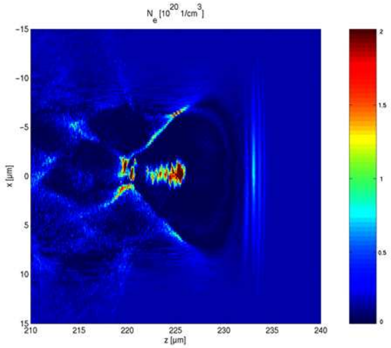
EP-4

Florian Grüner



Plasma Wakefield Acceleration

- **perspectives**:
  - ultra-high field gradient → **compact** (high-energy) accelerator
  - wakefield structure → **femtosecond-scale** bunches
    → high-peak currents

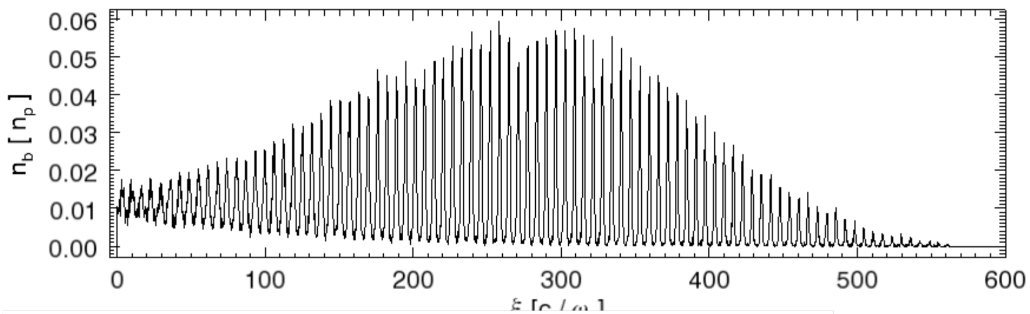
- **emerging** field – highlights:
  - first break-thru 2004: bubble regime experiments
  - 2006 1.0 GeV reached
  - 2007 beam-driven studies (energy doubling of 42 GeV beam)
  - 2009 laser-driven soft X-ray undulator source
  - 2010+2011: better stability, new schemes

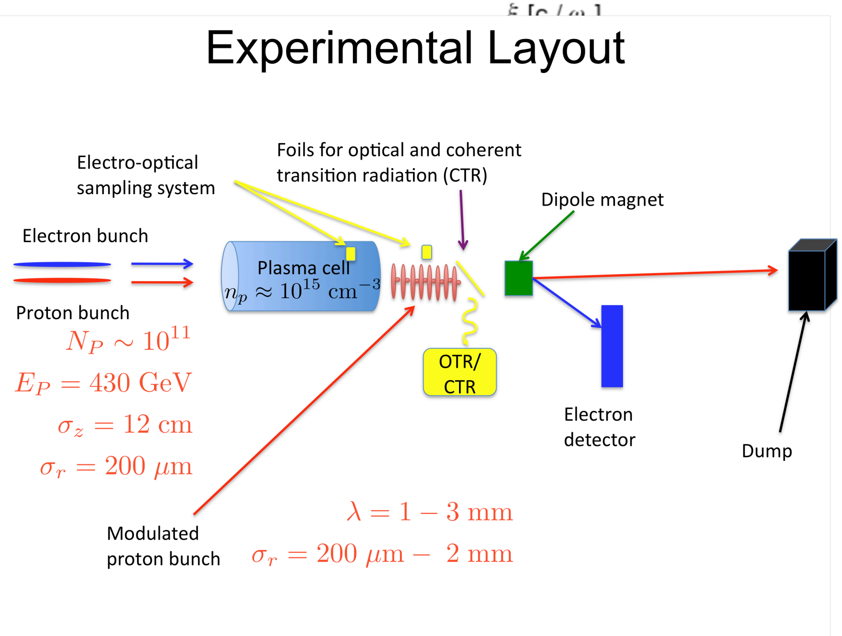
- many **open** questions → lots of **new** research to do!
  - basic: how does wakefield look like?
  - how to best inject and accelerate electrons? how to **control** PWA?
  - emittance growth/is staging scalable?
  - overall efficiency? collider design?
  - ….

