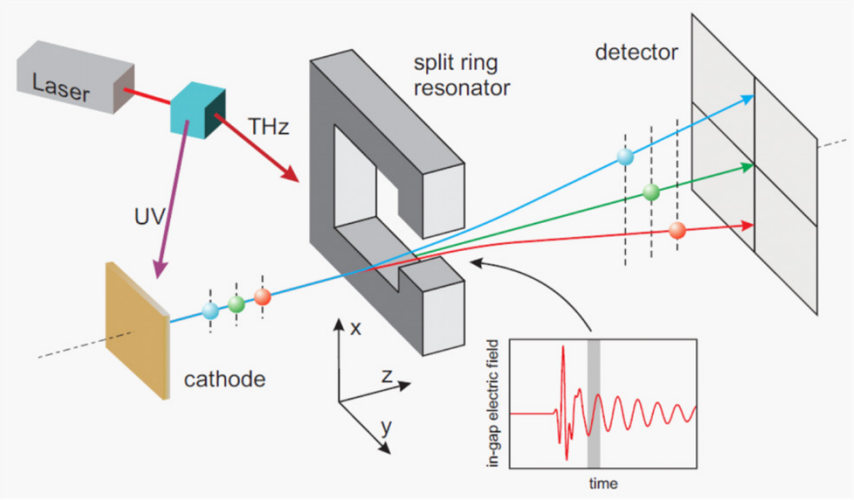
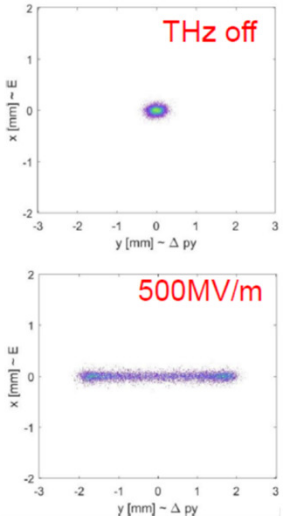
Design of a longitudinal electron diagnostics using THz fields excited in split ring resonator at FLUTE

A collaboration between Paul Scherrer Institut (PSI), the University of Bern, and Karlsruhe Institute of Technology (KIT)

Minjie Yan, KIT (IBPT)

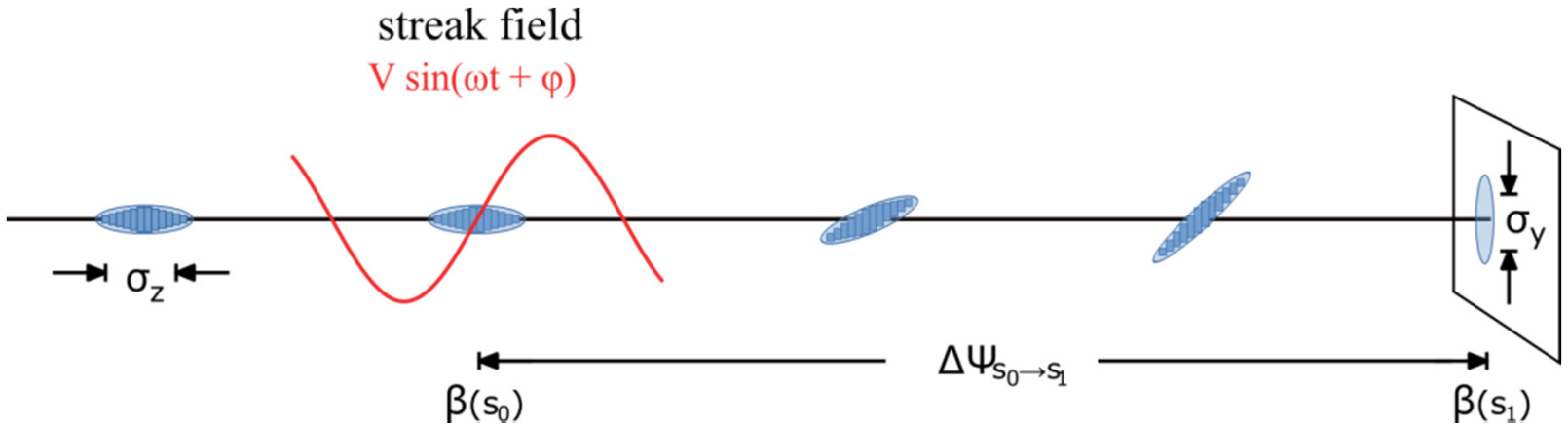




Diagnostics of the longitudinal electron bunch profile

- Spectral domain:
  - CTR/CDR
  - Reconstruction of the longitudinal profile possible
- Temporal domain:
  - Cross-correlation with an external laser:
    - Electro-optic effect
  - Streaking of the electron bunch:
    - Transverse deflecting RF structure
    - Split ring resonator

Streaking of the electron bunch



- At the zero-crossing of the streak field: $y \propto z$
- Streak effect: $S = \sqrt{\beta(s_0)\beta(s_1)}\ \sin(\Delta\Psi_{s_0 \to s_1})\ \frac{eV 2\pi f}{cE}$

	V	f	length
RF structure (XTCAV LCLS)	48 MV	< 12 GHz	1m *2
SRR structure	14 kV (@gap gradient of 500MV/m)	< 1000 GHz	<100µm

