Physics and Applications of High Brightness Beams workshop

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Laser Triggered Injection and Acceleration in Beam-driven Plasma Wakefield

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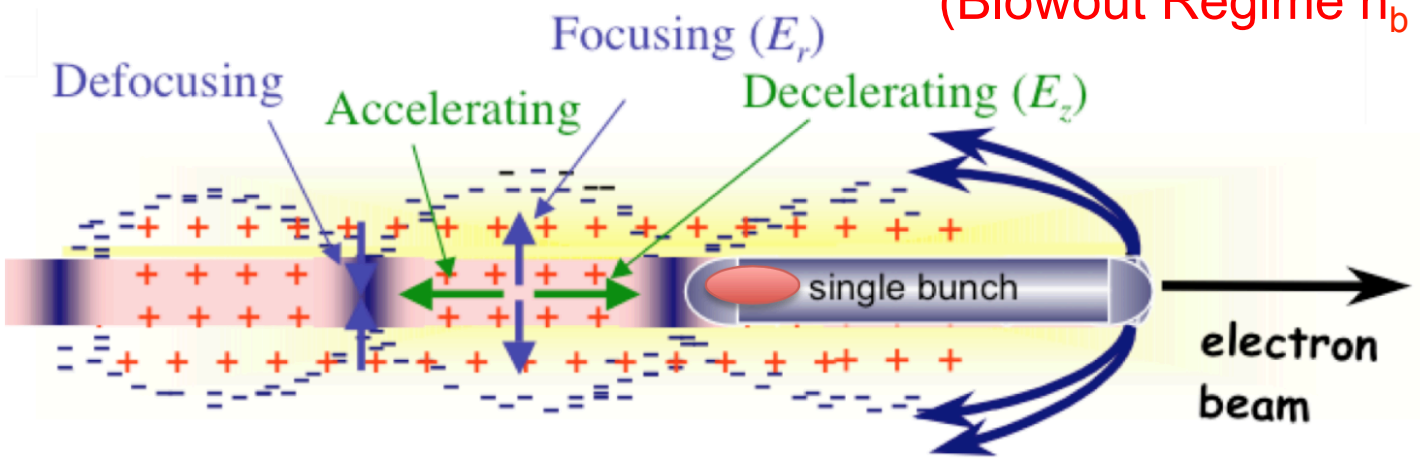
Beam-driven Plasma Wakefield Accelerator (PWFA)

(Blowout Regime $n_b > n_p$)



- **Space charge of the beam displaces plasma electrons**
- **Plasma ion channel exerts restoring force => wake oscillation**
- **Decelerating field at head of blow-out extracts energy from bunch**
- **Linear focusing force on beams ($F/r=2\pi ne^2/m$)**
- **Accelerating field independent of r**
- **No phase slippage**
- **Typical: $n_p \sim 10^{17}$ /cm^3, $\lambda_p \sim 100$ μm, E>10 GV/m**

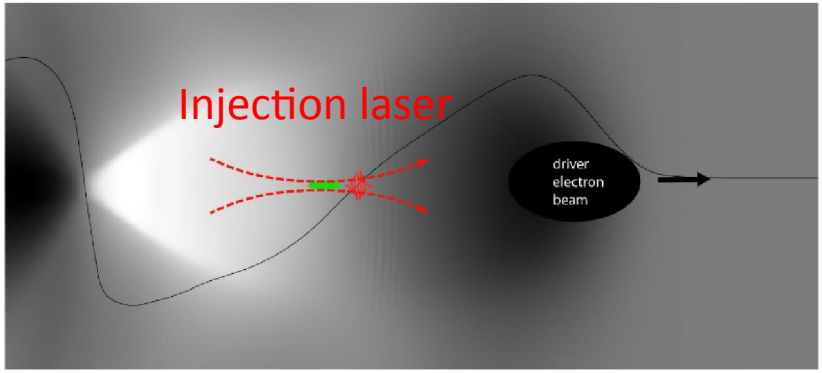
M. Hogan et al, PRL 2005, P. Muggli et al PRL 2004

PWFA experiment at FACET

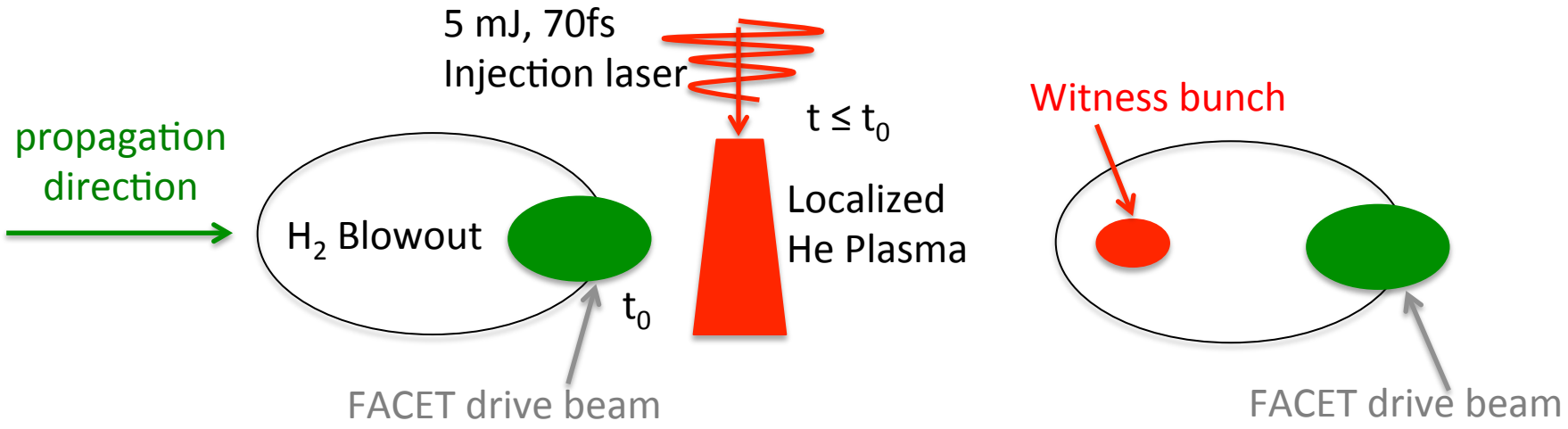
• FACET (Facility for Advanced Accelerator Experimental Tests) is a User Facility at SLAC. In 2015 a Hydrogen-based plasma beam line was installed.