Demonstration experiment on Proton-Driven PWA

- Large group of interested institutes (in D: MPP,IPP,Düsseldorf,DESY,Heidelberg,KIT,LMU)
- CERN has expressed interest in hosting project, SPS beam, tunnel and experimental area identified, Letter of Intent to CERN submitted – expect approval in October.
- D Groups will work on plasma cells, diagnostics, simulations, run experiment, data analysis

Work with modulated proton beam



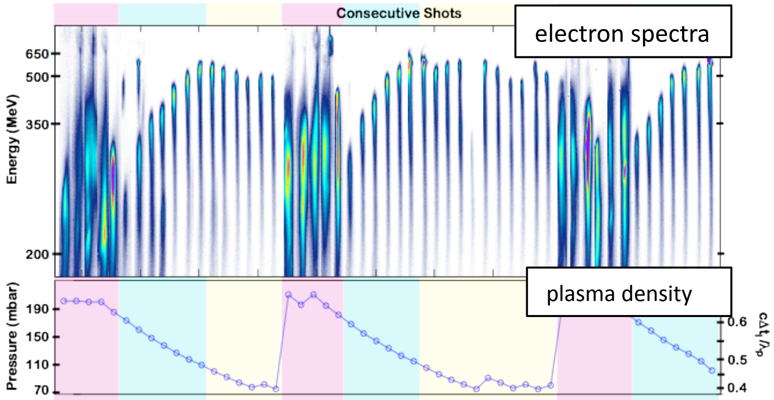


- Initial goal is to observe an electron energy gain of 1 GeV in 5 m plasma.
- A plan for reaching 100 GeV within 100 m plasma will be developed based on the initial round of experiment

Laser-driven electron acceleration at Munich (S. Karsch)

Wakefield physics

stable beams allow parameter scans to probe acceleration physics:



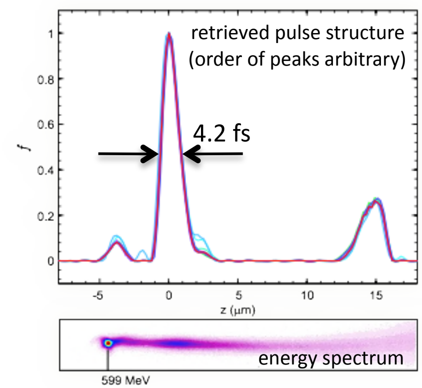
plasma density scan shows different acceleration regimes, driver depletion and dephasing. Currently up to 600 MeV, > 100 pC charge - lots of physics!

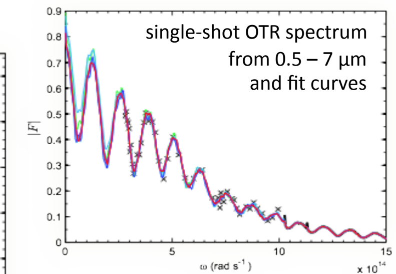
S. Karsch et al. New J. Phys. 9 415 (2007), J. Osterhoff et al., PRL 101, 085002 (2008), A. Popp et al., PRL 105, 215001 (2010), A. Popp et al, in preparation

Electron beam diagnostics - pulse duration

single-shot OTR spectroscopy (with B. Schmidt, DESY & S. Hooker, Oxford)

iterative phase retrieval in some cases indicates multi-bunching & sub-structure



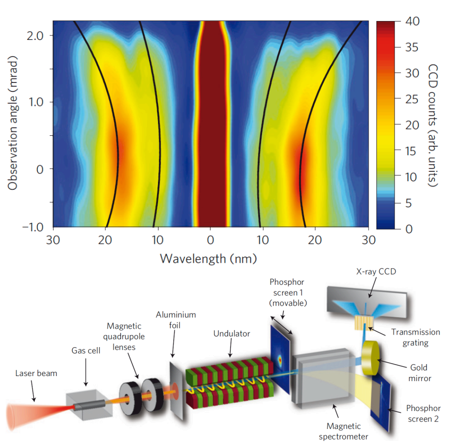


- main pulse duration approx 5 fs.
- transition from single to multi-bunching depends on density and interaction length.

