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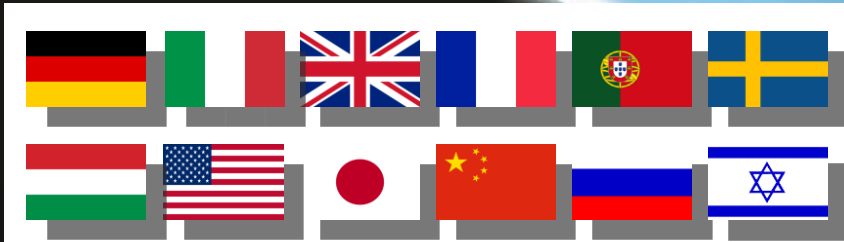


# Laser-plasma injectors in the frame of EuPRAXIA

3rd EAAC, Elba island, 25-29 September 2017

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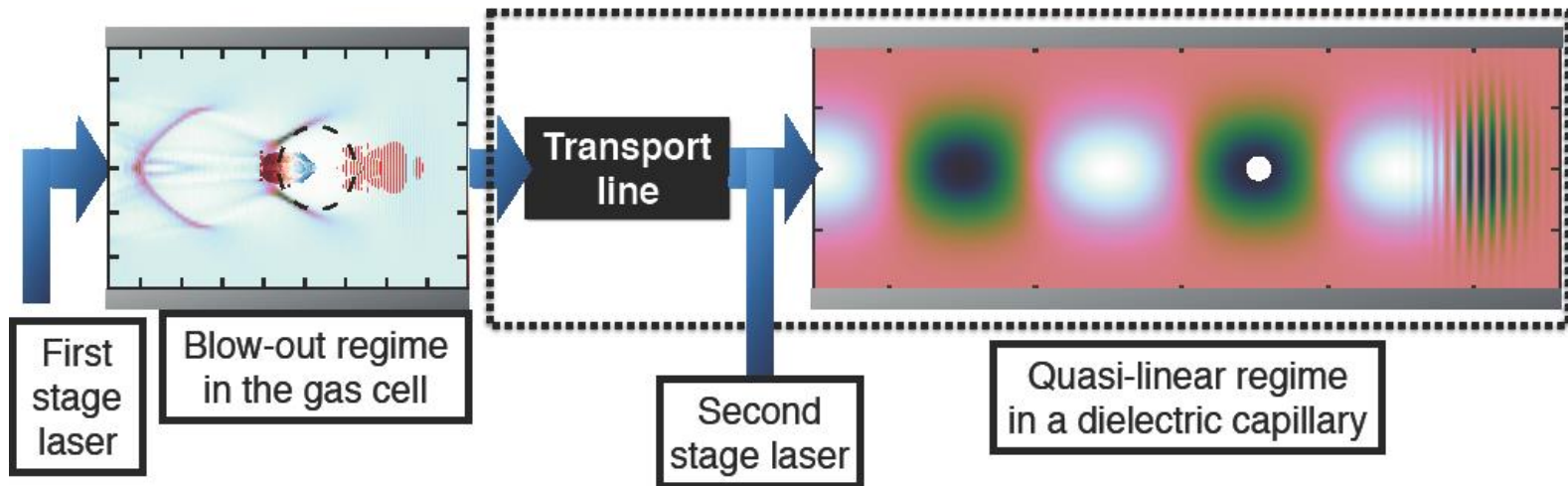


