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EUROPEAN PLASMA RESEARCH ACCELERATOR WITH EXCELLENCE IN APPLICATIONS

High Gradient Laser Plasma Accelerating Structure WP3

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Participants

- WP3 meeting held at Paris-Sud, 26th Oct 2016
- Participants:
  - Cros Brigitte - (Paris-Sud)
  - Audet Thomas - (Paris-Sud)
  - Zulfikar Najmudin - (JAI, Imperial College)
  - Hooker Simon - (JAI, Oxford)
  - Matthew Streeter - (Cockroft, Lancaster)
  - Enrica Chiadroni - (INFN, Frascati)
  - Alessandro Cianchi - (INFN, Frascati)
  - Andrea Mostacci - (Roma Sapienza)

WP3 first task

Task 3.2. Design plasma structures (injector & accelerator)
3.2.1: Define the regime of operation: Identify laser intensity, plasma density range and volume (effective acceleration length and transverse structure), repetition rate, …
3.2.2 : Plasma creation
3.2.3: Laser confinement
MS14: M3.1 REPORT Design for an electron injector and a laser plasma stage proposed,

first milestone report due in April 2017

Preparation of MS report

1. First draft by the end of December 2016 : contributions to this meeting
2. To be circulated among WP3 participants for additional input
3. Contributors to the report are co-authors

Other tasks

Task 3.3: Design plasma structure
3.3.1 : Determine requirements for plasma structure along with beam combining
3.3.2 : Study specific tasks
3.3.2a : Laser focussing
3.3.2b: Laser plasma alignment and control
3.3.2c: Vacuum system (gas load, sputtering)
3.3.2d: Activation (chamber, local shielding)
3.3.2e: Laser beam removal from electron axis
MS20: M3.2 REPORT Design for interaction chambers proposed
Task 3.4: Diagnostics
3.4.1: plasma diagnostics
3.4.2: plasma wave diagnostics
3.4.3: diagnostics of electrons in the plasma
3.4.4: laser diagnostics around focus, in/out plasma
MS21: M3.3 REPORT Design for implementation of proposed diagnostics
Task 3.5: design multistage LPA
3.5.1: Designing succesive plasma structures, identifying scalability parameters
3.5.2: Laser plasma coupling
3.5.2a: Plasma mirrors
3.5.2b: other options
3.5.3: Engineering issues for stability, timing and overlap
MS26: M3.2 REPORT Design for multi-stage coupling proposed

- MS20: end October 2017
- MS21: end October 2017
- MS26: end July 2018

D3.1: Report on the design of plasma structures

- End October 2018

Baseline parameters: 5 cases

Case n°	Injector	T1	Accel ST 1	T2	Accel ST2
Case 1A	**LPI 1G**		**LPAS 5G**		
Case 1B	**LPI 5G**				
Case 2A	RFI 0.15 G		**LPAS 1G**		**LPAS 5G**
Case 2B	RFI 0.15G		**LPAS 5G**		
Case 3A	**LPI 0.15G**		**LPAS 1G**		**LPAS 5G**
Case 3B	**LPI 0.15G**		**LPAS 5G**		
Case 4A	RFI 0.50G		BPAS1G		
Case 4B	RFI 0.50G		BPAS5G		
Case 5A	**LPI 1G**		BPAS5G		
Case 5B	RFI 0.15G		**LPAS 1G**		BPAS 5G
Case 5C	**LPI 0.15G**		**LPAS 1G**		BPAS 5G