A. Debus et al., PRL 105, 215001 (2010), M. Heigoldt et al., in preparation

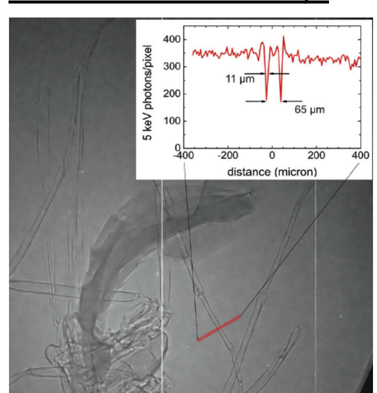
X-ray generation & application

Laser-driven undulator X-ray source at 18 nm (with F. Grüner)



M. Fuchs et al., Nat. Phys. 5, 826 (2009)

phase-contrast imaging with 5-10 keV betatron X-rays



single-shot image of moskito

J. Wenz et al., in preparation)

future plans

Wakefield physics:
- Injection and staging studies with multiple plasma cells and densities
- Model studies for beam-driven wakefields (laser-accelerated bunch drives wake and accelerates secondary beam) – indicated in present data

Beam diagnostics:
- Develop current OTR setup into standard diagnostics
- measure slice emittance (with F. Grüner, DESY)
- probing of transverse phase space by spatially-resolved OTR diagnostics

X-ray generation and applications:
- Develop laser-undulator source and FEL (with F. Grüner, DESY)
- Develop high-repetition rate hard X-ray Thomson source
- Betatron X-ray phase-contrast tomography

Facility development
- move ATLAS laser to new CALA infrastructure, upgrade to 300 TW & 3 PW
- develop kHz, multi-10TW OPCPA system (with Zs. Major, MPQ)
- set up new high-energy electron beamline infrastructure in CALA

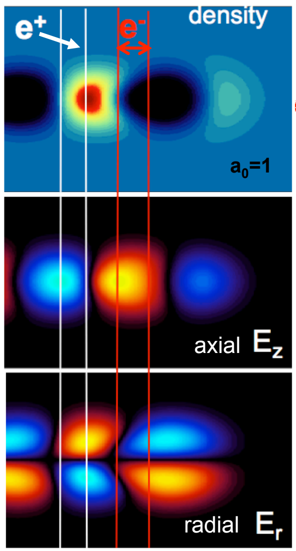
Studien zur strahlgetriebenen Plasmabeschleunigung

B. Foster, F. Grüner,
G. Moortgat-Pick, J. Osterhoff

R. Brinkmann, E. Elsen,
B. Schmidt, F. Stephan

Die Anlagen PITZ und FLASH (beide DESY) bieten ideale Voraussetzungen für experimentelle Studien zur elektronenstrahlgetriebenen Plasmabeschleunigung mit Gradienten im GV/m-Bereich

