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EuPRAXIA

6D Characterization of Witness Beam before Injection in LWFA

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1st EuPRAXIA Collaboration Week

DESY, 19-23 June 2017

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Characteristics of Witness Beams

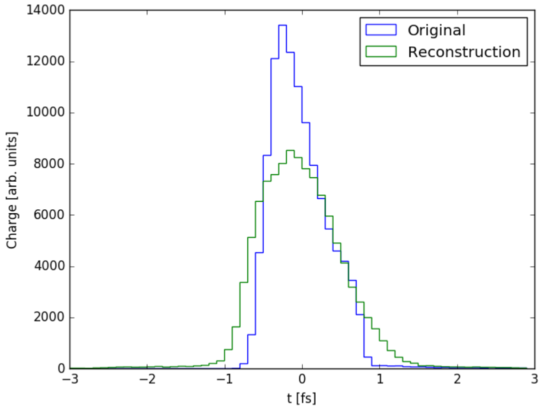
From EuPRAXIA parameter table LWFA with external injection:

Quantity	Symbol	Baseline value	Range of exploration	
			Lower limit	Upper limit
RF injector beam: at entrance of plasma 2				
Energy	E	160 MeV	100 MeV	200 MeV
Charge	Q	50 pC	10 pC	50 pC
Bunch length (RMS)	τ	38 fs	3 fs	30 fs
Peak current per bunch	I	3 kA	1 - 10 kA	
Shaped profile	-	Gaussean	triangular	
Total energy spread (RMS)	σ_E/E	0.2 %	0.2 %	
Transverse normalized emittance	$\varepsilon_{N,x}$, $\varepsilon_{N,y}$	1 mm mrad	1 mm mrad	
Transverse norm. slice emittance	$\varepsilon_{N,x,S}$, $\varepsilon_{N,y,S}$	tbd	tbd	
Slice length	z_s	tbd	tbd	
Jitter, beam to global reference (RMS)	$\sigma_{\Delta t}$	10 fs	10 fs	

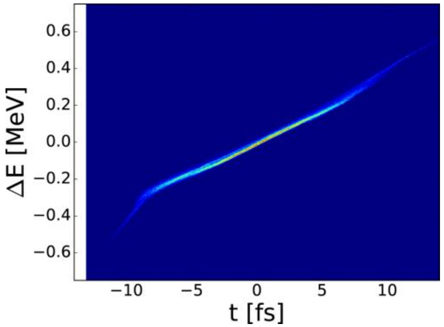
- At SINBAD we are investigating the range Q=0.5pC-30pC, especially **the limit in the characterization of very low charge and ultra-short e-bunches**.

6D e-Beam Characterization includes

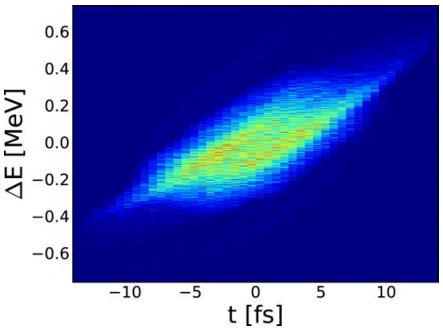
> Bunch Length and Longitudinal Charge Profile



> Longitudinal Phase Space



original

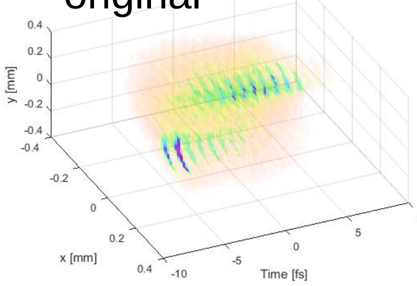


measured

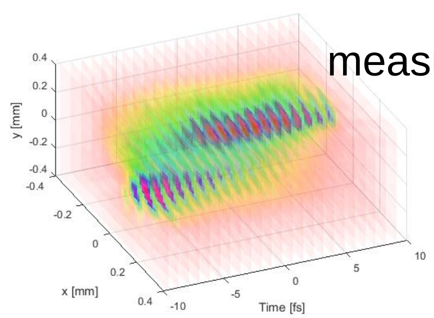
> Slice emittance on different transverse planes

> 3D Reconstruction of e-Bunch Charge (new technique, relies on novel design of TDS not yet experimentally tested)

original

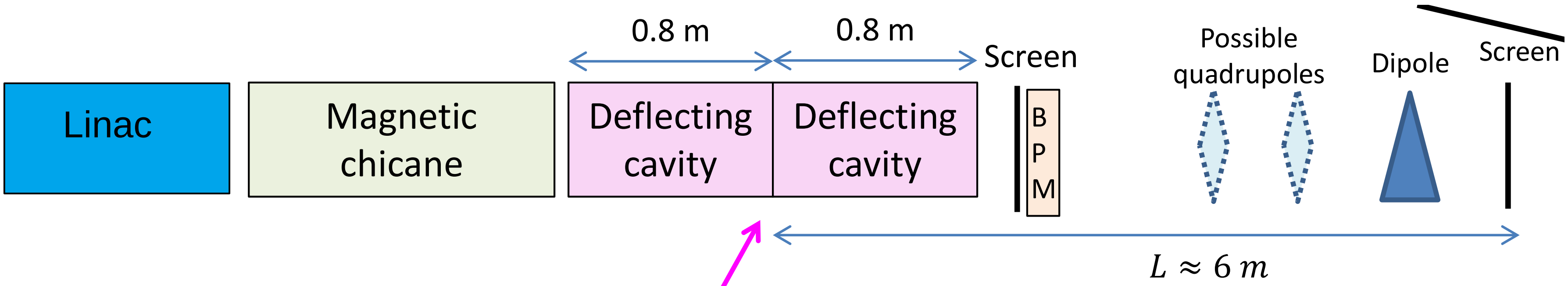


measured



Simulations by D. Marx,
More details in joint WP3-WP5
Meeting Wednesday 16.00-18.00