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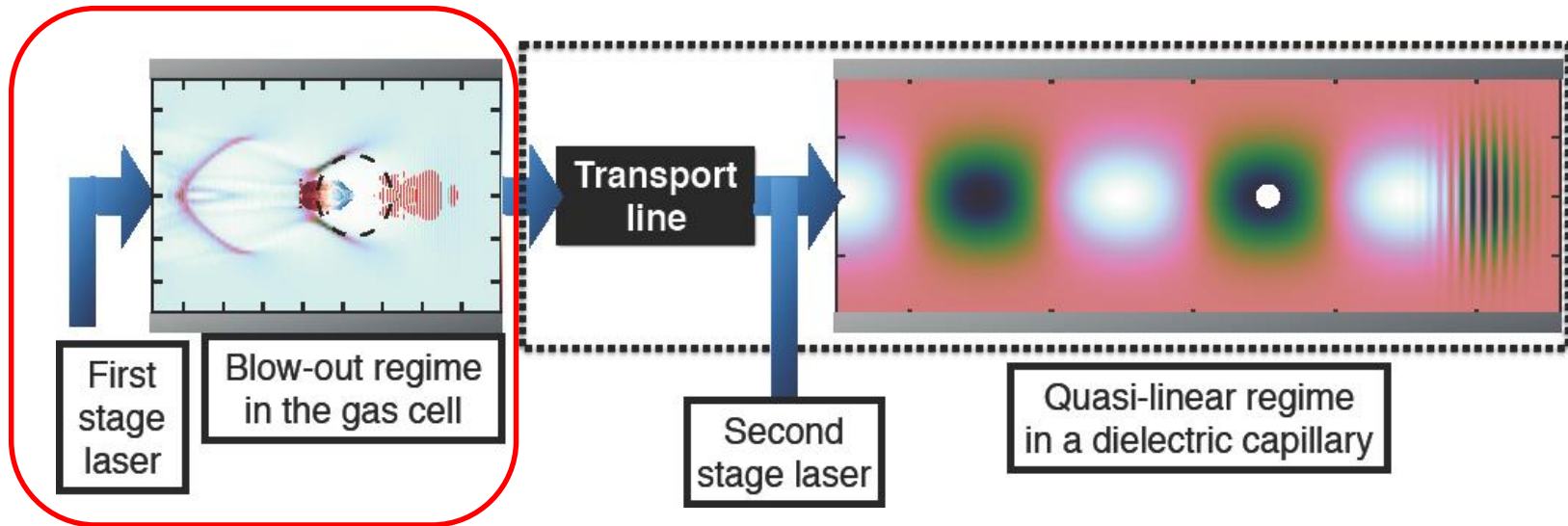
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  - Free electron laser science area
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Quantity	Target value
Energy	150 MeV [100 – 200 MeV]
Charge	100 pC [30 – 100 pC]
Bunch length	5 fs (rms) [3 – 20 fs]
Repetition rate	10 Hz [1 – 100 Hz]
Total energy spread	5 % (rms) [1 – 5 %]
Transverse normalized emittance	1 mm.mrad
Transverse beam size	0.58 $\mu\text{m}$ (rms) [0.5 – 0.71 $\mu\text{m}$ ]
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- These target properties are given at the entrance of the second stage  
 → Impact of transport on charge, bunch length and spatial properties

- We compared experimental results with electron energy in the range of EuPRAXIA
- We focused on properties that will not be changed or improved during transport :
  - Energy
  - Charge
  - Energy spread
- We looked at four injection schemes :
  - SI : self-injection
  - CPI : colliding pulse injection
  - DGI : density gradient injection
  - III : ionization-induced injection