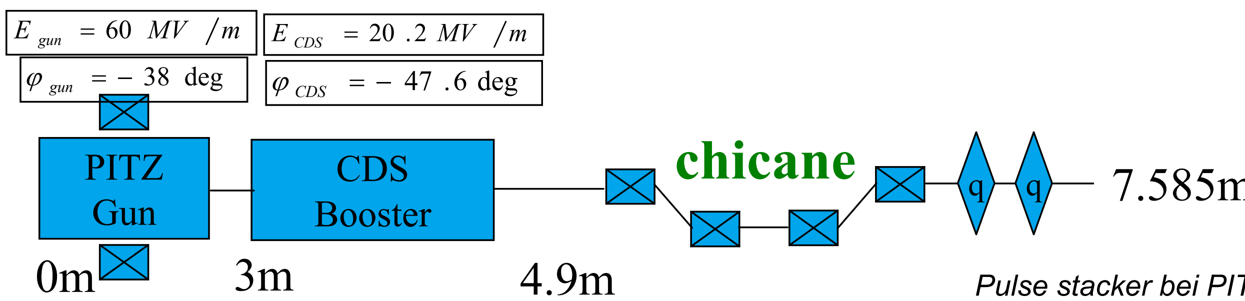
Quasi-linear



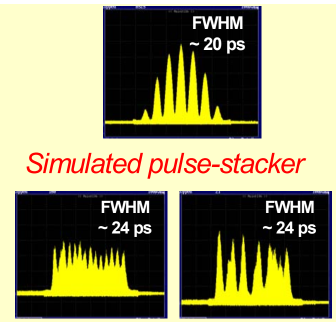
by courtesy of E. Esarey

$\lambda_p \propto n_p^{-1/2}$

Aufbau PITZ



Pulse stacker bei PITZ

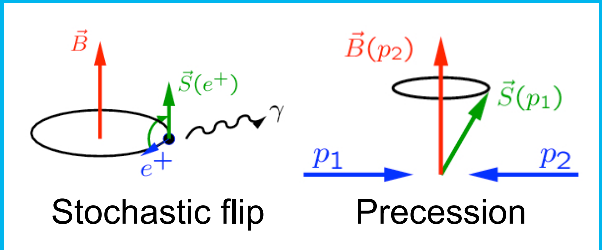


Ziel der Studien:

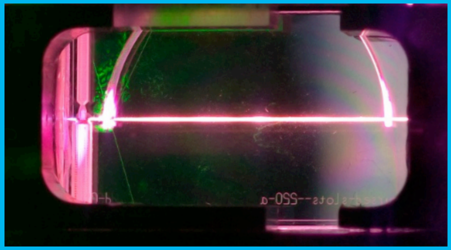
- Erforschung großer Transformationsverhältnisse durch maßgeschneiderte Elektronenbunchstrukturen
- Erste Versuche zur Elektronenbunchselbstmodulation

Dazugehörige Aktivitäten:

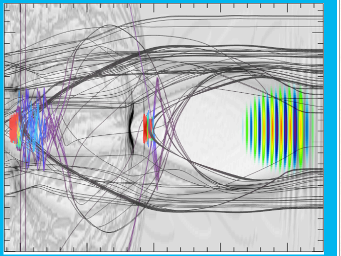
Studien zu Spintransport in Plasma



Plasmatargetentwicklung



PIC Simulationen



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UCLA

Univeristät Düsseldorf, Institut für Theoretische Pysik I
Prof. Alexander Pukhov

1. Theory and simulations of plasma wakefield acceleration
   - weakly nonlinear wakefields, both laser-driven and beam-driven
   - particle injection into wakefields for high-quality acceleration, reaching XFEL requirements
   - theory of bubble regime

2. Theory and simulations of proton acceleration
   - light sail regime: target stabilization and multi-species targets

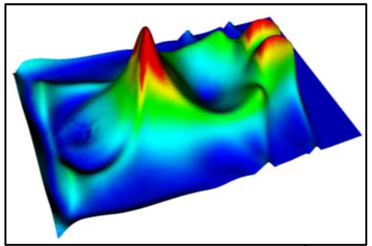
3. Development of advanced numerical codes
   - hybrid models for high quality simulation of large scale plasmas

Numerische Verfahren hoher Genauigkeit für PWFA-Simulationen

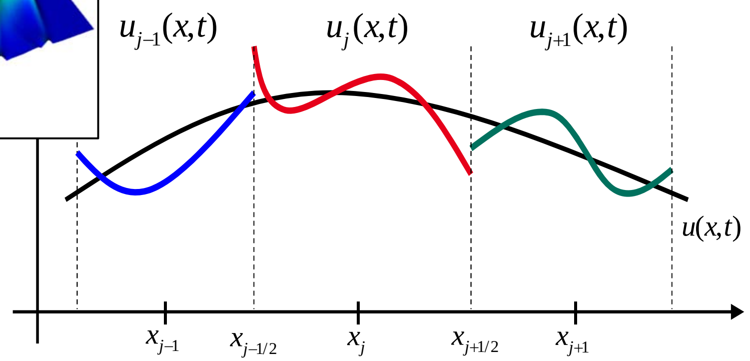
TECHNISCHE UNIVERSITÄT DARMSTADT

„First principles" PWFA-Simulationen sind aufwendig und fehleranfällig:

- Breitbandig
- Nichtlinear
- Multiskalen (Laserwellenlänge, Plasmaresonanzen, Debye-Länge...)