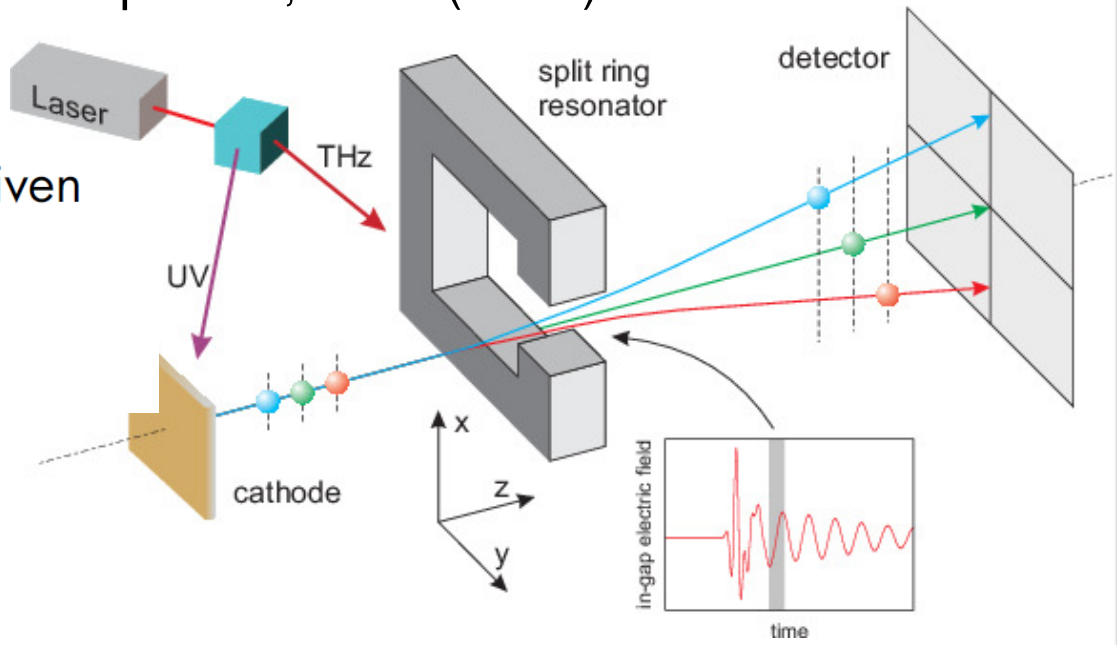
P. Krejcik et.al., IBIC13

Principle of the split ring resonator diagnostics

- J. Fabianska et al., Scientific Reports 4, 5645 (2014)

Split ring resonator based THz-driven electron streak camera featuring femtosecond resolution

Justyna Fabiańska[1], Günther Kassier[2] & Thomas Feurer[1]



- S. Bogiante et al., Scientific Reports 5, 8051 (2015)

Giant Electric Field Enhancement in Split Ring Resonators Featuring Nanometer-Sized Gaps

S. Bagiante[1,2], F. Enderli[1,2], J. Fabiańska[2], H. Sigg[1] & T. Feurer[2]

THz field enhancement

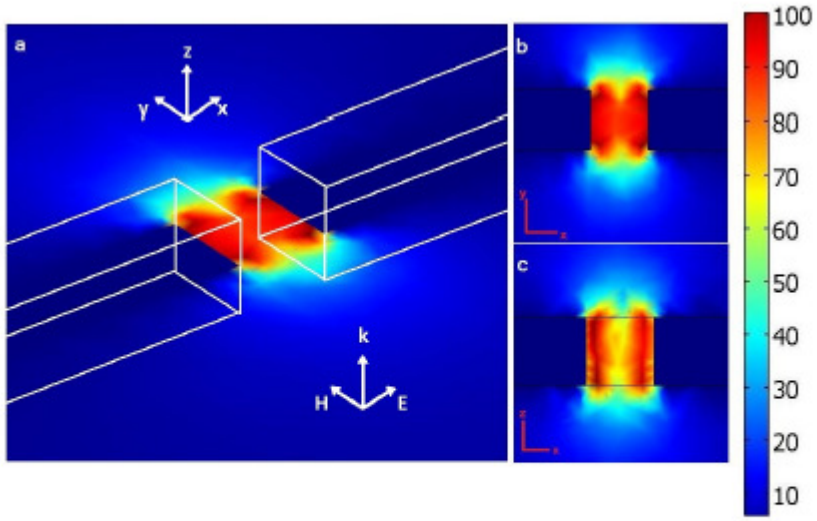


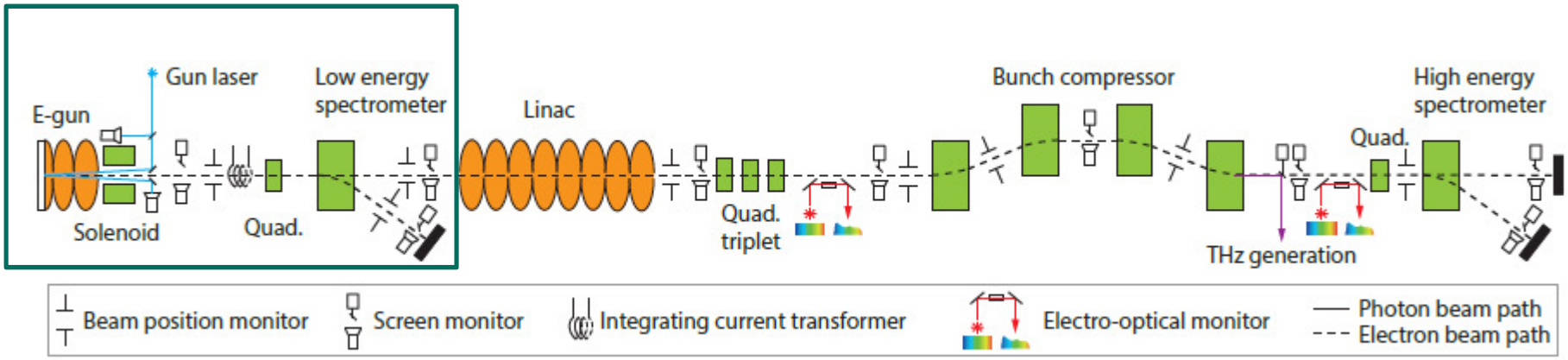
Figure 2 | Simulated electric field distribution. (a) E_x component normalized to the incident field in a plane through the middle of the gap of the split-ring resonator (SRR) at 300 GHz, (b) horizontal and (c) vertical field distributions across the gap.