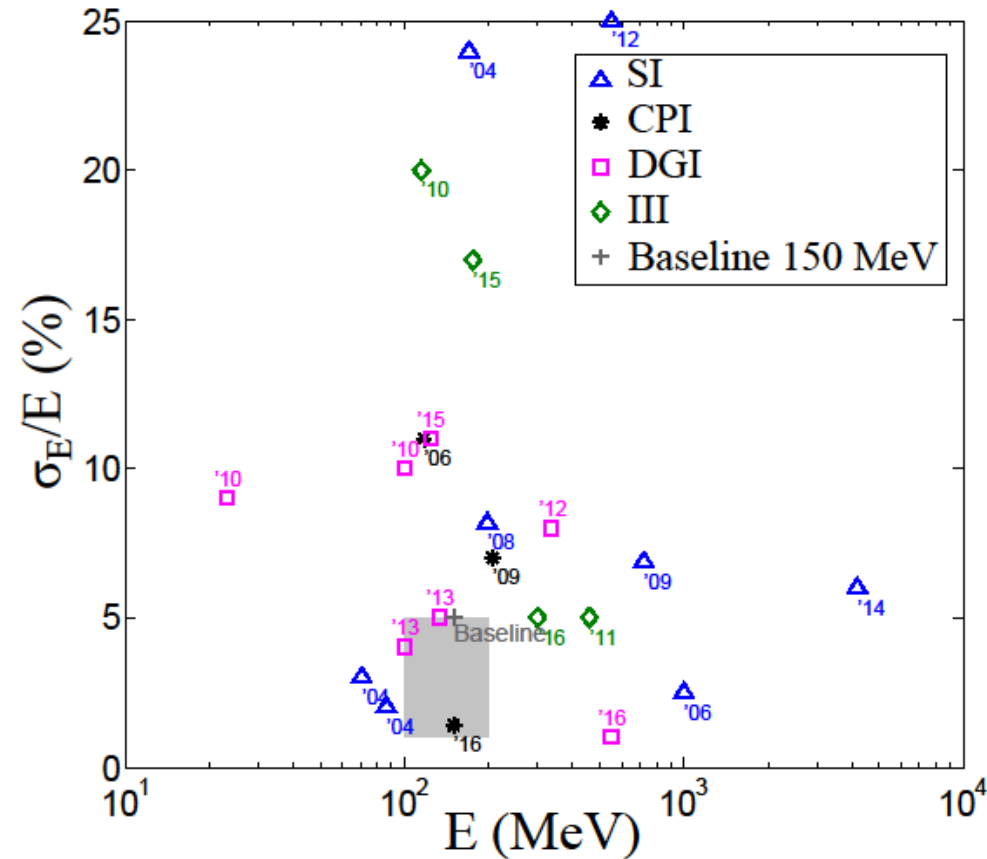


SI : Self Injection

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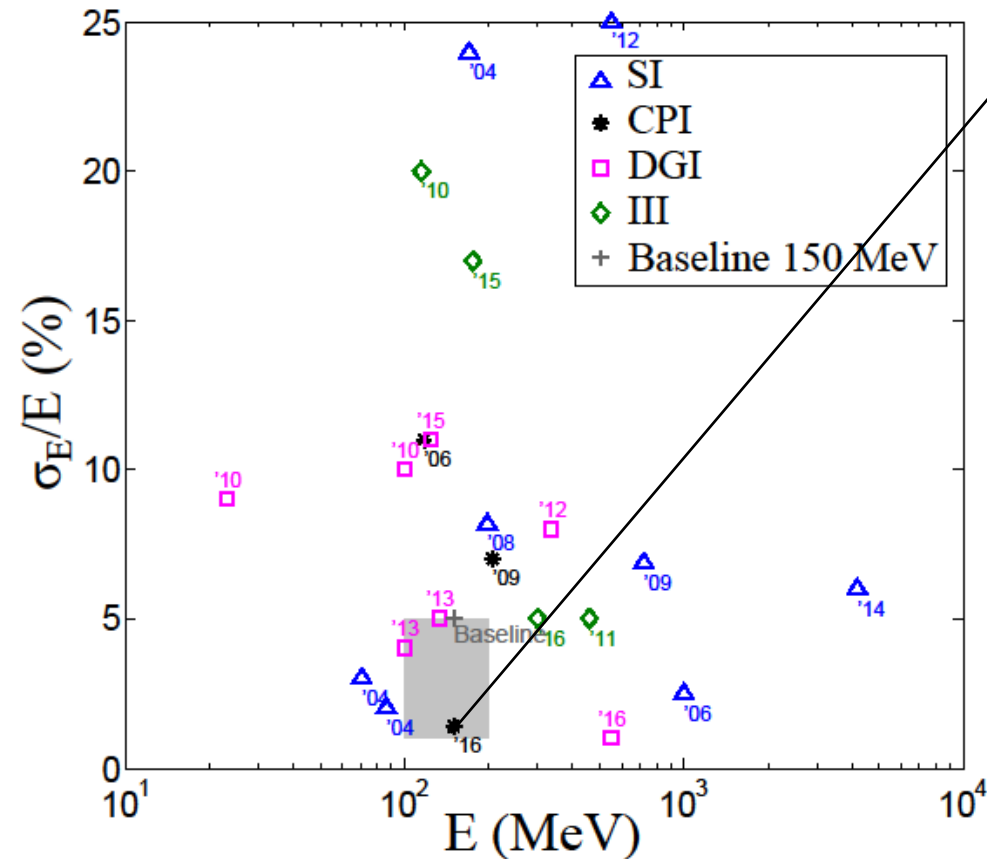


