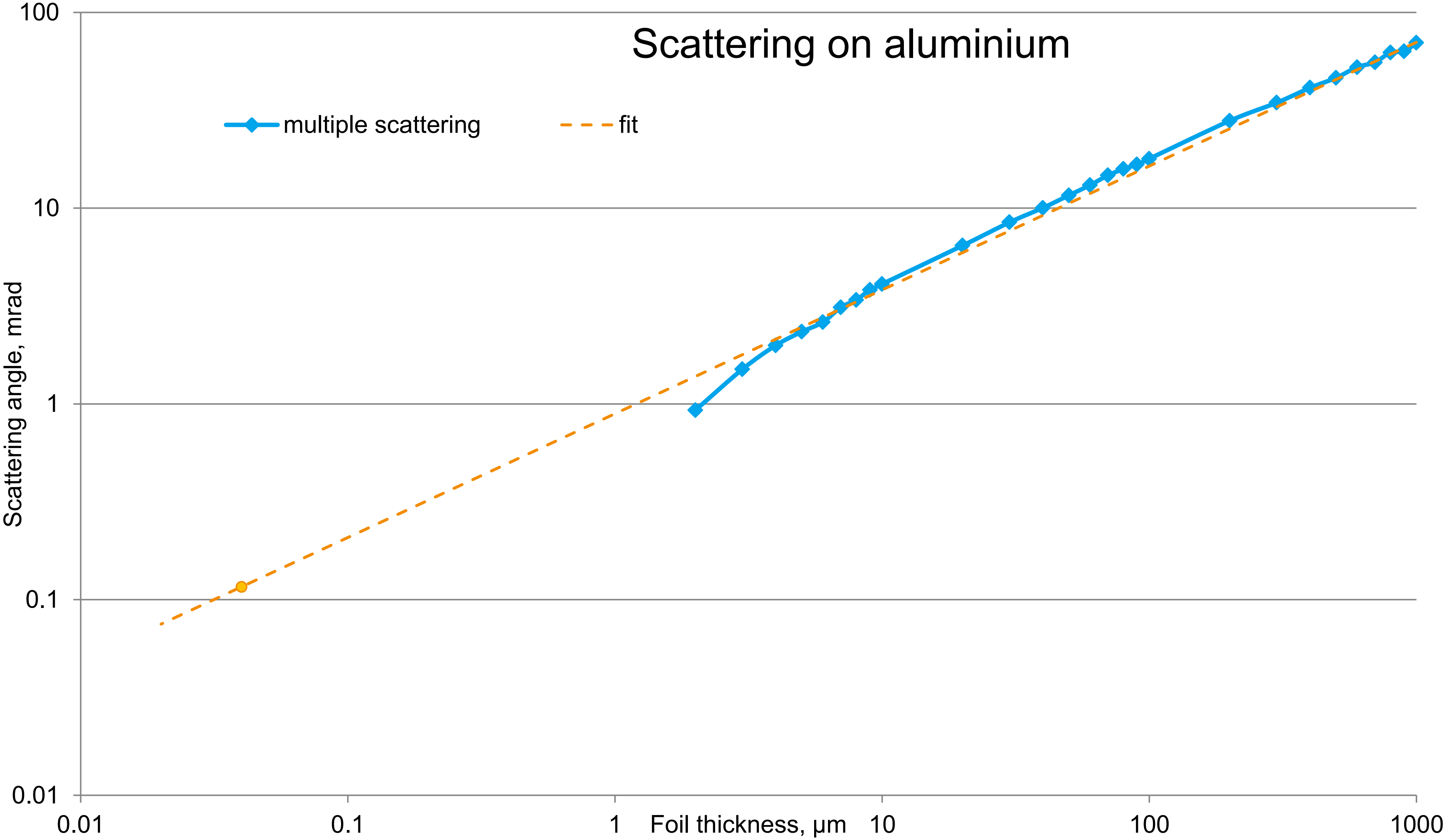
Experiments at PITZ beamline

Simulations by Rico Schuetze



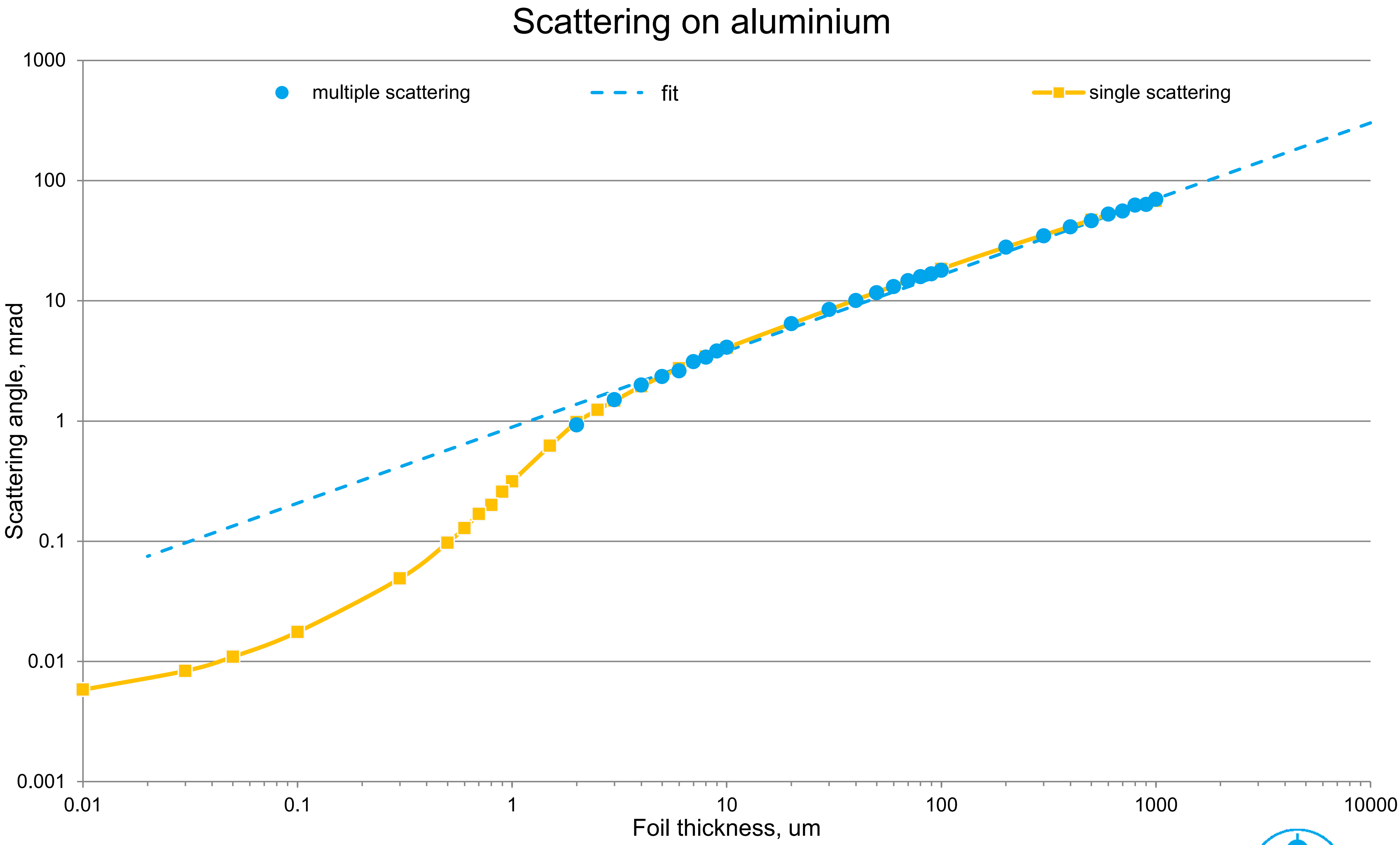
- 2014.02.07N – Kapton 50 µm + (?) Gold 5 nm
- 2014.05.15A – Mylar 6 µm + Gold coating of unknown thickness
- 2015.03.07M – Mylar 2 µm
- 2015.10.22M – PET (Mylar) 0.9 µm + 37.5 nm Al coating both sides