- 10µm* 10µm gap size, 300GHz
  → enhancement of 100

J. Fabianska et al.; Scientific Reports 4, 5645 (2014)

FLUTE (Ferninfrarot Linac und Test Experiment)

Proof of principle SRR experiment



FLUTE parameters

parameter	value
Electron energy	7.7 MeV
Electron bunch charge	Wide range, 10fC ~ 3nC
Laser wavelength (fundamental)	800nm
Laser wavelength (THz)	150µm

SRR parameters (M. Dehler et al., IBIC2015)

f (THz)	0.1	0.3	1
width (µm)	370	130	50
deflector gap (µm)	10	10	10
kick (eV/c), 1 MV/m in gap	43.0	27.7	26.5
Q factor	10.8	10.3	11.8

Up to 500MV/m possible

Challenge:
electron beam size < 10µm at the IP in the gap

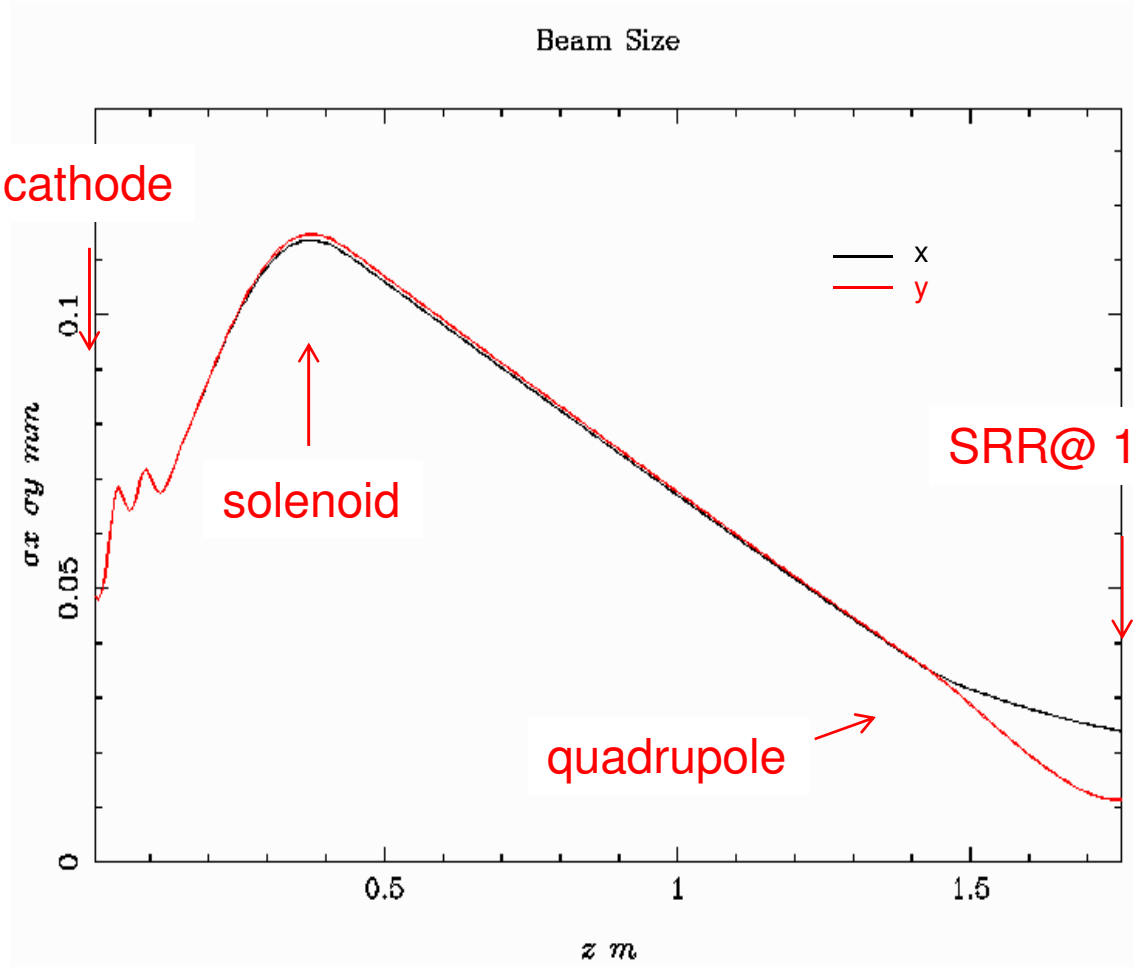
- Thermal energy of the electrons at the cathode
  - 200meV (D. Dowell, J. Schmerge, PRST-AB 12, 074201, 2009)
- Laser parameters
  - Transverse laser profile type: Gaussian
  - Laser pulse length: Gaussian with rms 2ps
- Focusing element
  - solenoid and one quadrupole
- Fixed distance from the cathode to the gap
  - 1.76m

- Knobs for the optimization:
  Charge Q, transverse laser beam size, Gun phase, Gun amplitude, solenoid field strength