General idea of Lattice Design



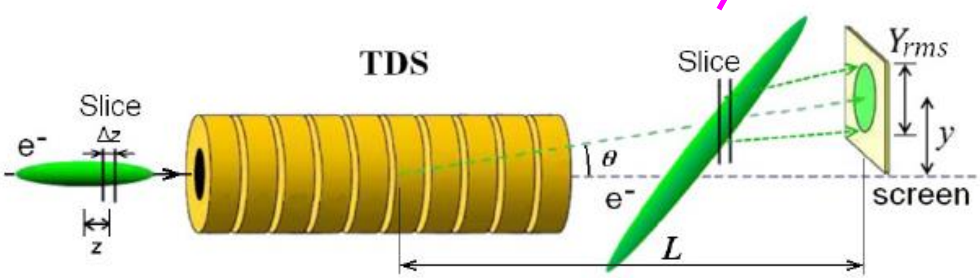


Fig. Credits: D. Malyutin PhD thesis

> High frequency ~12 GHz (X-band) allows 3-4 times higher resolution than S-band

Longitudinal Resolution:

$$\mathcal{R}_{t,e} = \frac{\sigma_{y0}}{S_y} = \frac{\sqrt{\beta_y(s)\varepsilon_y}E}{\sqrt{\beta_y(s)\beta_y(s_0)}\sin(\Delta\phi_y)e\omega V_y}$$

e-bunch:

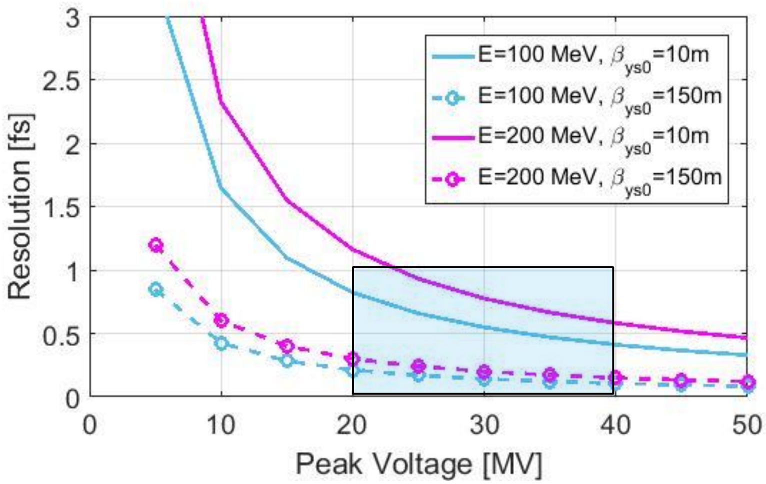
- Energy E
- Vertical emittance ε_y

RF cavity:

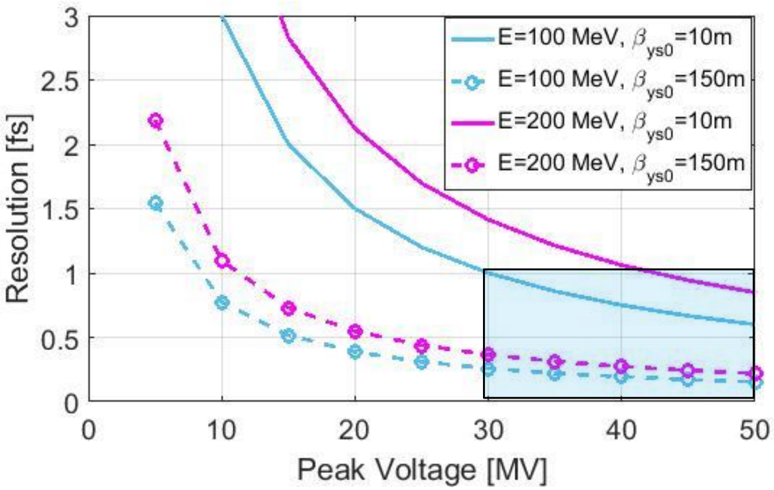
- Frequency f = ω/(2π)
- Peak deflection voltage V_y

Resolution Range EuPRAXIA case

ε_n=0.3mm*mrad
$\Delta\varphi = \pi/2$
f=12GHz



ε_n=1mm*mrad
$\Delta\varphi = \pi/2$
f=12GHz



- Typical β function after bunch compression <30m.
- At low energies (100 MeV) the e-beam evolves relatively quickly (the e-bunch properties change along a few m drift or matching lattice).

Technical Issues to be addressed in the WP5 discussion

Resolution & lattice design:

- At which energy is/are the diagnostics line/s?
- High β - low V option vs low β - high V option
- Integration of diagnostics line with focusing to plasma

Limits high voltage TDS operation:

- RF Phase jitter
- Arrival time beam jitter
- Temperature stability of the cavity

Limits high resolution measurement at low charge

- Signal to noise ratio on the measurement screen