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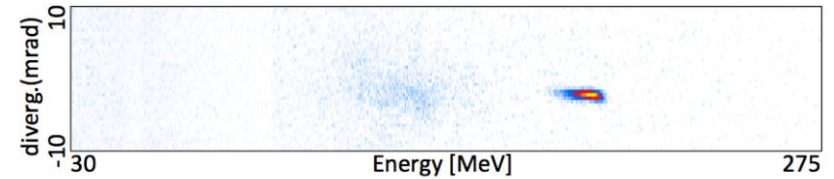
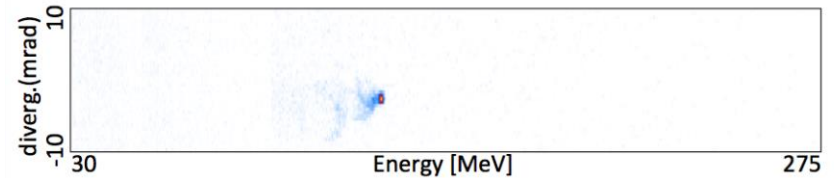
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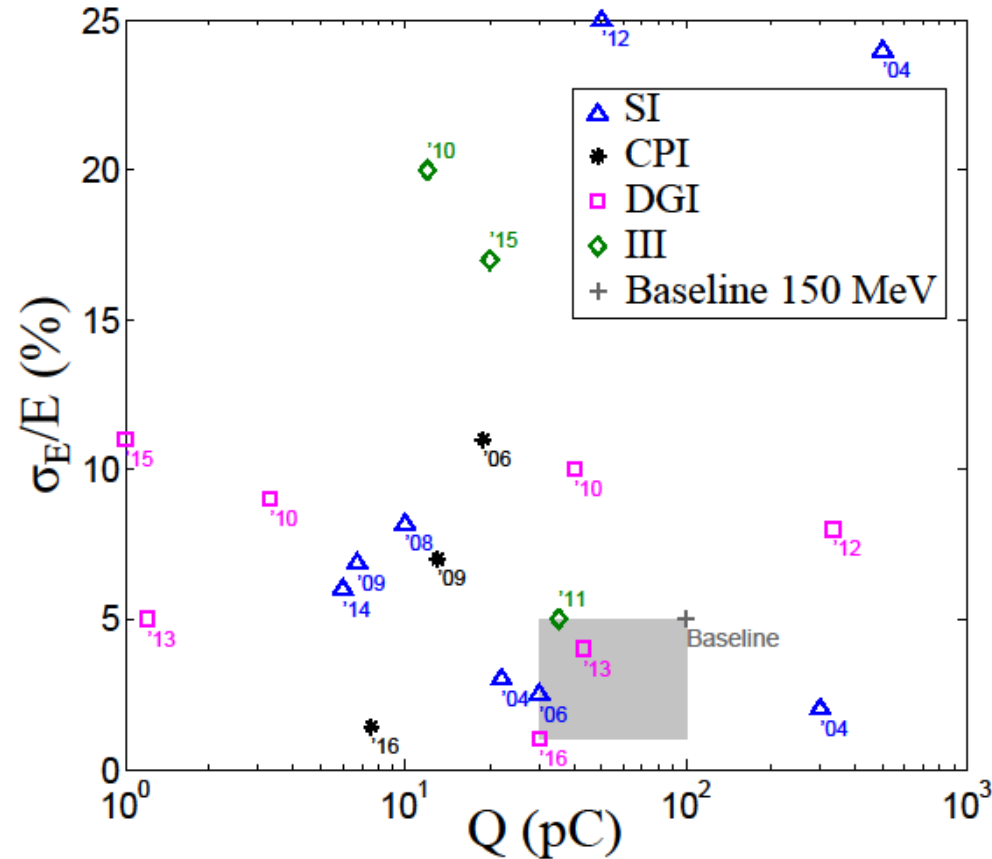


C.G.R. Geddes et al. AIP Conf. Proc. (2016)



- CPI in gas jet
- $a_0 = 1.2$  &  $0.6$
- $n_e \sim 10^{19} \text{ cm}^{-3}$
- $E = 150 \text{ MeV}$
- $\frac{\sigma_E}{E} = 1.4 \%$  (fwhm)
- $Q \sim 8 \text{ pC}$