ASTRA simulations: rms beam sizes @ IP

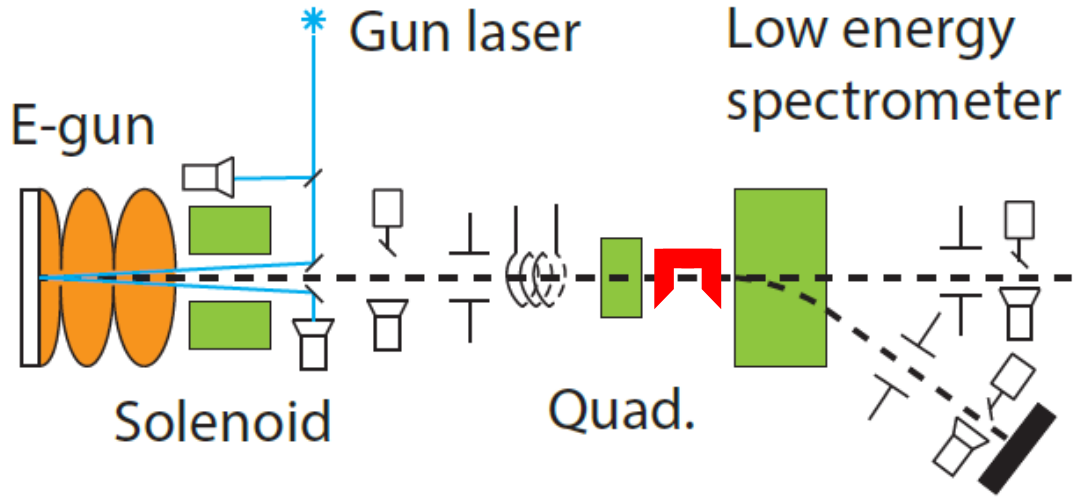
	Charge Q [pC]	Laser $\sigma_{x,y}$ [um]	Solenoid [T]	rms σ_y@ IP [um]	rms σ_x@ IP [um]
a	0.01	10	0.230	8	11
b	0.01	20	0.223	10	16
c	0.01	50	0.220	11	21
d	0.02	50	0.219	11	22
e	0.03	50	0.220	11	23
f	0.05	50	0.220	11	24
g	0.1	50	0.221	11	35
h	0.1	100	0.218	13	45

ASTRA simulations: rms beam sizes



ASTRA simulations: streaked beam on the imaging screens

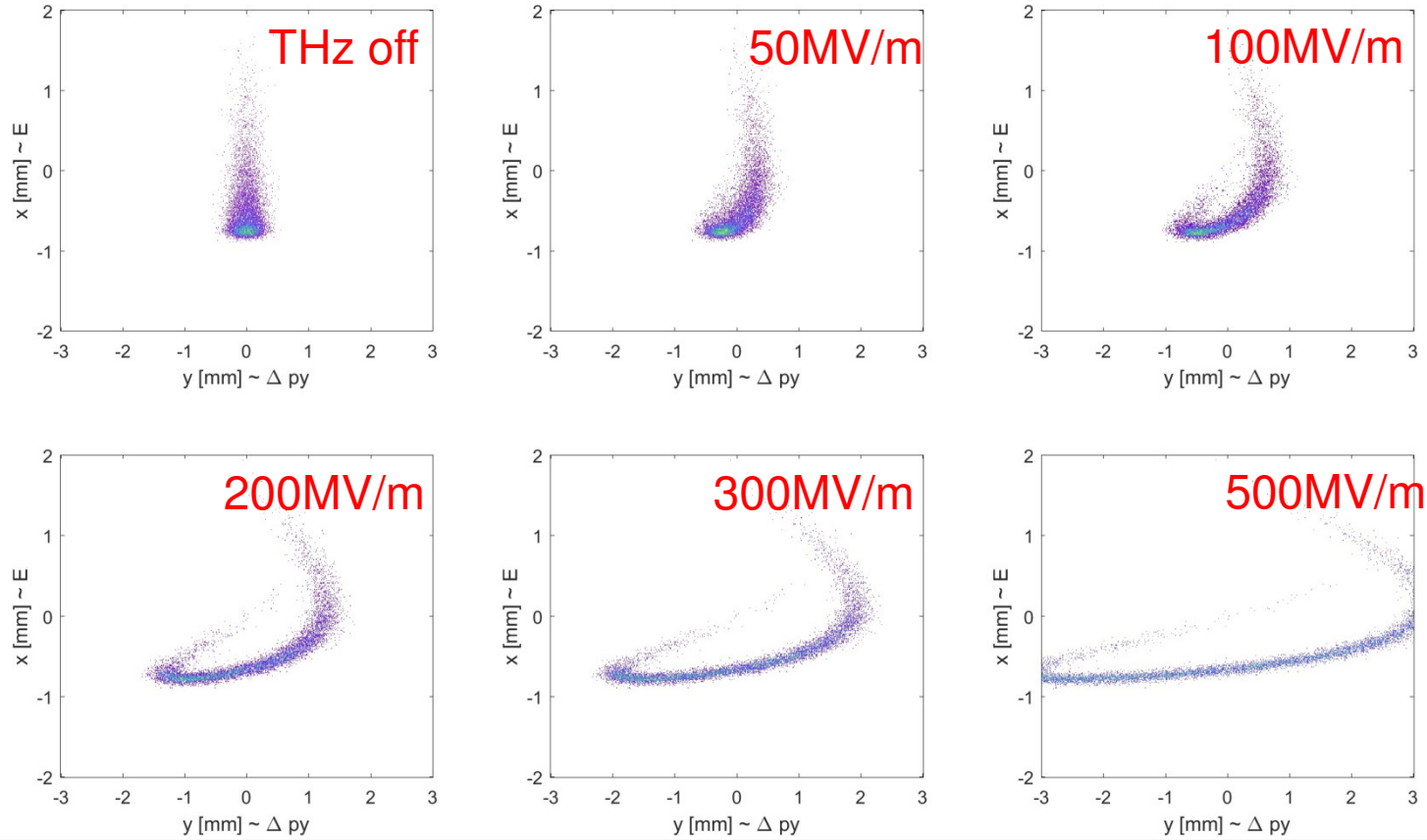
- One screen in the spectrometer beam line → Longitudinal phase space
- One screen in the straight section → longitudinal profile
- Pixelated images with resolution of 10µm/pixel
- Different THz frequencies and gap gradients are investigated



