 Beam dynamics simulations for The SMI experiment at PITZ

- Motivation
- Experimental conditions
- First simulation results
- Summary

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> Use high energy proton beams from SPS to drive plasma wave

> Convert proton beam energy to accelerate electron beam in single stage

High accelerating gradient requires short bunches ($\sigma_z$ less than 100µm)

Existing proton machines produce long bunches (10cm)

$E_{z,\text{max}} = 240(MV \ m^{-1}) \left( \frac{N}{4 \times 10^{10}} \right) \left( \frac{0.6}{\sigma_z (\text{mm})} \right)^2$

Caldwell et al., Nature Physics (2009):

120 fs < 450 mJ Ionizing Laser Pulse

PHIN RF gun
10-20 MeV 1.2x10^9 e
3 mm $\sigma_z$, 0.25 $\sigma_r$
$\varepsilon_N = 2$ mm-mrad

7-10 m long 2 mm wide Rb Vapor Plasma 10^{14} \cdot 10^{15} \text{ cm}^{-3}

Fast valve

400 GeV 3x10^{11} p^+
12 cm $\sigma_z$, 0.2 $\sigma_r$
$\varepsilon_N = 3.5$ mm-mrad from SPS

EOS Diagnostic
e$^-$ spectrometer 0.1-2 GeV

Laser dump Diagnostics

OTR/CTR Diagnostics

CERN Industrial Beam Complex

CNGS experimental area

Courtesy:
Patric Muggli, Erdem Öz
The ArF laser timing was scanned in order to change plasma density at the time of the electron beam arrival.

Q=0.97 nC
Max plasma density: ≈10^{14} cm^{-3}
Simulated Self-modulation Experiment

Longitudinal Phase-space studies

Simulations: Martin Khojoyan / Dmitriy Malyutin

Plasma density: $10^{15} \text{ cm}^{-3} \rightarrow \lambda_p \approx 1\text{mm}$

In front of plasma cell

After plasma cell (assuming zero initial energy spread)

In front of dipole

Expected phase space
Experimental conditions

- “Flattop” laser profile, ~22 ps
- BSA=1.26 mm, XYrms=0.298 mm
- Gun@MMMG, 6.5 MeV/c
- Booster@MMMG, 22.3 MeV/c

Measure\Plasma\20161009M\VC2\1413

FC1:823 pC
LOW.ICT1/0.921: 973 pC

LT=90%
SC-dominated vs relaxed emission: LPS and bunch current after the booster position

Experiment: Measured@HEDA2
Temporal profile of the initial ASTRA distribution

- No diagnostics on the laser table
  - e-beam temporal profile@PST.Scr1 as a reference
Beam transport

TDS: $\sigma_y = 1.3\ mm$

Plasma entrance:
$\sigma_{xy} = 80\ \mu m$

PST.Scr1:
$\sigma_{xy} = 0.343 mm$

High2.Scr2:
$\sigma_x = 0.39\ mm$
$\sigma_y = 0.44\ mm$
Experiment: Plasma parameters

- Plasma is not homogeneous (both Li vapor and ionization laser profiles)
- Plasma density is about 1e14 cm\(^{-3}\)
- Peak-to-peak momentum modulation is about 400 keV/c
Simulation (HiPACE)

plasma density: $10^{14} \text{ cm}^{-3}$

I_{main}=389 A

I_{main}=393 A
Simulated beam in HEDA2 (ongoing)
Simulated Self-modulation Experiment

Longitudinal Phase-space studies

Plasma density: $10^{14}$ cm$^{-3} \rightarrow \lambda_p \approx 3.34$ mm

In front of plasma cell

After plasma cell (assuming zero initial energy spread)
Despite “guessed” initial parameters, simulations show a reasonable agreement with the experimental data.

Beam transport needs further optimization (for better resolution, lower TDS induced energy spread).

Not implemented yet:

- Beam scattering on the plasma cell electron windows
- Plasma density profiles
Next generation plasma cell

Entrance electron window: 0.9 μm PET foil coated with 37.5 nm Al both sides

new sidearms geometry

groove-based heat pipe
Evolution of $X_{\text{rms}}$ after plasma

$I_{\text{main}} = 389$ A

$I_{\text{main}} = 393$ A