• The nominal running parameters: 20 GeV, 3nC, σ_z = 30 um ,$\sigma_{x,y}$ = 30 um

• **The E210 experiment** studies laser triggered injection and acceleration in PWFA, nominated the "**Trojan Horse Injection PWFA**". First attempt was Feb. 2016.

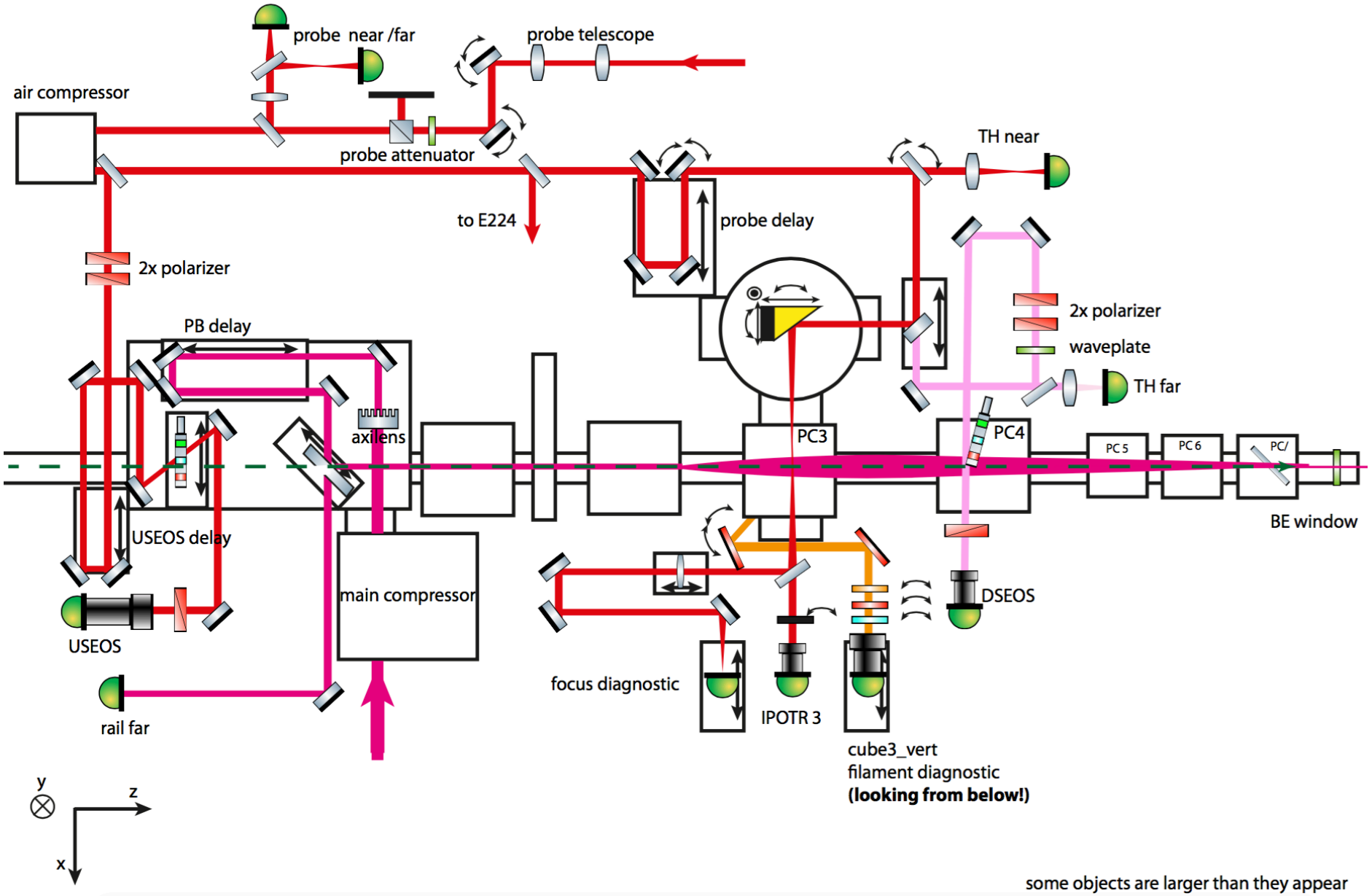


90° Laser Triggered Injection PWFA



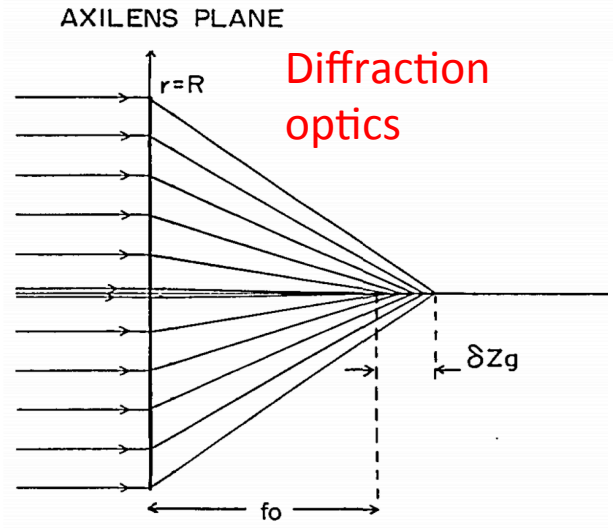
- 50:50 H_2 / He gas mixture was used.
- The drive electron beam excites plasma blow-out in the Hydrogen.
- An injection laser generates a localized He plasma.