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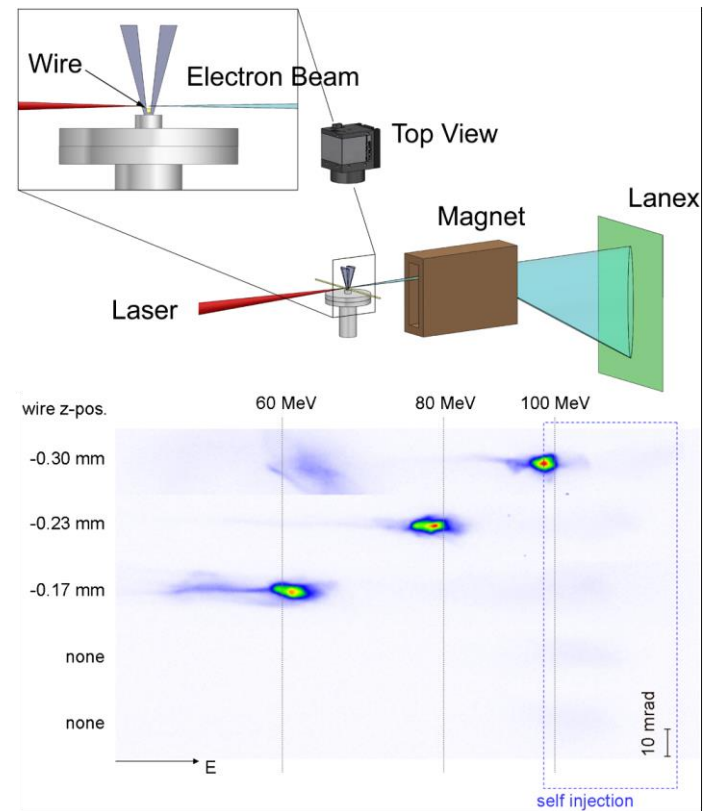
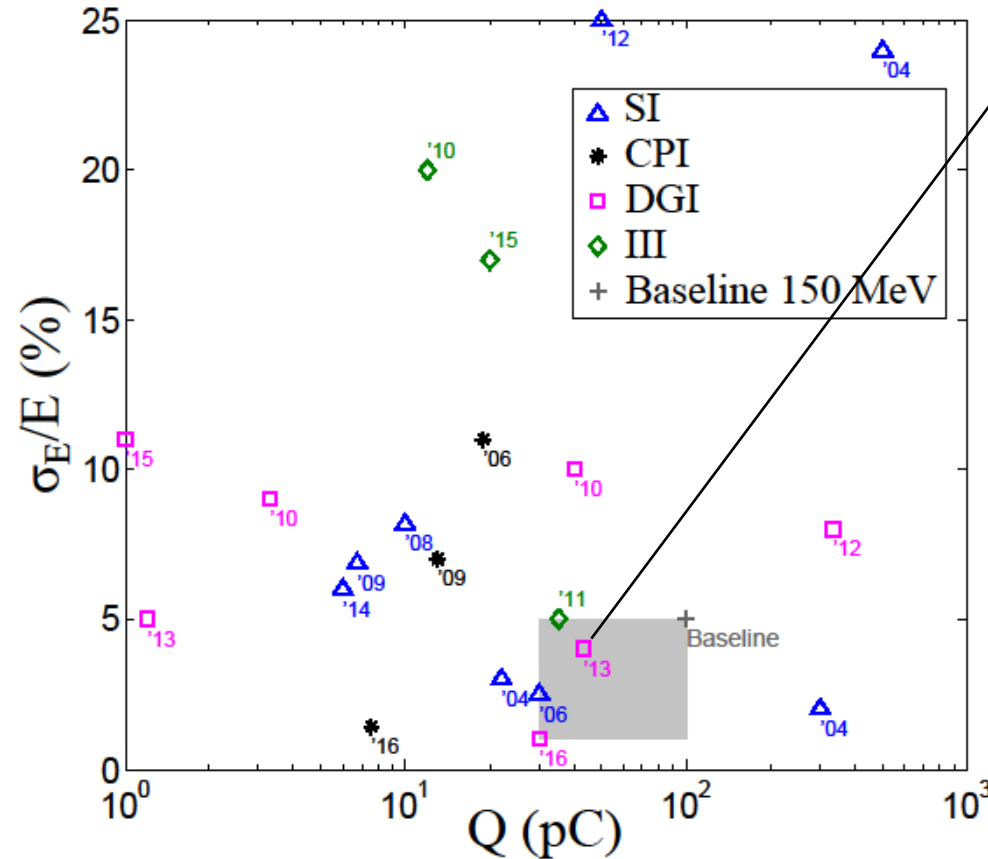