LPI= Laser Plasma Injector

RFI= Radio-Frequency Photo-Injector

nG = output energy of electrons in GeV

LPAS= Laser Plasma Accelerating Stage

BPAS= Beam Plasma Accelerating Stage

T = transport device

Summary of plasma requirements

150 MeV laser injector:
Length: 2-5 mm; injection: self, ionisation, shock

1 GeV injector:
Length: 0.5-2 cm; injection: self, ionisation

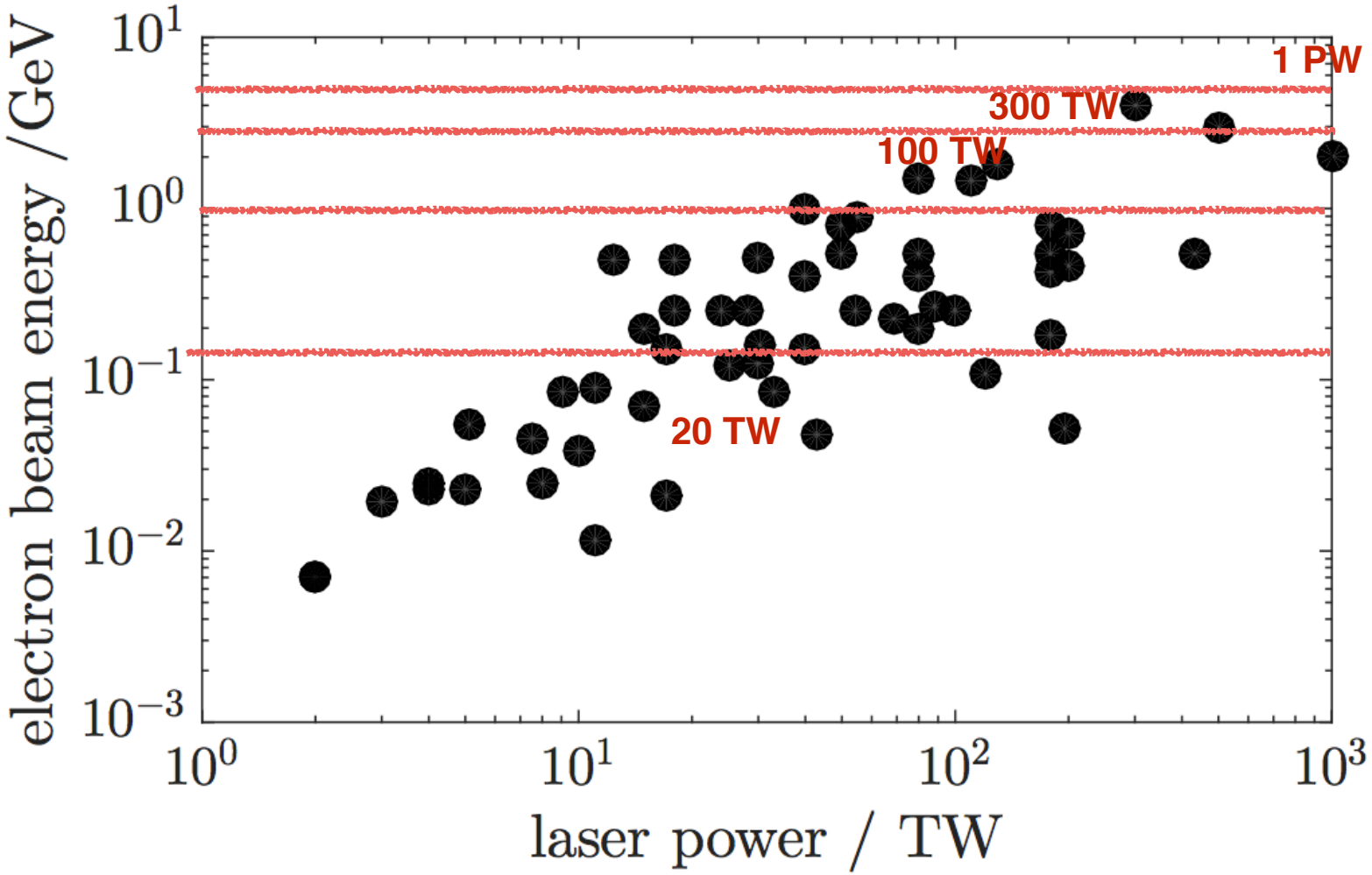
5 GeV injector:
Length: 10 cm - 20 cm; injection: self, ionisation

1-5 GeV acceleration:
Length: 5 cm - 1 m; injection: external

Questions:
1. targets for beam transport (e.g. capillary lens)?
2. targets for PWFA