- The density perturbation leads the trapping of the witness bunch to be accelerated.
- Perfect timing will bring the ionization happened exactly in the “Blow-out”.

E210 Experiment Setup on FACET



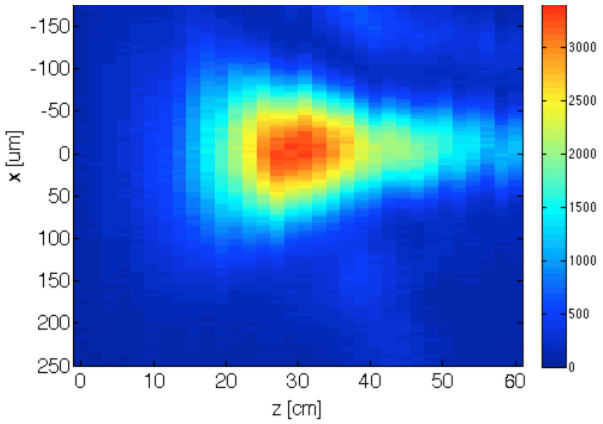
some objects are larger than they appear

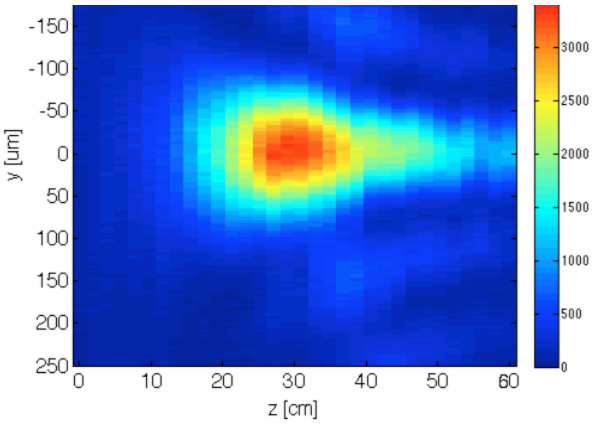
Pre-ionized Plasma Generated by Holographic Axilens

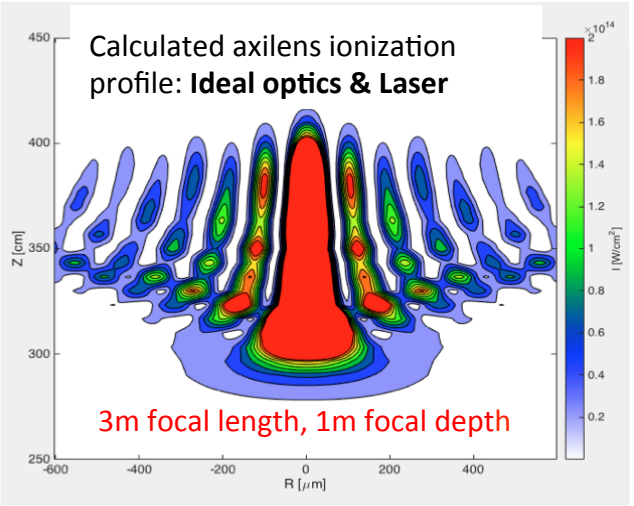


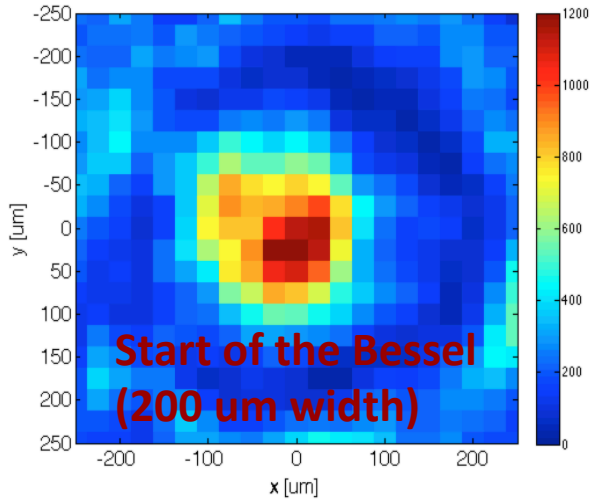
150 mJ, 50fs FACET laser provides a 100 um wider and ~50 cm long pre-ionized plasma in Hydrogen!