ASTRA simulations: streaked beam on the imaging screens

- 0.1pC, Laser 2ps, oncrest, σ_{laser} =50um, σ_y=11um@IP

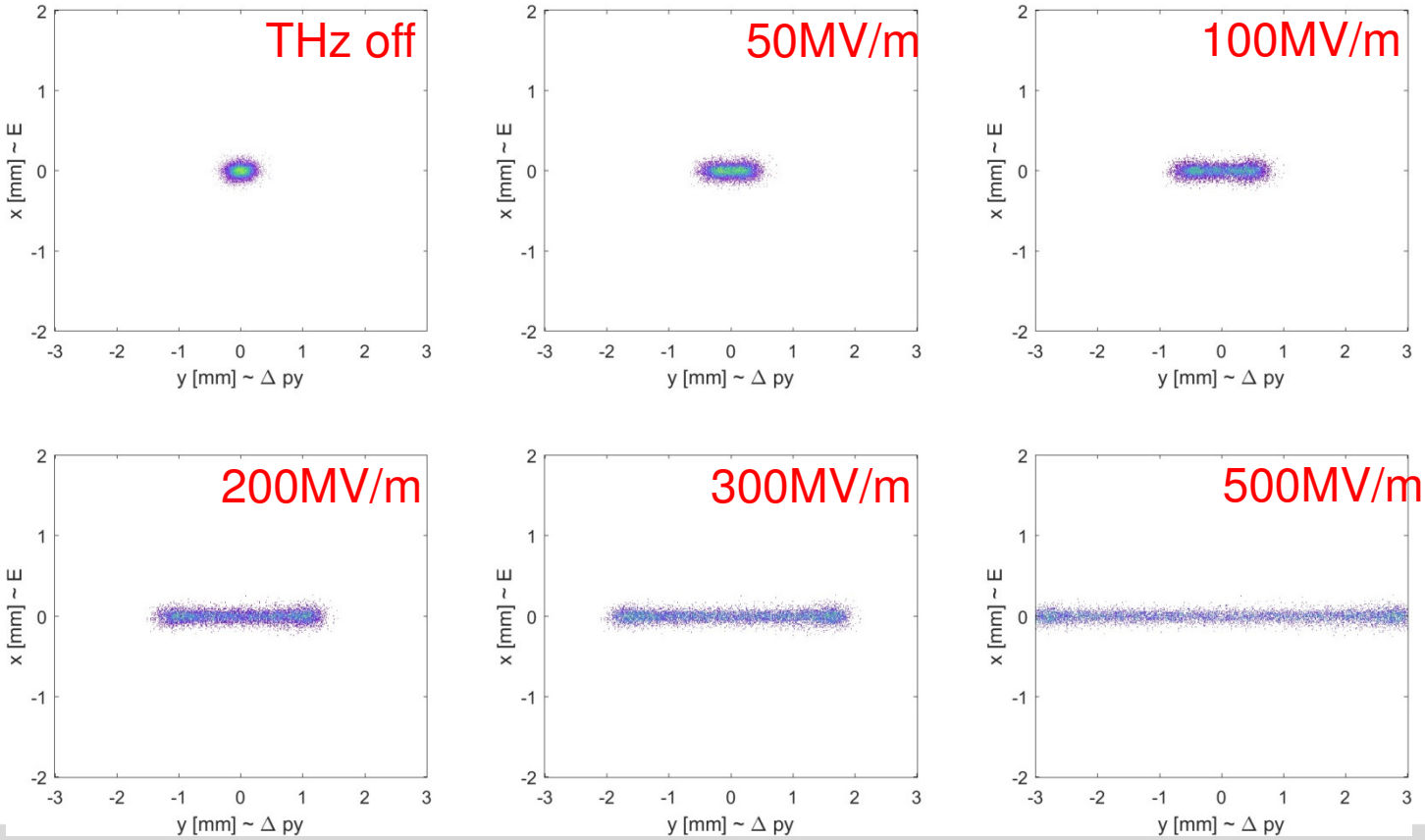
f=0.1THz, dispersive screen



ASTRA simulations: streaked beam on the imaging screens

- 0.1pC, Laser 2ps, oncrest, σ_{laser} =50um, σ_y=11um@IP

f=0.1THz, non-dispersive screen



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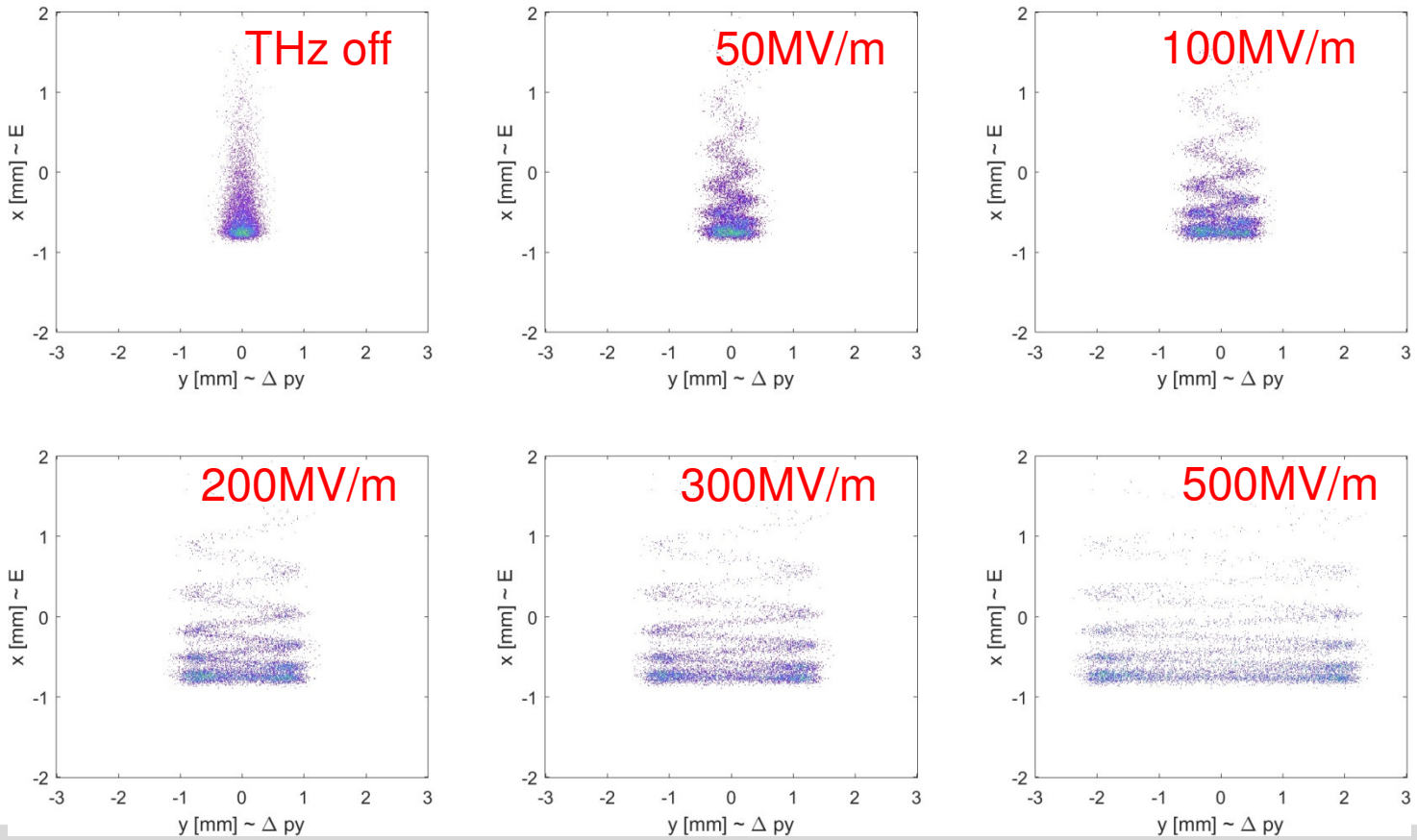