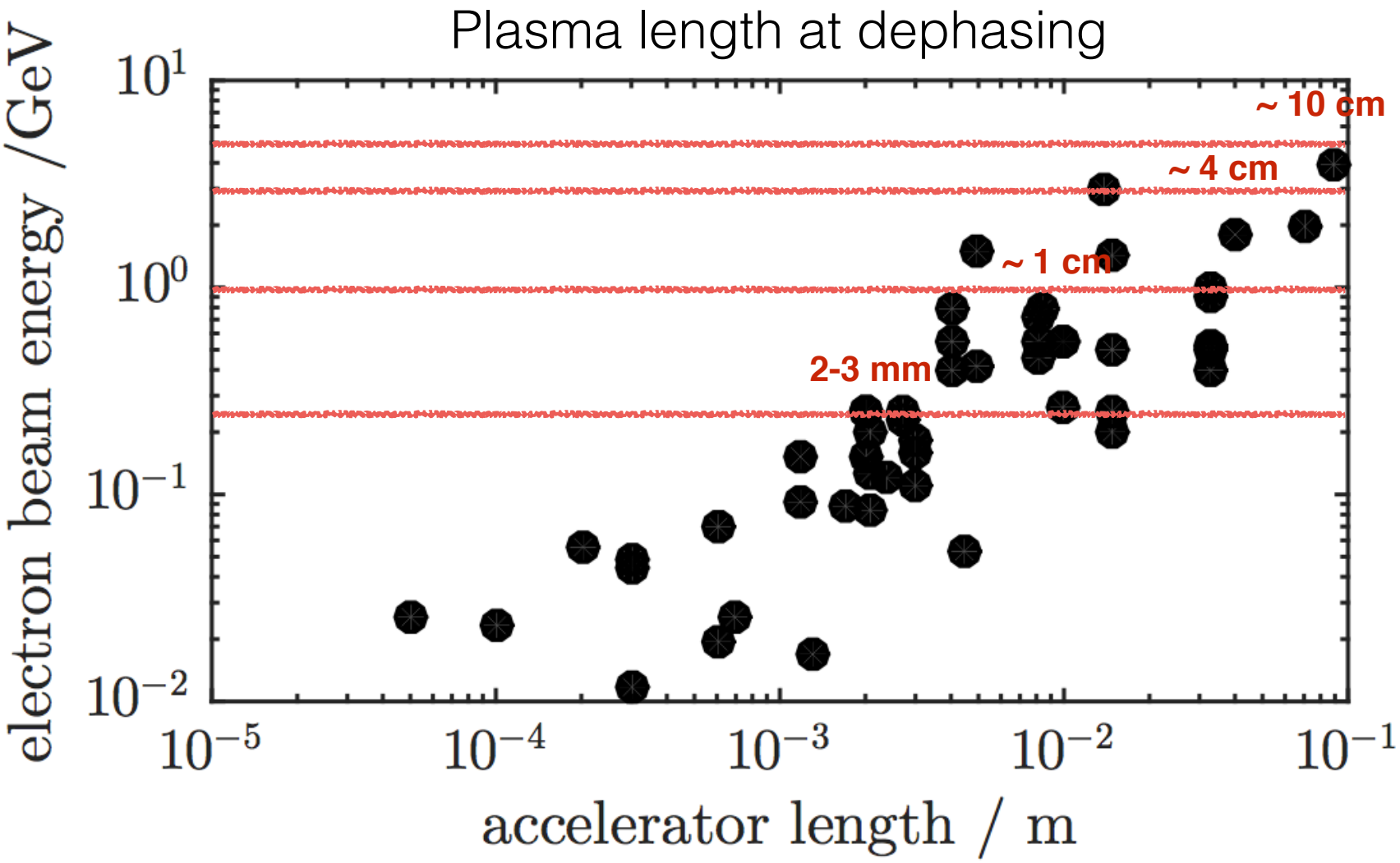
Scaling of target requirements

Laser energy required at dephasing



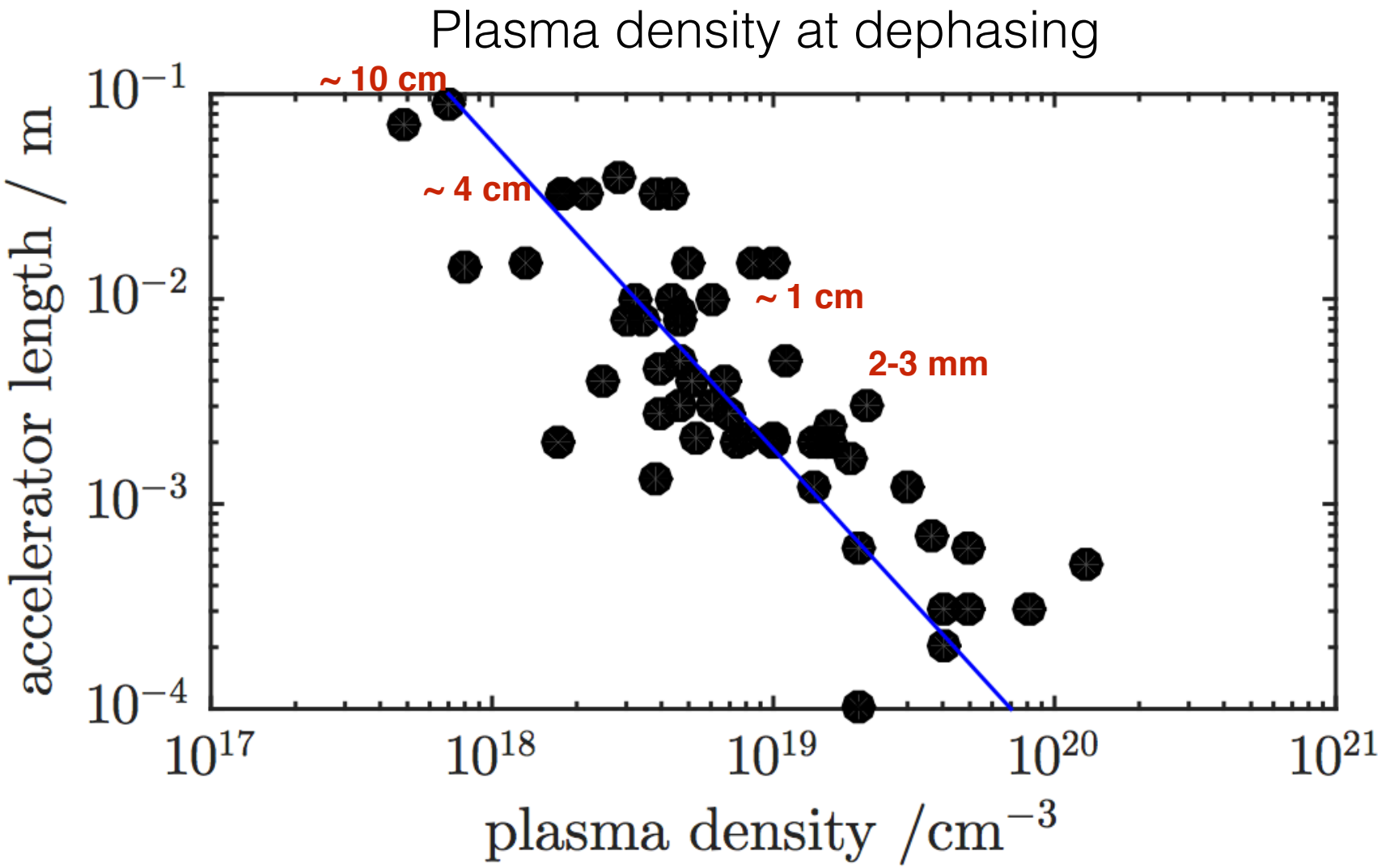
Mangles, CERN reports 2016

target requirements for injector



Mangles, CERN reports 2016

Scaling of target requirements



Mangles, CERN reports 2016

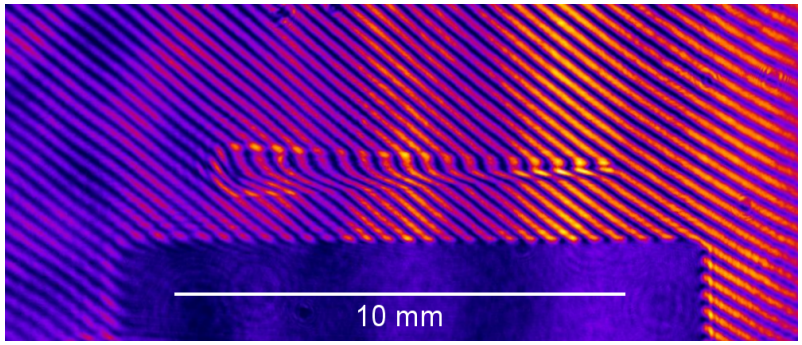
possible plasma sources

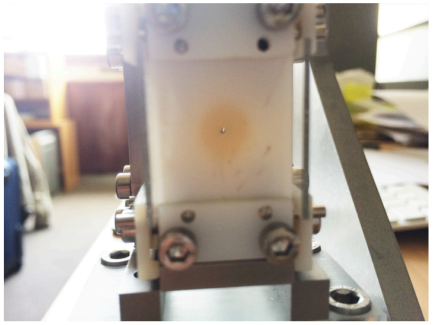
Gas jets:
Length: 2-5 mm; injection: self, ionisation, shock
Pros: Turbulent driven instabilities, flexibility, easy diagnosis
Cons: high charge? lack of flexibility

Gas cells:
Length: 0.5-10 cm; injection: self, ionisation, external
Pros: long + variable lengths, flexible (compartments)
Cons: guiding at long length?