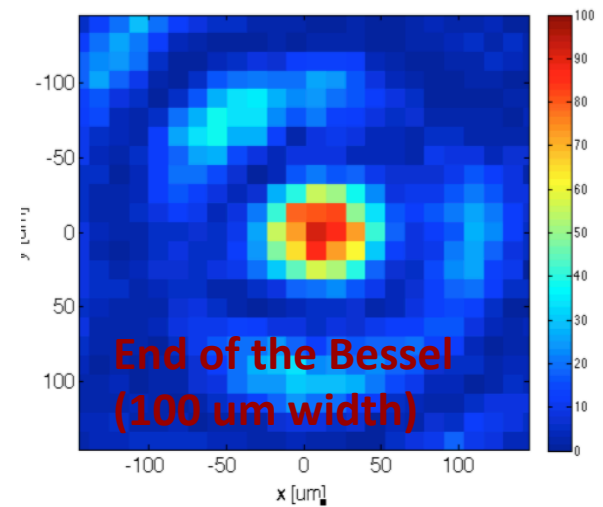
Measured transverse Bessel intensity distribution along Z











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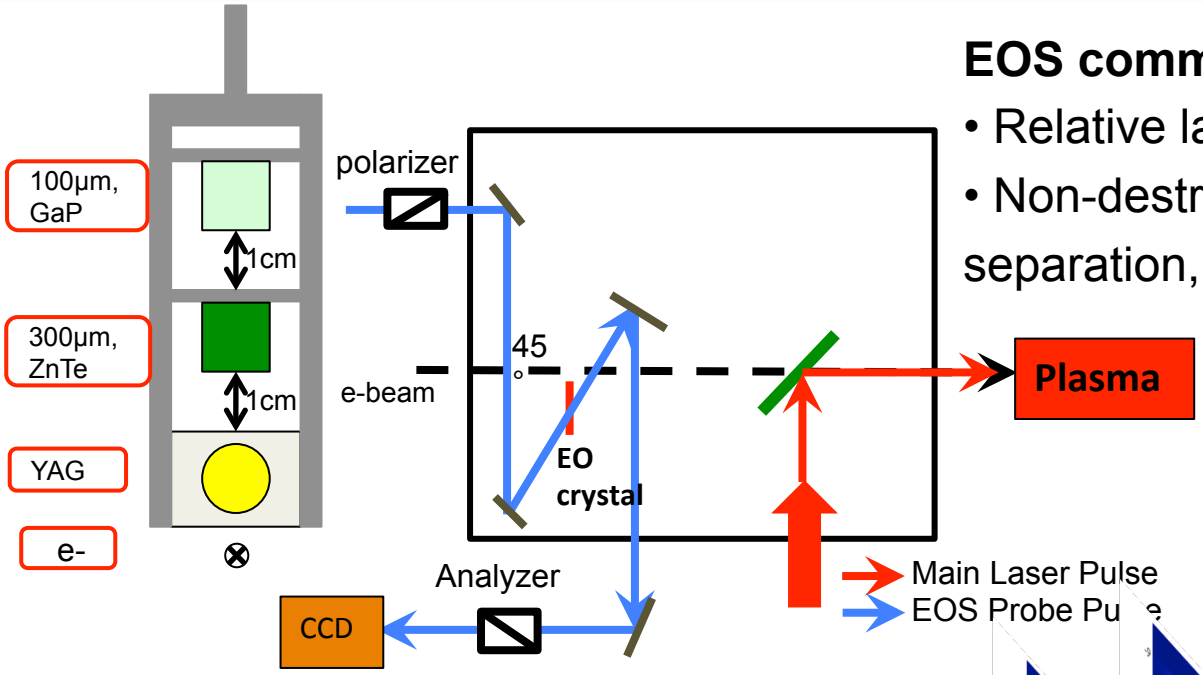
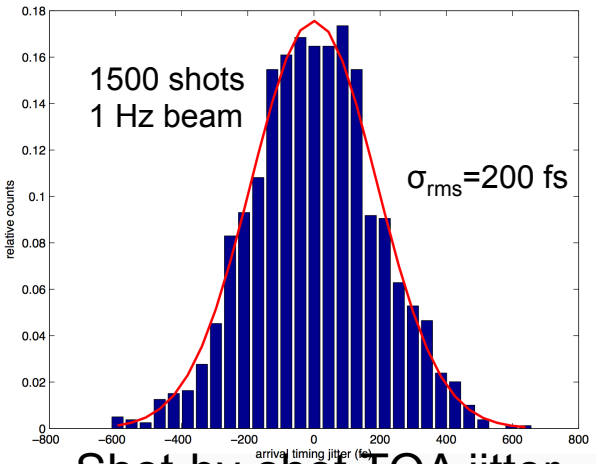
Spatial encoding Electro-Optic Sampling (EOS)

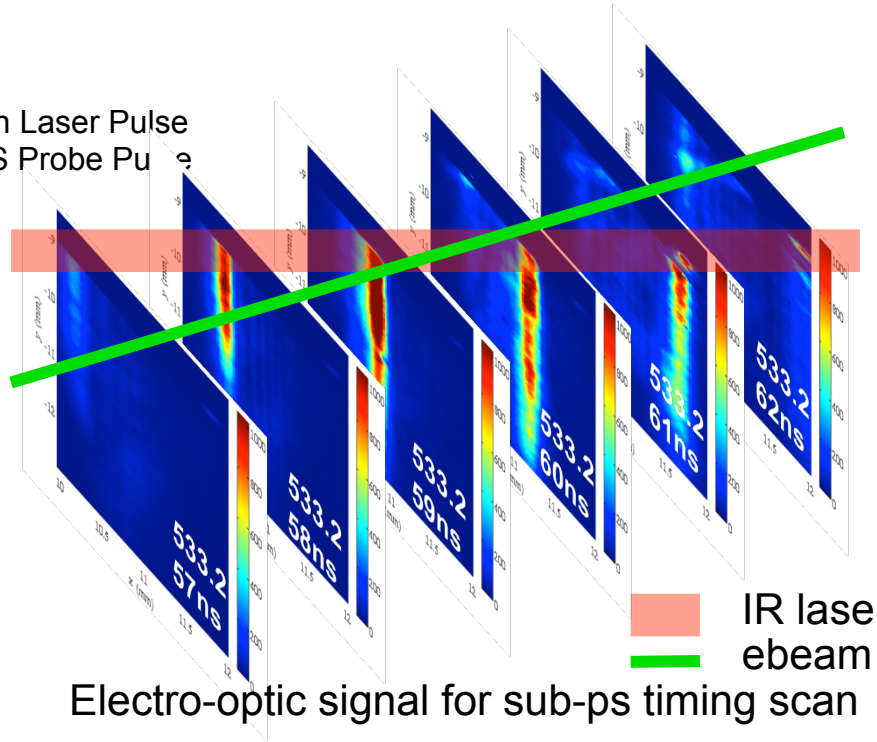


EOS commissioned in E210 experiment:

- Relative laser - electron beam TOA
- Non-destructive single-shot bunch length, separation, shot-by-shot jitter of TOA

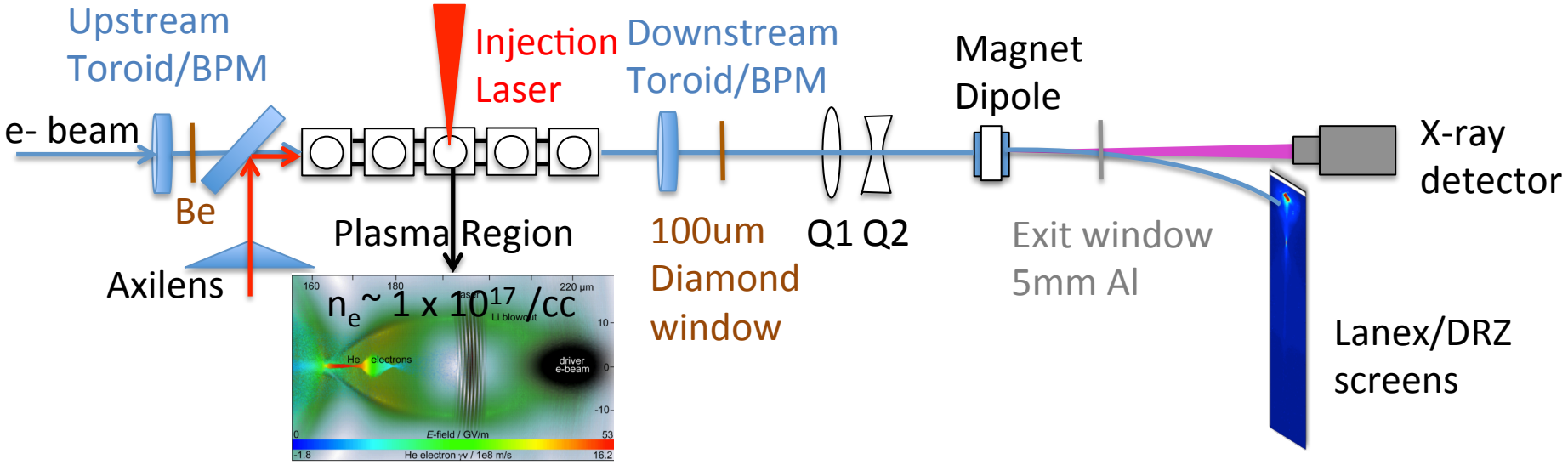


Shot-by-shot TOA jitter



Electro-optic signal for sub-ps timing scan

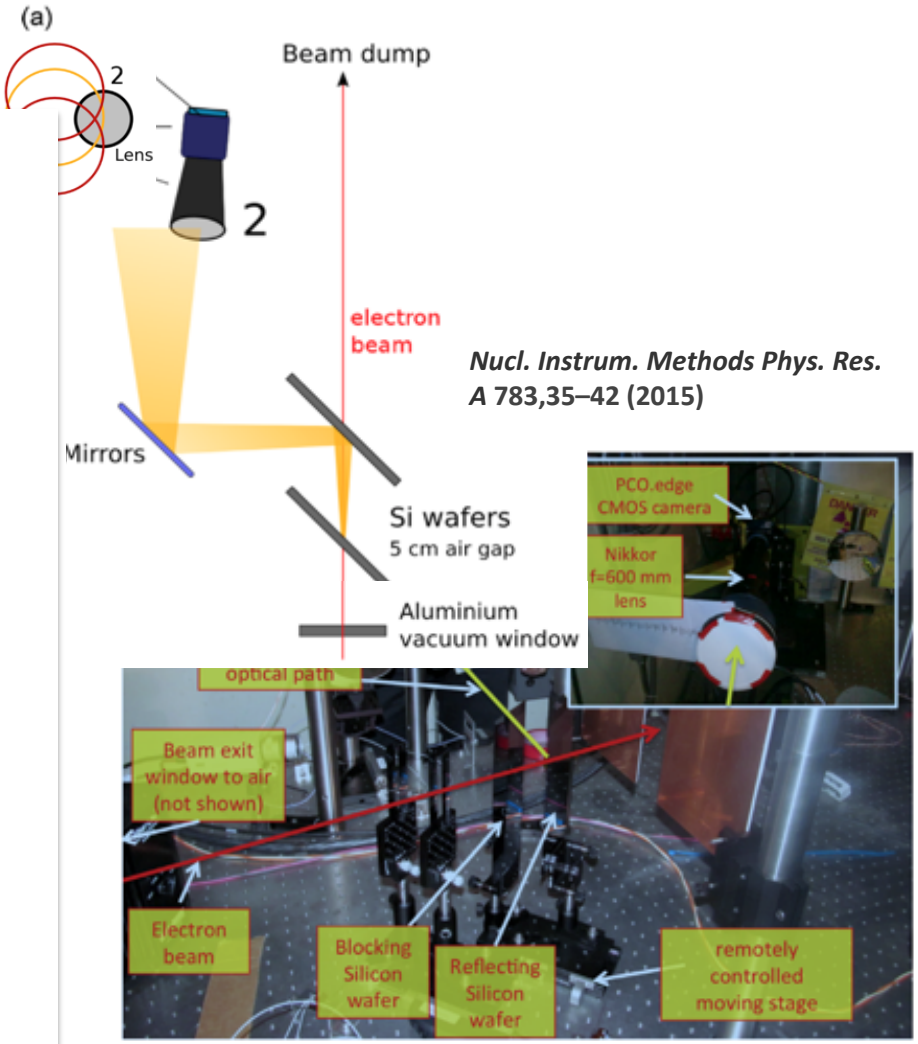
Witness Bunch Diagnostics