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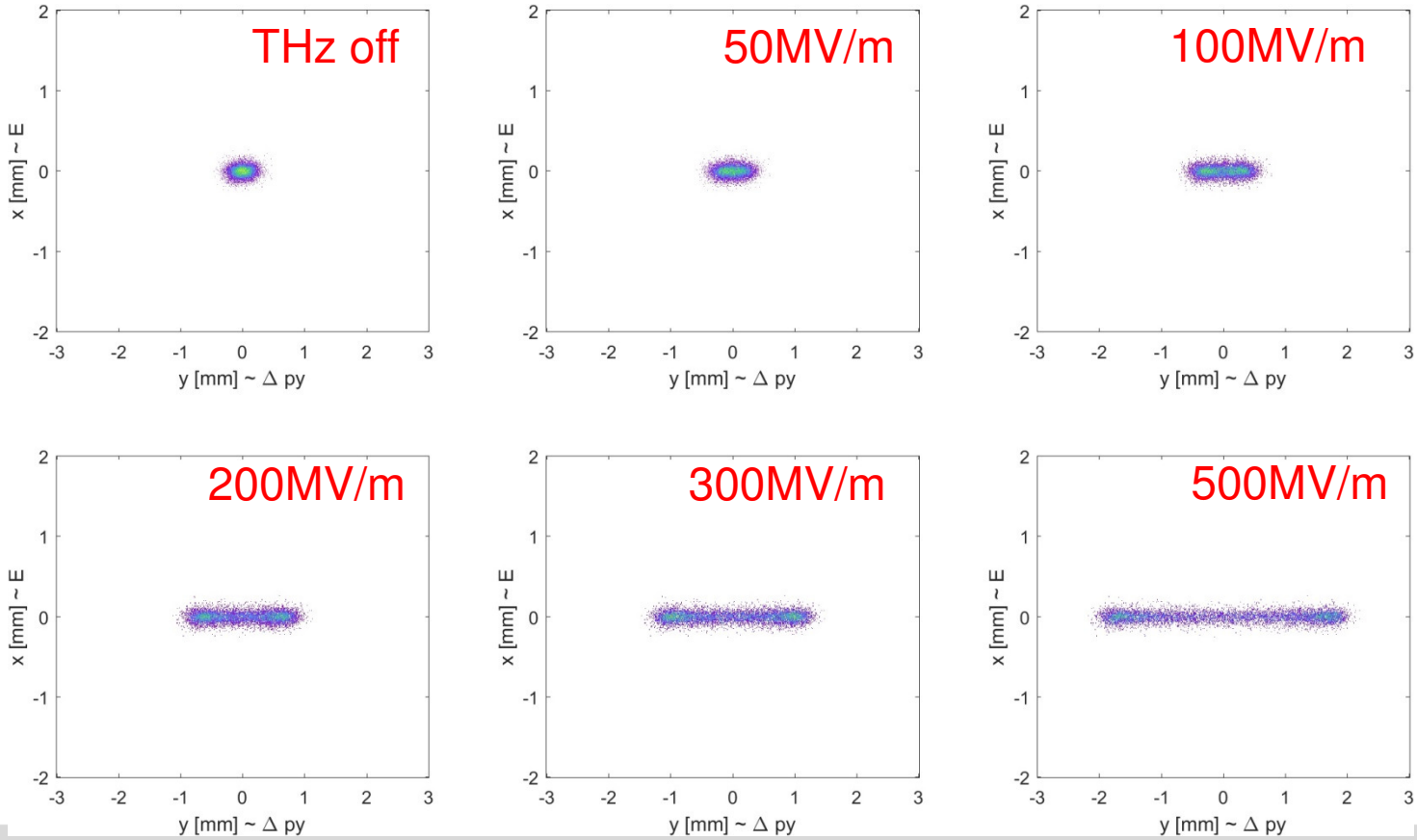