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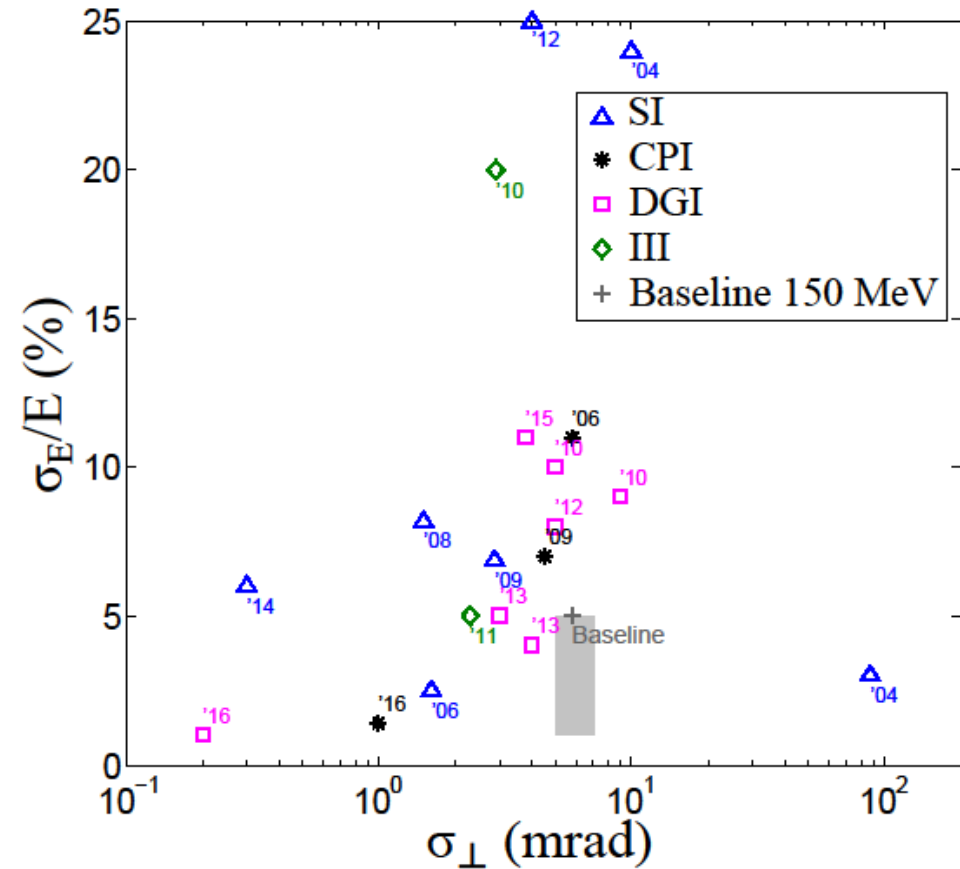
III : Ionization Induced Injection