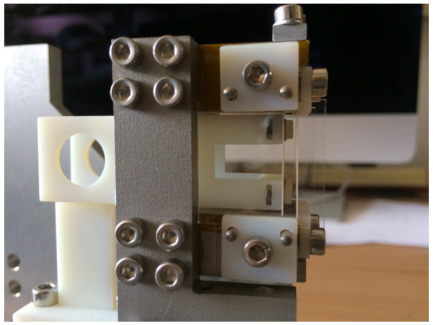
Capillaries:
Length: 0.5-10 cm; injection: self, ionisation, external
Pros: preionised, long lengths, guiding
Cons: damage? diagnosis?

Comparison of gas jets and cells

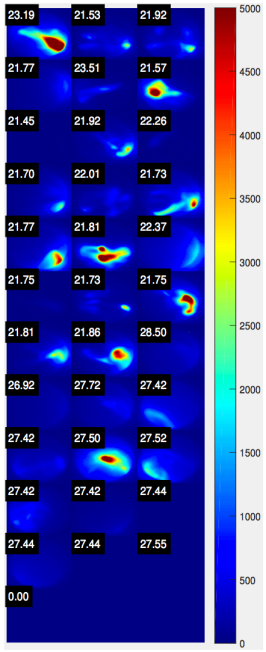


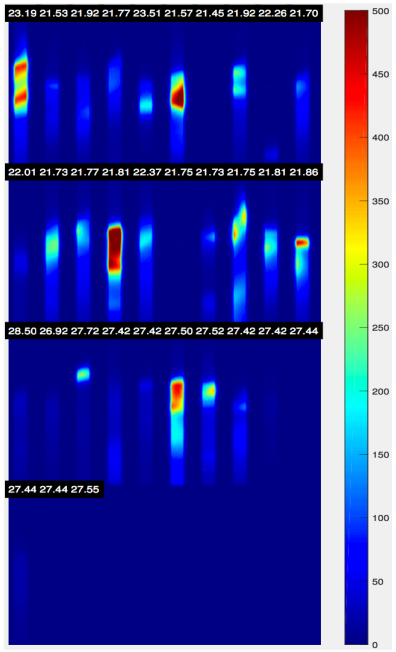


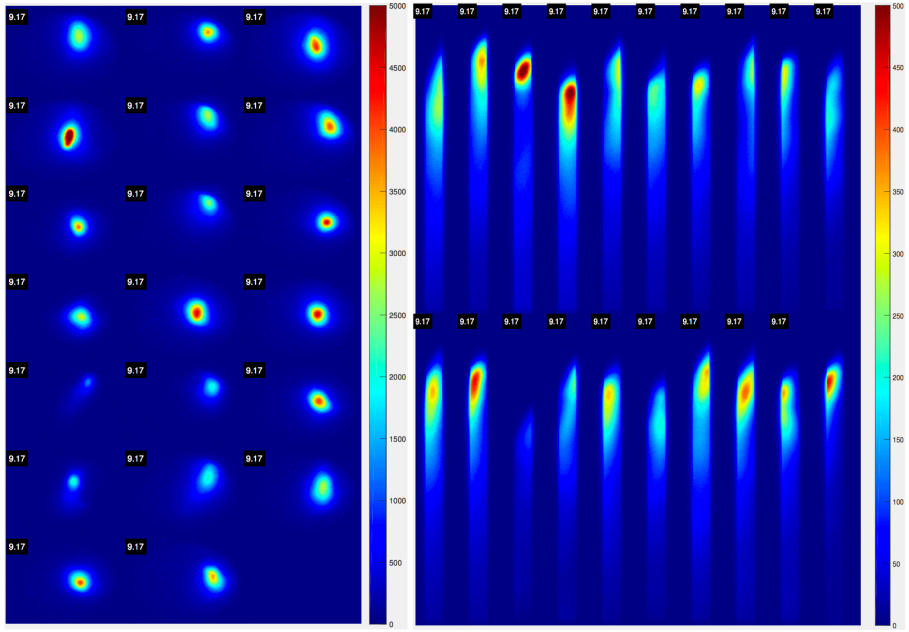
(a) Transverse profile of the gas cell. The orange hue on the cell is due to the energy in the wings of the focussed beam damaging the cell.