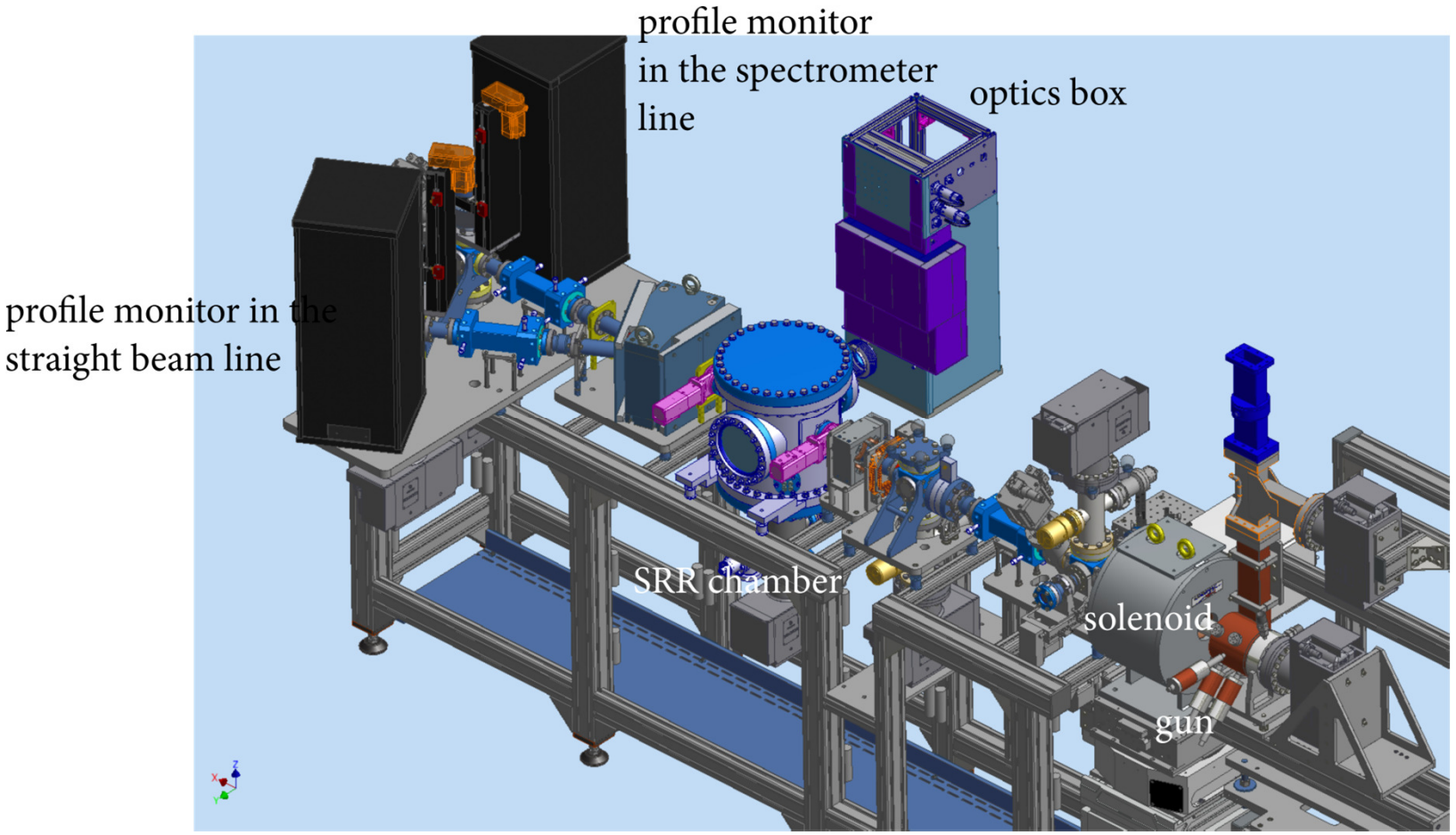
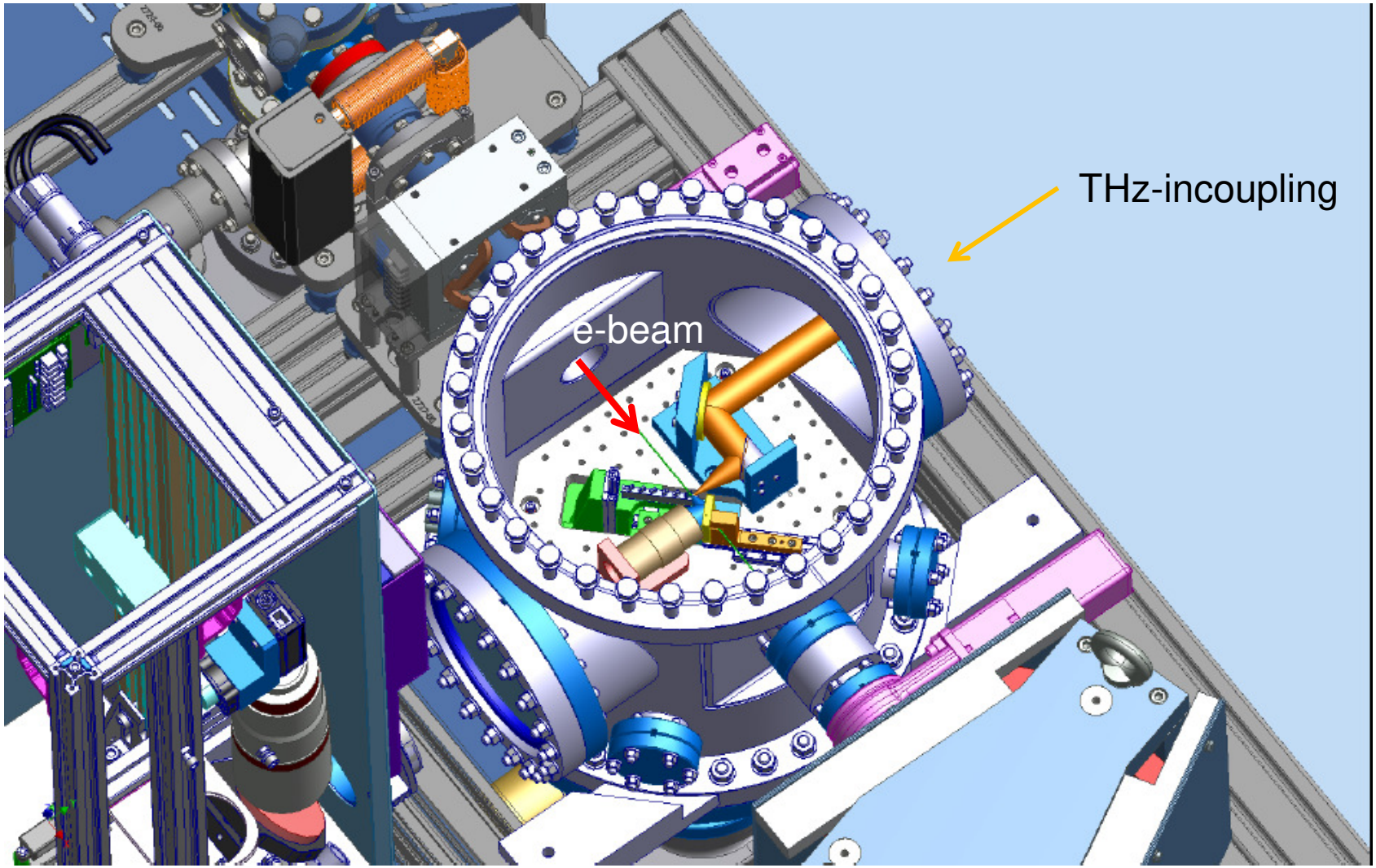