FLUKA: multiple scattering

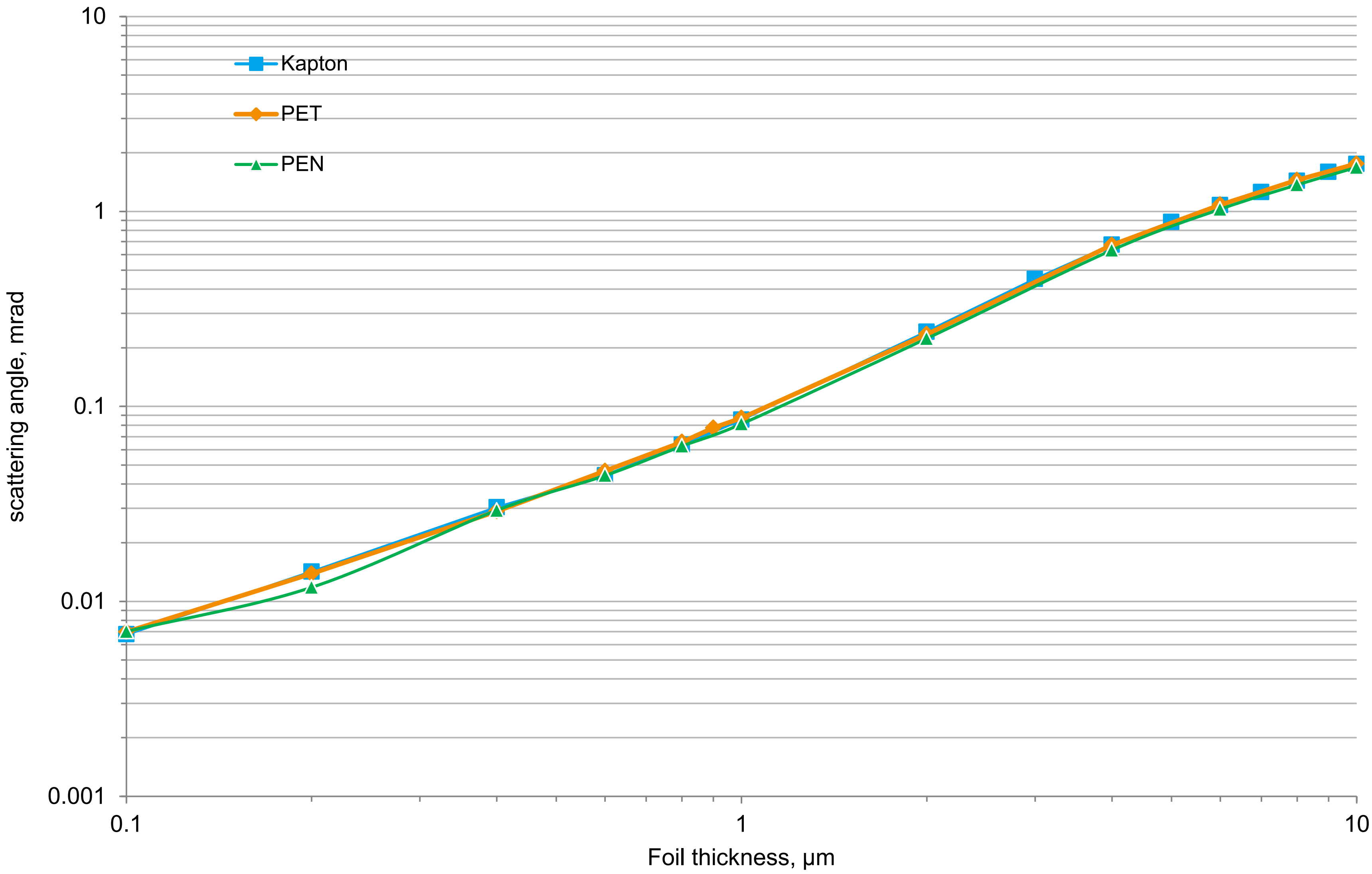


> Extrapolation gives ~0.1 mrad for only one 37.5 nm layer of Al

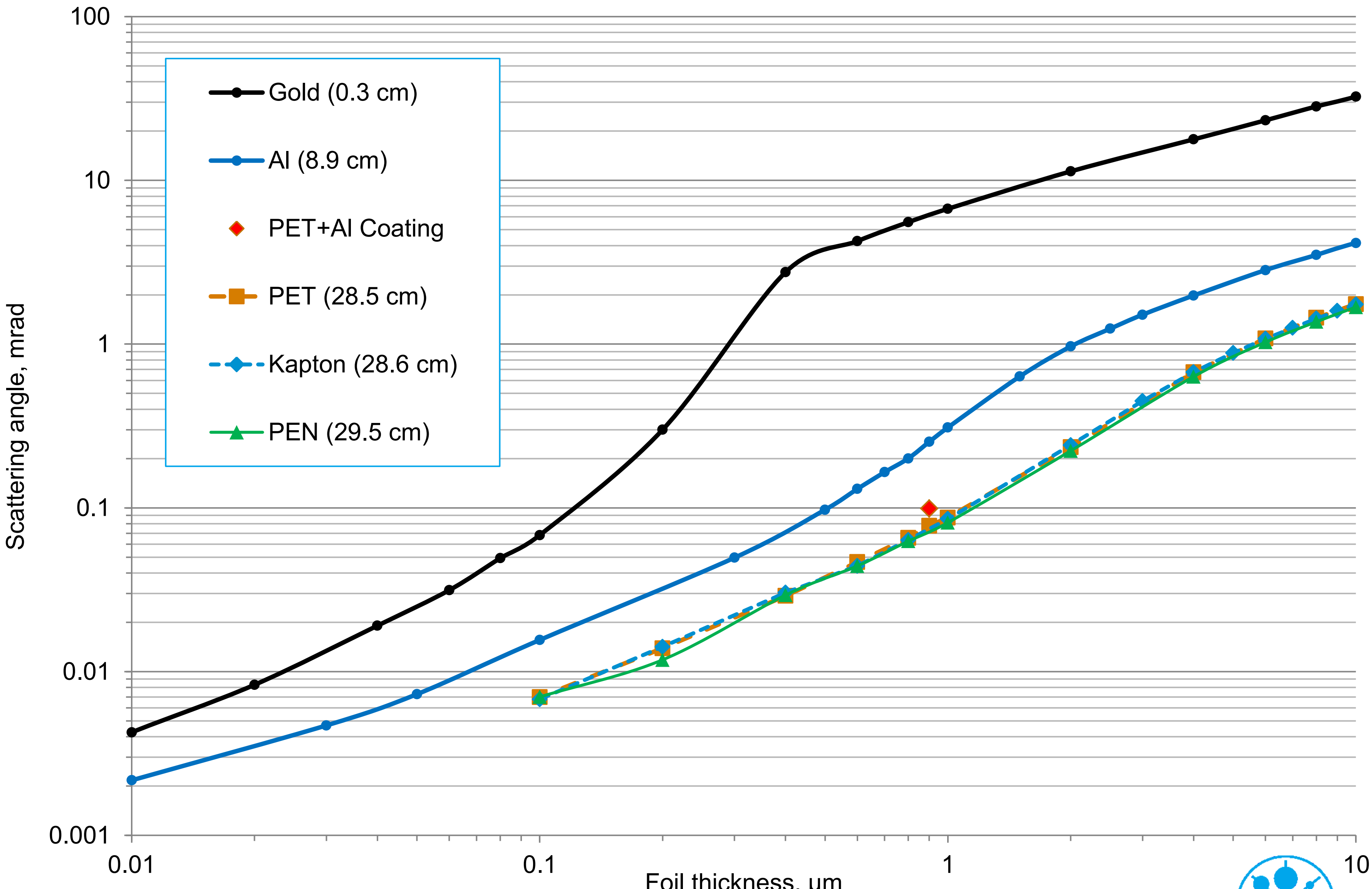
FLUKA: forced single scattering



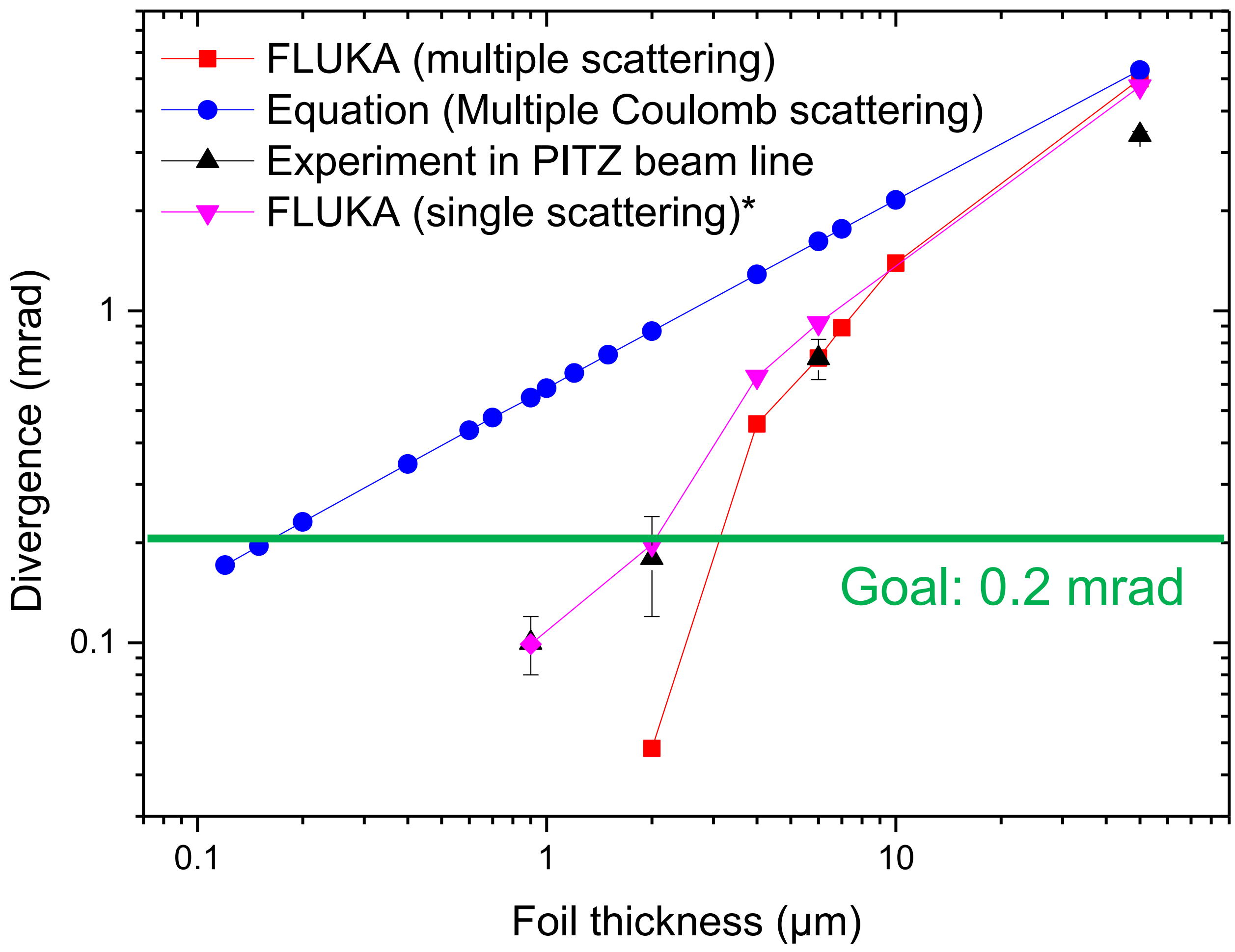
Polymer foils: scattering



Polymer films and coating materials: scattering



Summary plot



*for the last point (0.9 µm) the coated foil is simulated

Polymer foils: gas permeation