M. Burza et al. PRSTAB (2013)



- DGI in gas jet
- $n_e \sim (6 \rightarrow 3) \times 10^{18} \text{ cm}^{-3}$
- $E = 100 \text{ MeV}$
- $\frac{\sigma_E}{E} = 4 \% \text{ (fwhm)}$
- $Q \sim 43 \text{ pC}$

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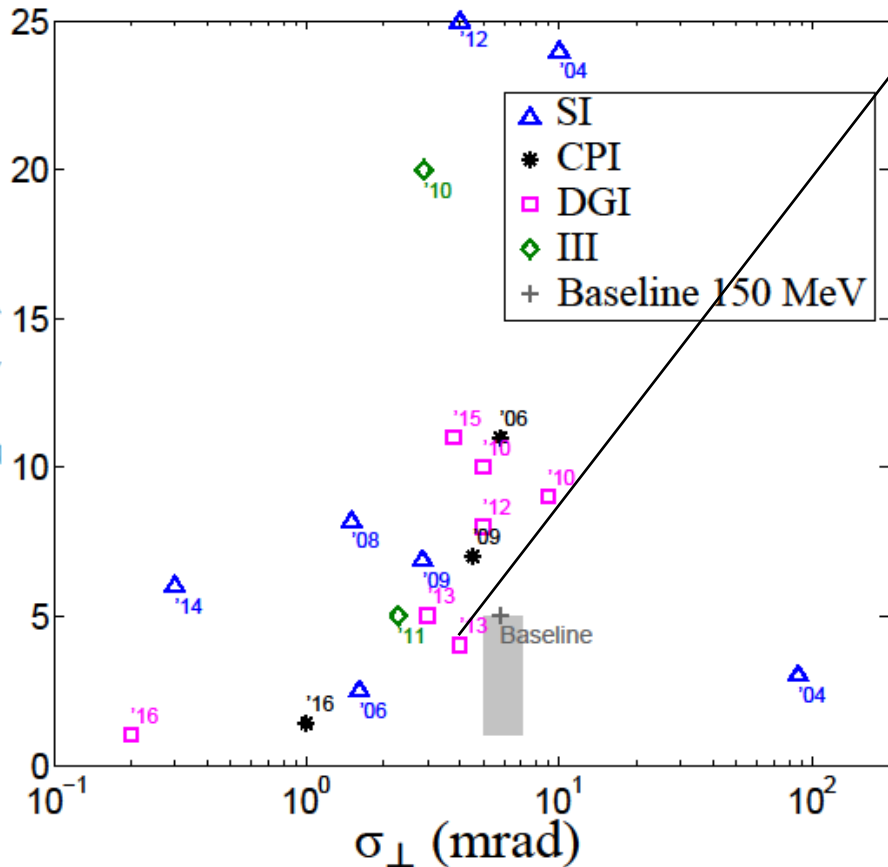


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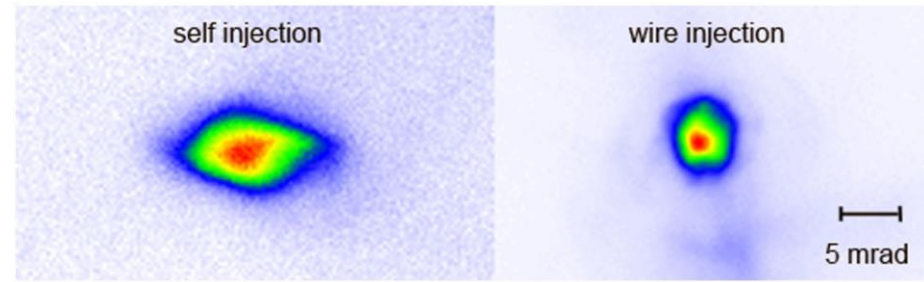
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- $Q \sim 43 \text{ pC}$
- $\sigma_\perp = 4 \text{ mrad (fwhm)}$

Quantity	Target value	Published results
Energy	150 MeV [100 – 200 MeV]	✓
Charge	100 pC [30 – 100 pC]	✗
Bunch length	5 fs (rms) [3 – 20 fs]	✓ ✗
Repetition rate	10 Hz [1 – 100 Hz]	✓
Total energy spread	5 % (rms) [1 – 5 %]	✓
Transverse normalized emittance	1 mm.mrad	✗
Transverse beam size	0.58 μm (rms) [0.5 – 0.71 μm]	✓ ✗
Transverse divergence	5.8 mrad (rms) [5 – 7.1 mrad]	✓

Critical issue :

- High charge (100 pC) **combined with** low energy spread (5 % rms) and low emittance (1mm.mrad)

- Published results only partially match EuPRAXIA injector parameters
    - Optimization investigated through simulations P. Lee PRSTAB (2016)  
P. Lee PRSTAB (to be submitted)
  - Ionization induced injection in a gas cell with tuned density profile
  - Density transition injection in a gas jet
  - Self-truncated ionization induced injection in gas jet ?
- ... in quasi-linear regime



- Published experimental results are getting closer to EuPRAXIA target parameters :
  - Energy, energy spread and divergence are already achievable
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- } Managing space charge effects
- Stability (pointing, charge, energy ...) is mandatory for injection into a second plasma stage → more results on stability are needed
  - Transport will have an impact on the stability
    - Up to a factor ~10 in size and pointing stability → A. Maitrallain (to be published)
    - A stable injector producing wider energy distribution but large pC/MeV could also be an option

Thank you !