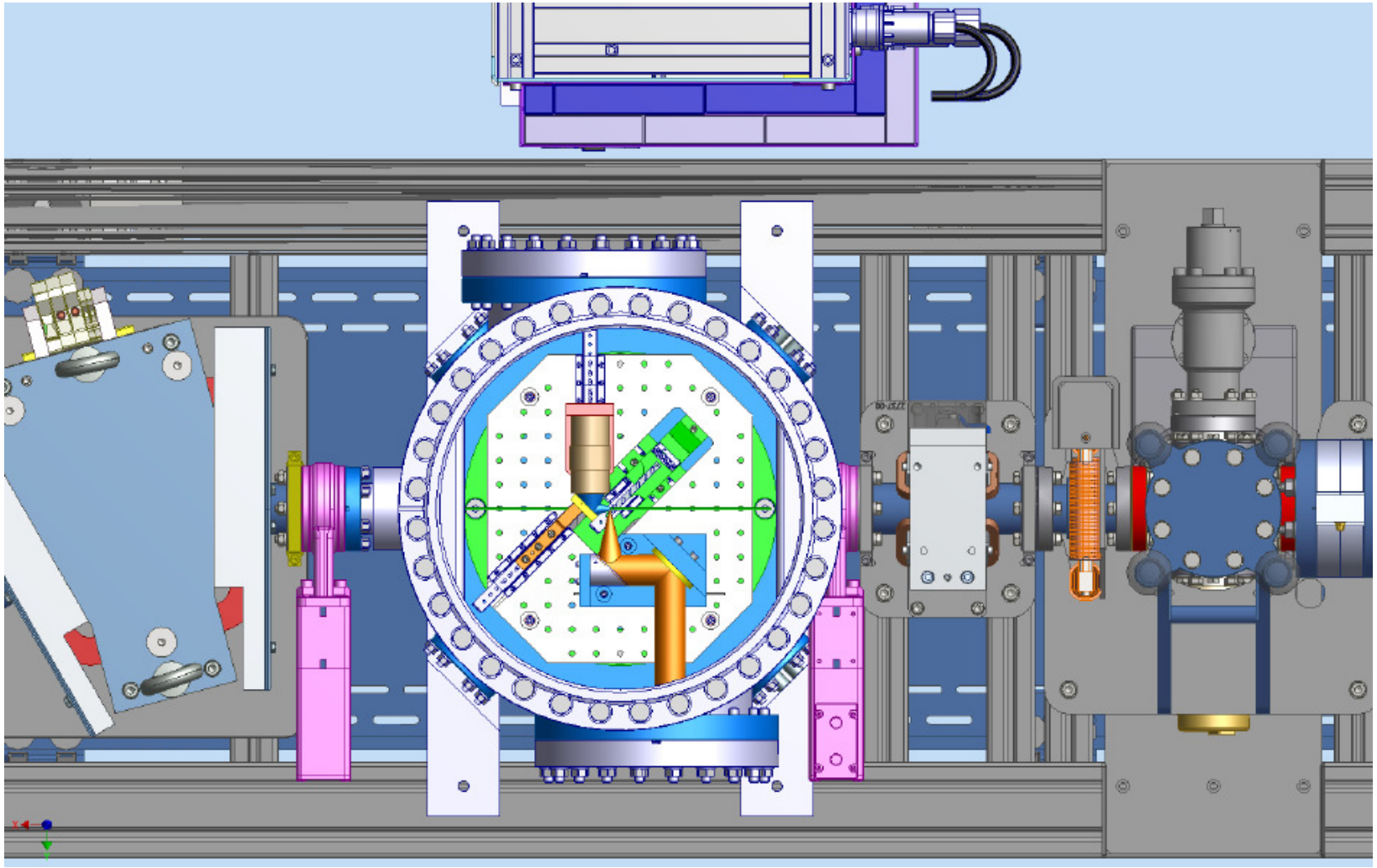
CAD drawings of the beam line



SRR chamber



SRR chamber



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