Experimental data by D. Richter

foil	$K/(m^2\,s^{-1})$	gas	$\dot{Q}$ into PITZ/$(mbar\,l/s)$
M, 2 μm	$9.88 \cdot 10^{-9}$	He	$3 \cdot 10^{-5}$
M, 6 μm, gold coated	$5.77 \cdot 10^{-9}$	He	$5 \cdot 10^{-6}$
K, 25 μm	$1.97 \cdot 10^{-13}$	He	$4 \cdot 10^{-11}$
K, 8 μm	$9.85 \cdot 10^{-15}$	Ar	$4 \cdot 10^{-12}$
P, 0.9 μm, aluminum coated $2 \times 37.5\,nm$	$2.58 \cdot 10^{-14}$	Ar	$1 \cdot 10^{-10}$

- Maximum acceptable gas load is $1 \cdot 10^{-6}$ mbar l s^{-1}
- Double sided coating decreases gas permeation without introducing too much scattering

Summary

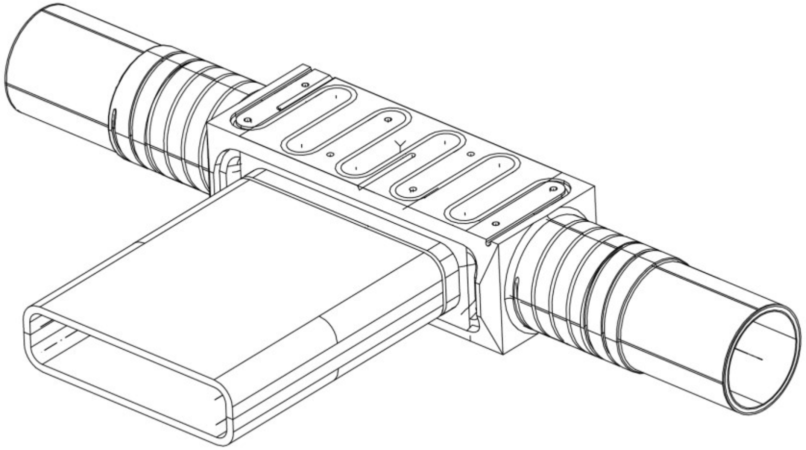
- 0.9 µm PET + 2x37.5 nm Al is a primary candidate for the electron windows for the plasma cell and the gas discharge cell
- If this foil fails the dummy plasma cell tests, PEN foil is the next option
- **Summer 2016: plasma experiments with improved hardware**

Problems	Solutions
Heating wires overpowered	• Stronger heater / better heat insulation
Lithium accumulation in cooling zones	• Axial grooves or finer mesh→ better lithium transport • Longer side arms
Insufficient density of lithium vapor	• Stronger heater / better heat insulation • Fine adjustment of buffer gas pressure
Only 10% laser pulse energy delivered to plasma cell	• Better optics (e.g. cylinder lenses; antireflection coating) • Better beamline sealing