(b) Side view of the gas cell.

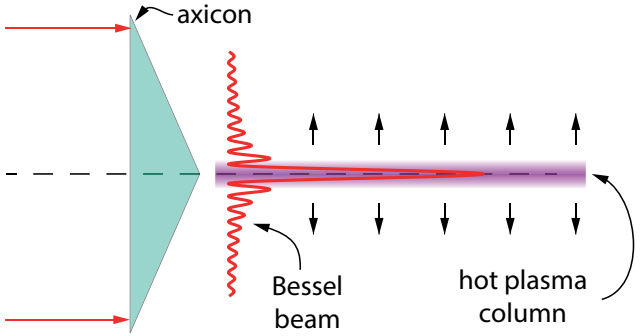


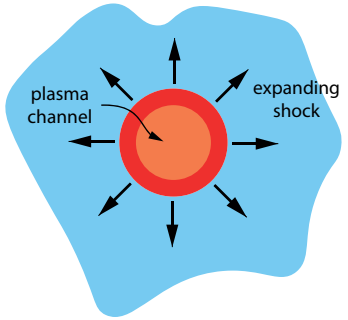


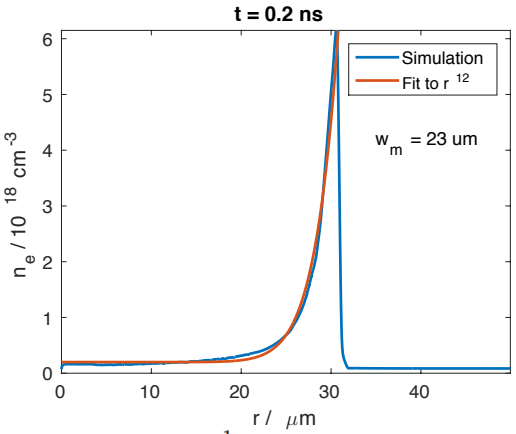


Low Density Plasma Channels Created by Hydrodynamic Expansion of OFI-heated Plasma Columns

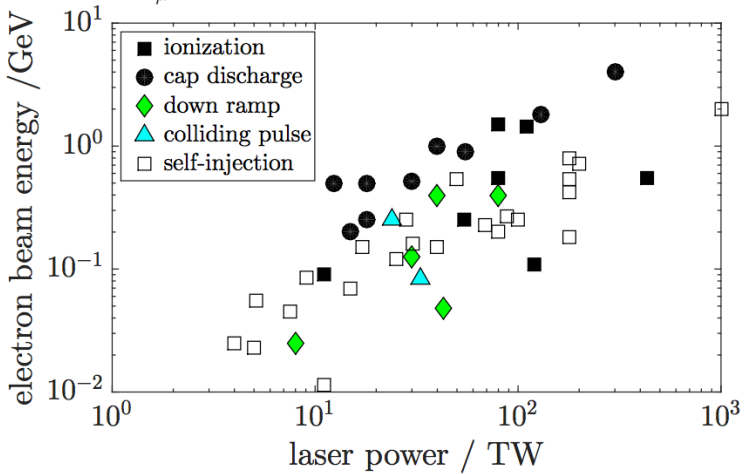
- OFI can generate hot plasma columns at arbitrarily low density
  - Heating can be controlled with polarization
- Subsequent hydro expansion could form plasma channels:
  - With low density
  - At multi-kHz repetition rate
- Initial hydro simulations show formation of channels with
  - On-axis densities 2 × 10^{17} cm^{-3}
  - Matched spot sizes of tens of microns
- Required laser energy to generate channels is 100s mJ per metre.
  - Most pump energy not absorbed. Could be recycled?







FLASH hydro simulation of He^{2+} plasma channel



possible injection sources

Self-injection:
Energy: 0.15 - 5 GeV;
Pros: easy? (high charge?)
Cons: reliability? less control of output parameters

Ionisation:
Energy: 0.15 - 5 GeV ;
Pros: easy to control charge, injection can be localised
Cons: tolerances, synchronisation?

Shock:
Energy: 0.15 MeV ;
Pros: inherently low energy spread
Cons: high energy gain not proven?

Hybrid schemes

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