- Energy (E or γ) & energy spread(ΔE/E or Δγ/γ)
- Charge Q
- Transverse Emittance (ε or ε_n) or Beam size (σ_r)

Cherenkov Light-based Electron Beam Profile Diagnostic

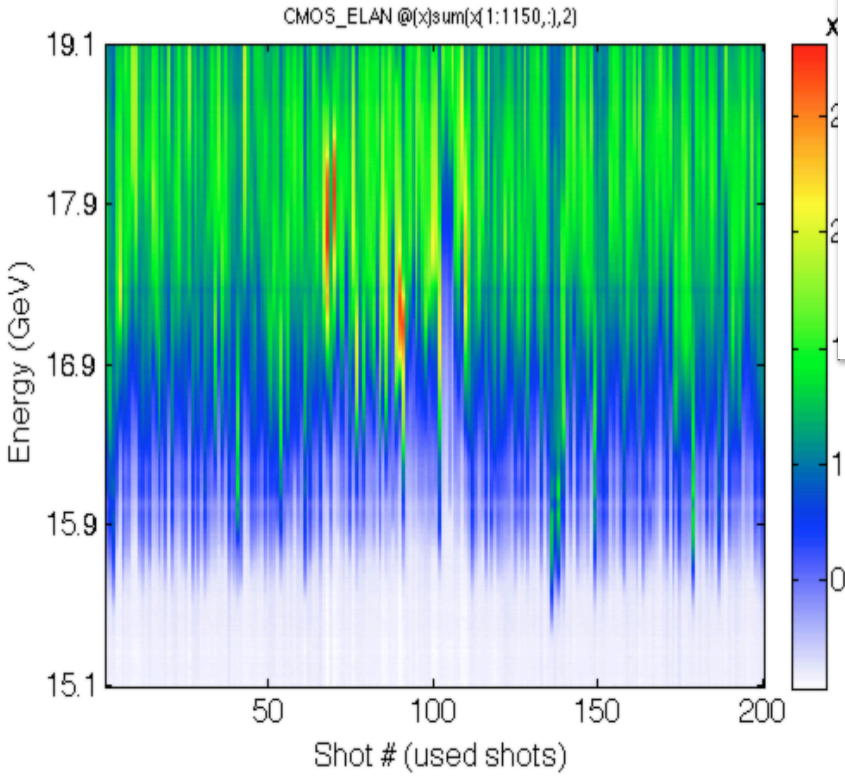
Embargoed-publication pending



Nucl. Instrum. Methods Phys. Res. A 783,35–42 (2015)