> Backup

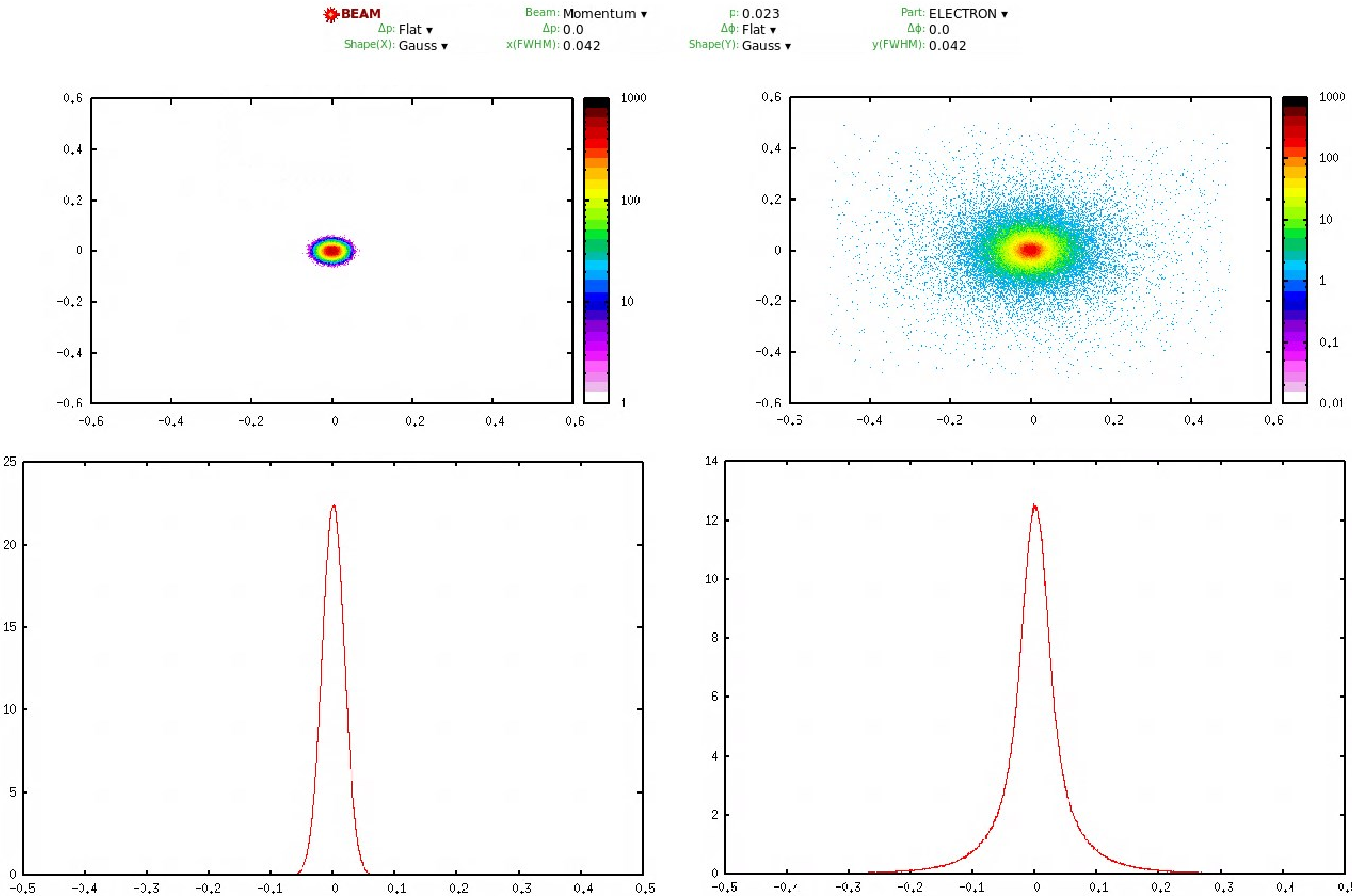
New plasma cell

A test heat pipe with channels instead of the metal mesh is in preparation



The new plasma cell design with flat arms is being finalized

Beam parameters for simulation



Theory: Multiple Coulomb Scattering

- From: Claus Grupen "Teilchendetektoren": Multiple Coulomb Scattering

The rms of the projected scattering angle distribution:

$$\theta_{rms} = \frac{13.6MeV}{\beta pc} z \sqrt{\frac{x}{X_0}} \left[1 + 0.038 \ln\left(\frac{x}{X_0}\right)\right]$$

$$\beta pc = 22MeV;\ z = 1;\ X_0 = 0.28m$$

- Important: Radiation length X_0
  - Gold: 0.3 cm
  - Aluminium: 8.9 cm
  - Kapton (Polyimide): 28.6 cm
  - Mylar (PET): 28.5 cm
  - Teonex (PEN): 29.5 cm
  - Beryllium: 35.3 cm
  - Polyethylene: 50.3 cm