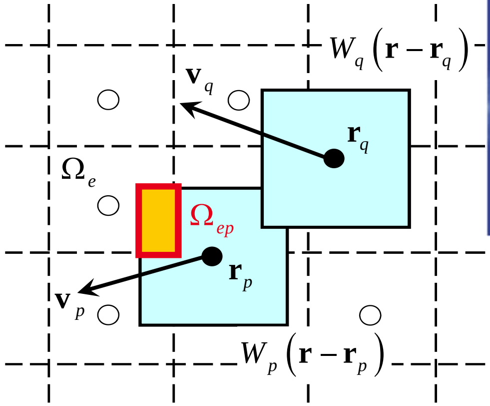
Discontinuous Galerking Verfahren mit Ansatzfunktionen hoher Ordnung



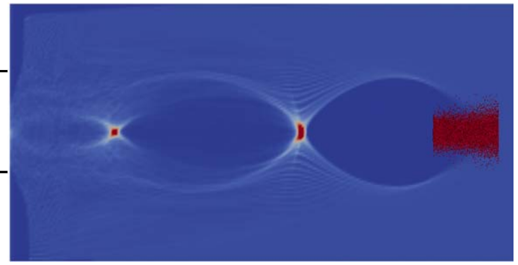
Typische Simulationszeiten: mehrere Tage/Wochen auf massiv parallelen Großrechnern

Idee: Anwendung moderner Verfahren hoher Genauigkeit für PWFA-Simulationen:

- Diskretisierungsverfahren hoher Ordnung zur Lösung der Maxwellschen Gl.
- Strominterpolation mit Ansatzfunktionen hoher Ordnung
- Hybride MPI/GPU-Parallelisierung mit optimaler Lastbalancierung



Beispiel: „beam driven" PWFA



T. Weiland, E. Gjonaj, TU Darmstadt

Multi-stage Plasma Wakefield (PWFA) accelerator

- **Arcturus facility is a two beam laser system**
- **Investigations of different two-stage injection schemes**
- **Two gas jets or gas cell targets**

DESY and TU Darmstadt (GSCE/TEMF and IMP)
Design of an integrated BAM with fs resolution

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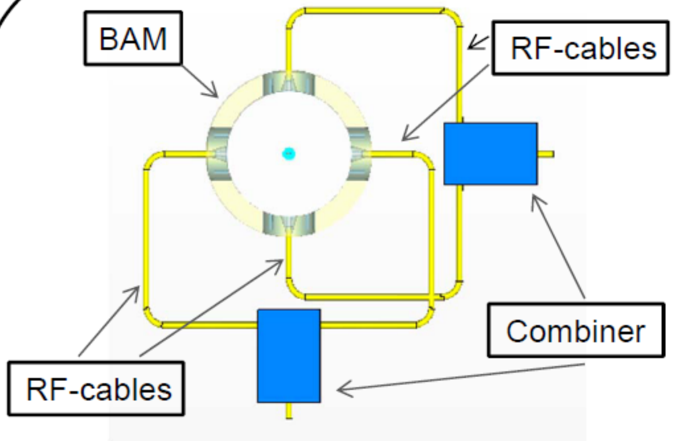

- **Requirements and typical setup**:
  - Broadband pickup up to 40GHz
  - Small fabrication tolerances for RF-front end fabrication
  - Temperature stability
  - Pre-operation calibration required

- **Proposed solution**:
  - Integration of transmission lines, limiter and combiner onto a single substrate
  - Increased temperature stability
  - Lower manufacturing tolerances
  - Re-calibration during operation possible