Energy Loss on Lanex

Nominal drive beam energy:
E_0=20.35 GeV

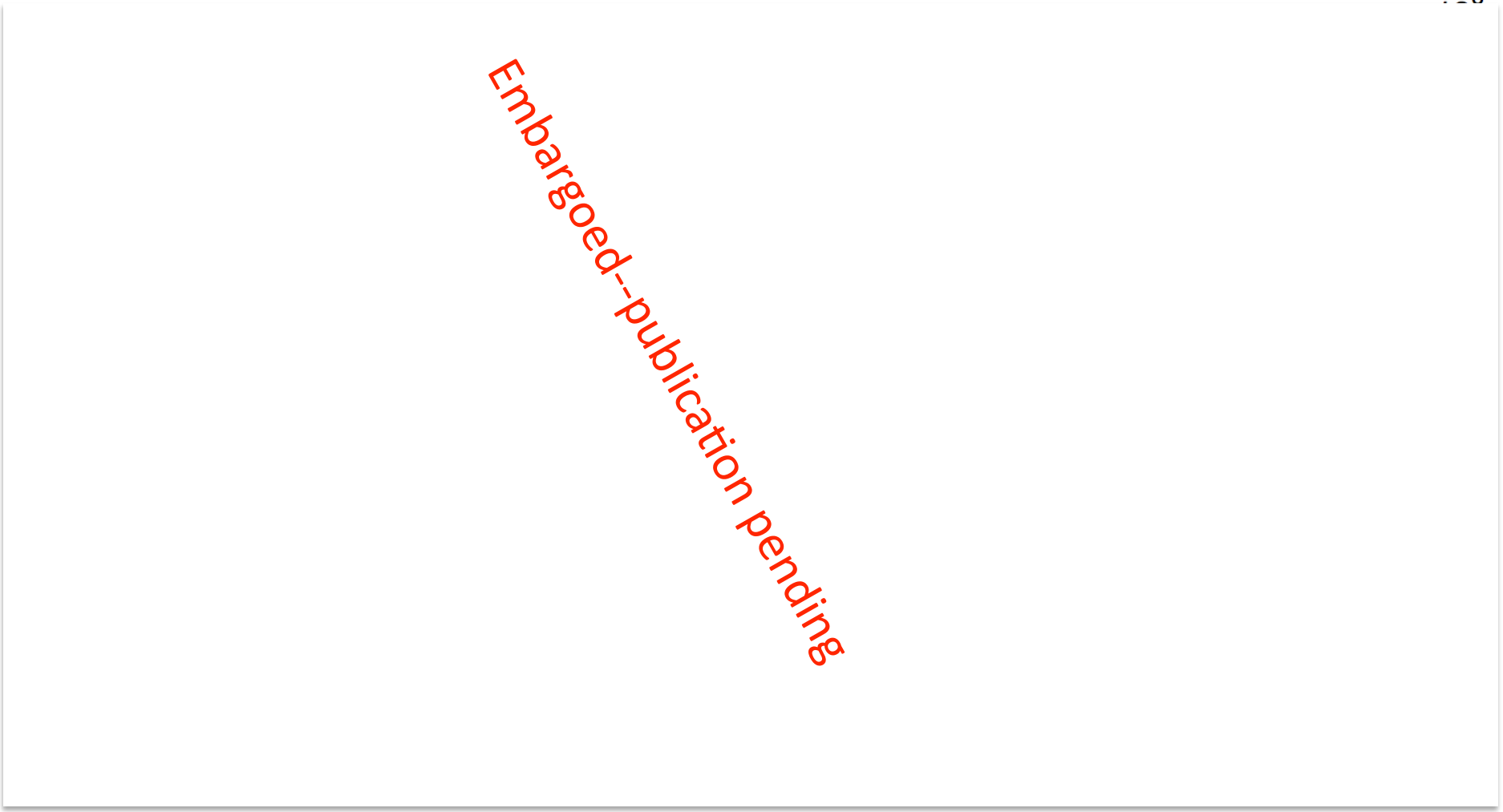


Embargoed-publication pending

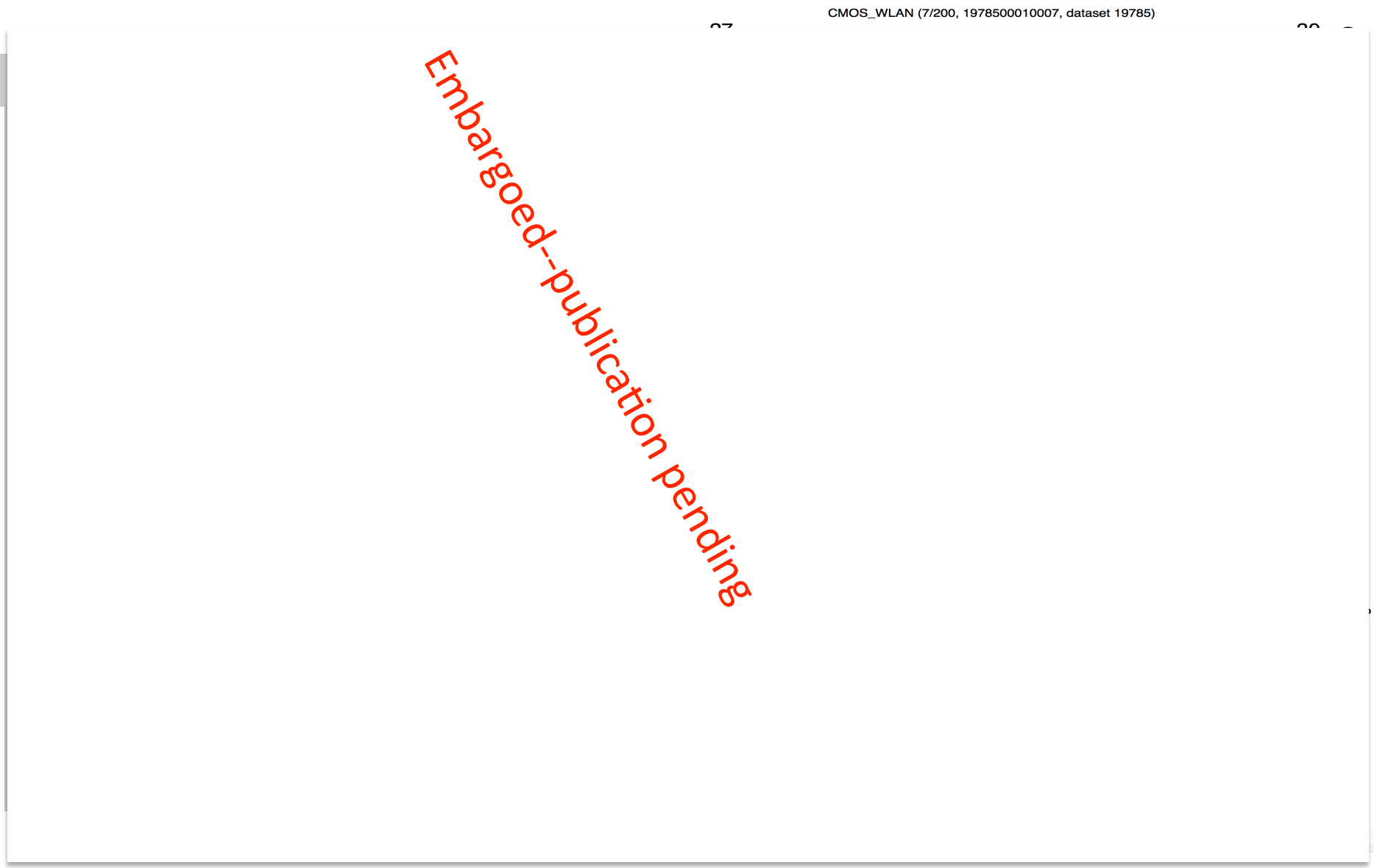
Up to ~5 GeV energy loss of the drive beam, same as the Cherenkov light-based results.

Extra Trapped Charge with Injection Laser

Extra charges show up on the DS BPMs and have correlation with the spectrometer when the injection laser is on!



Witness Bunch Energy Spectra



Lower Laser Energy brings the Real Trojan Horse Injection to Light

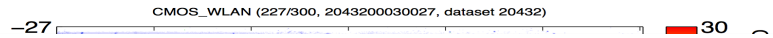
High energy laser excites wide and long last plasma, causing more trapped charge.

Less energy laser narrows the plasma, causing less trapped charge.

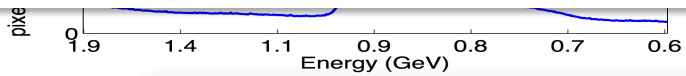
Laser energy is too low to have pre-ionized strong plasma, but bring the Trojan Horse injection to light.

Laser OFF shows the background trapped charge from the PWFA: Dark Current.

“Trojan Horse” Injected witness bunch

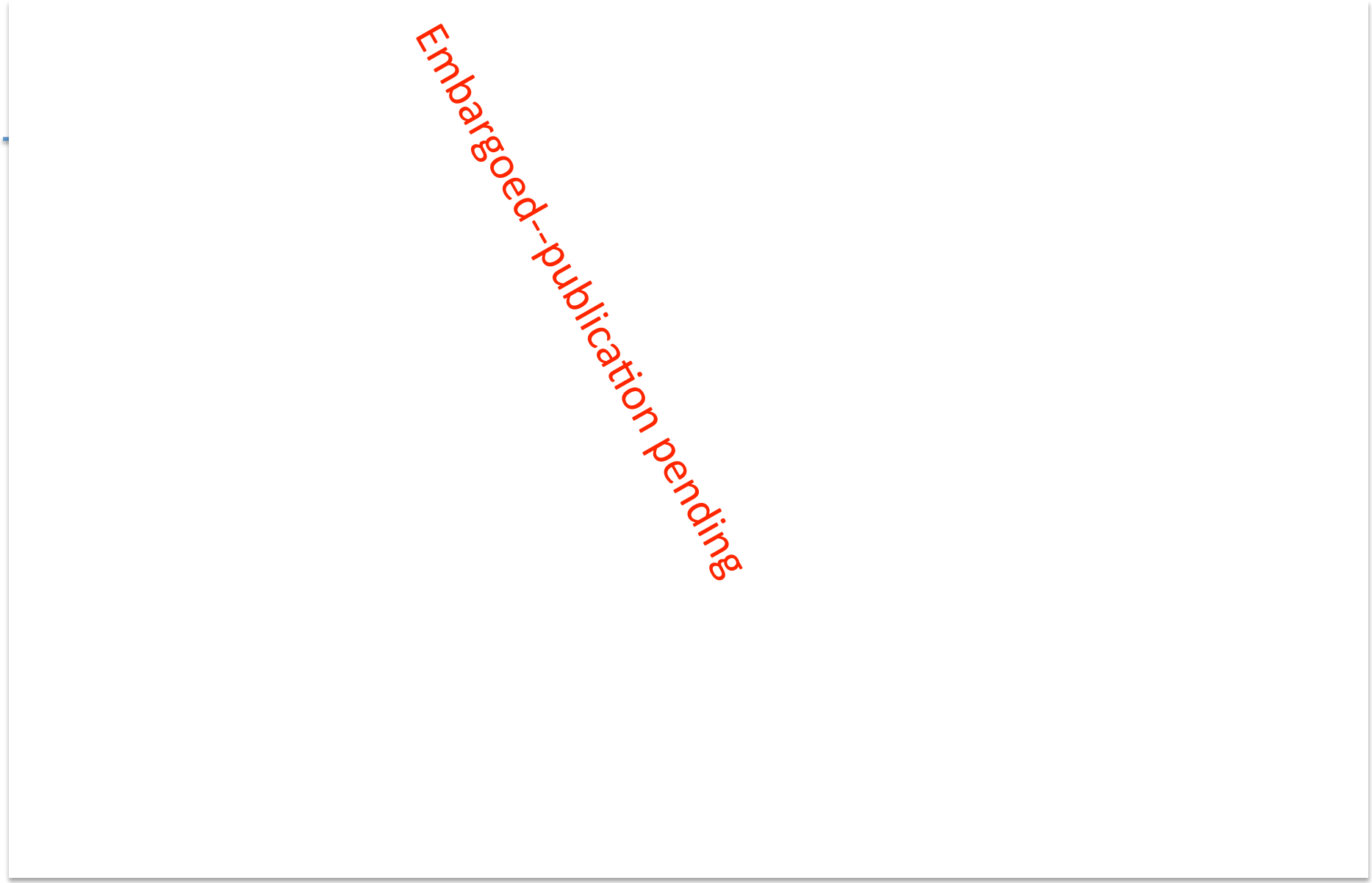


Embargoed-publication pending



Preliminary Data Analysis

Preliminary estimation of emittance



Conclusion & Future Scenarios

- Proof-of-principle of laser triggered injection PWFA experiment was a success.
- Synchronization of laser & e-beam can be nailed down to “Blow-out” size (temporally and spatially).

- Develop nice plasma source
- Develop diagnostics for high brightness beam with low emittance.
- Compact, staged TH-PWFA, different injection configurations etc.
- Next generation of light source based on TH_PWFA.
- …