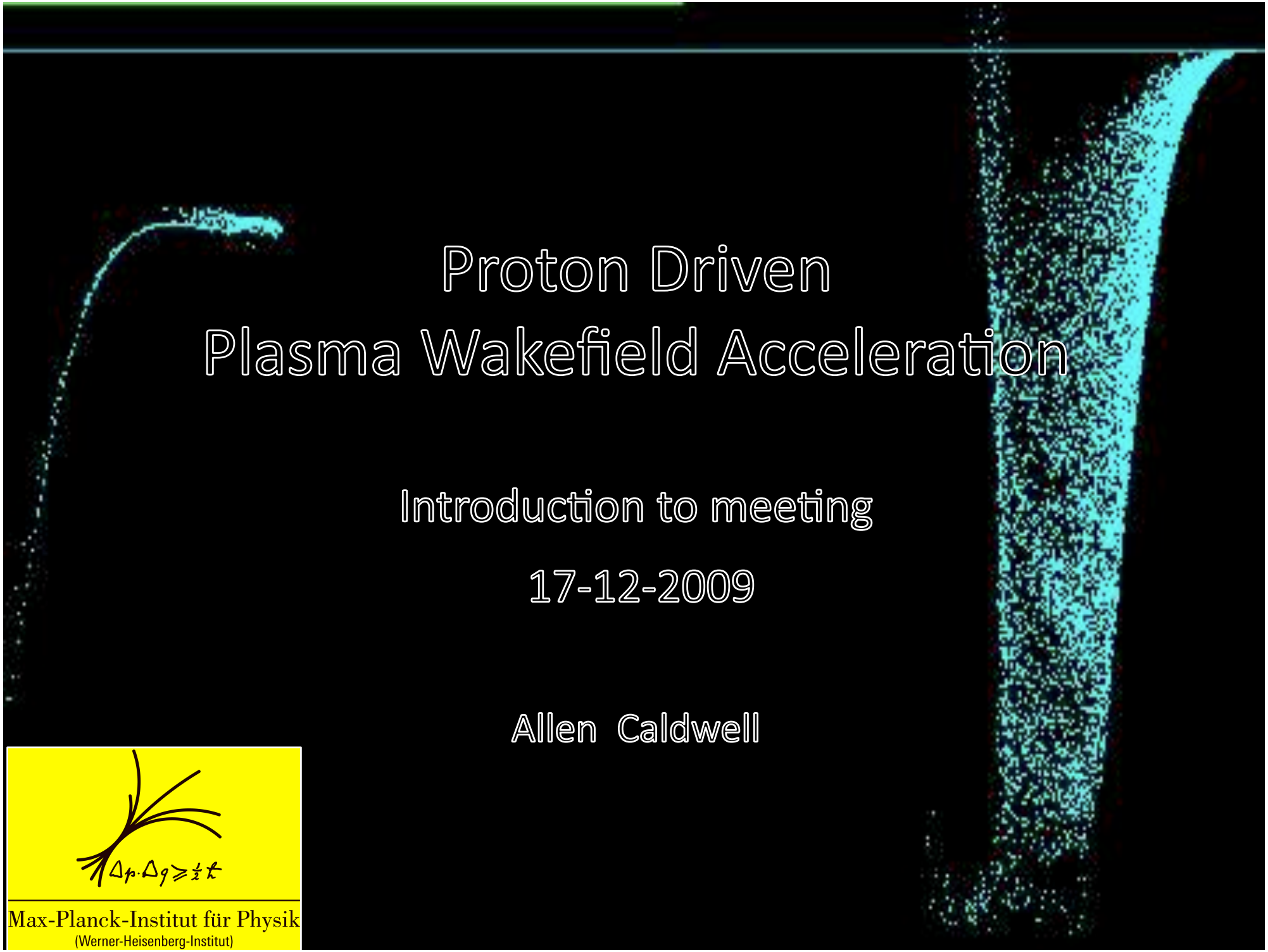


Proton Driven Plasma Wakefield Acceleration

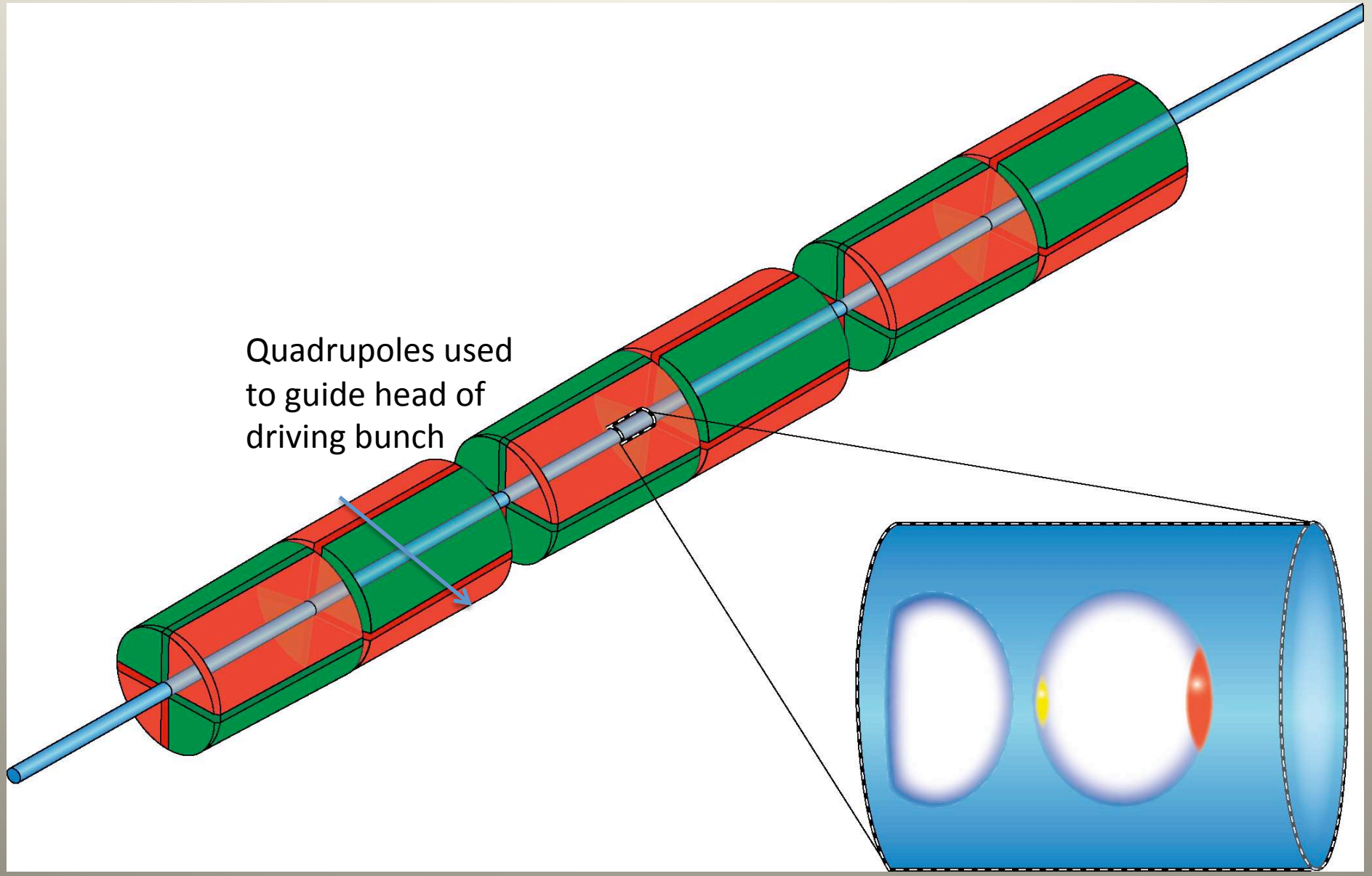
Introduction to meeting

17-12-2009

Allen Caldwell

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

Simulation study

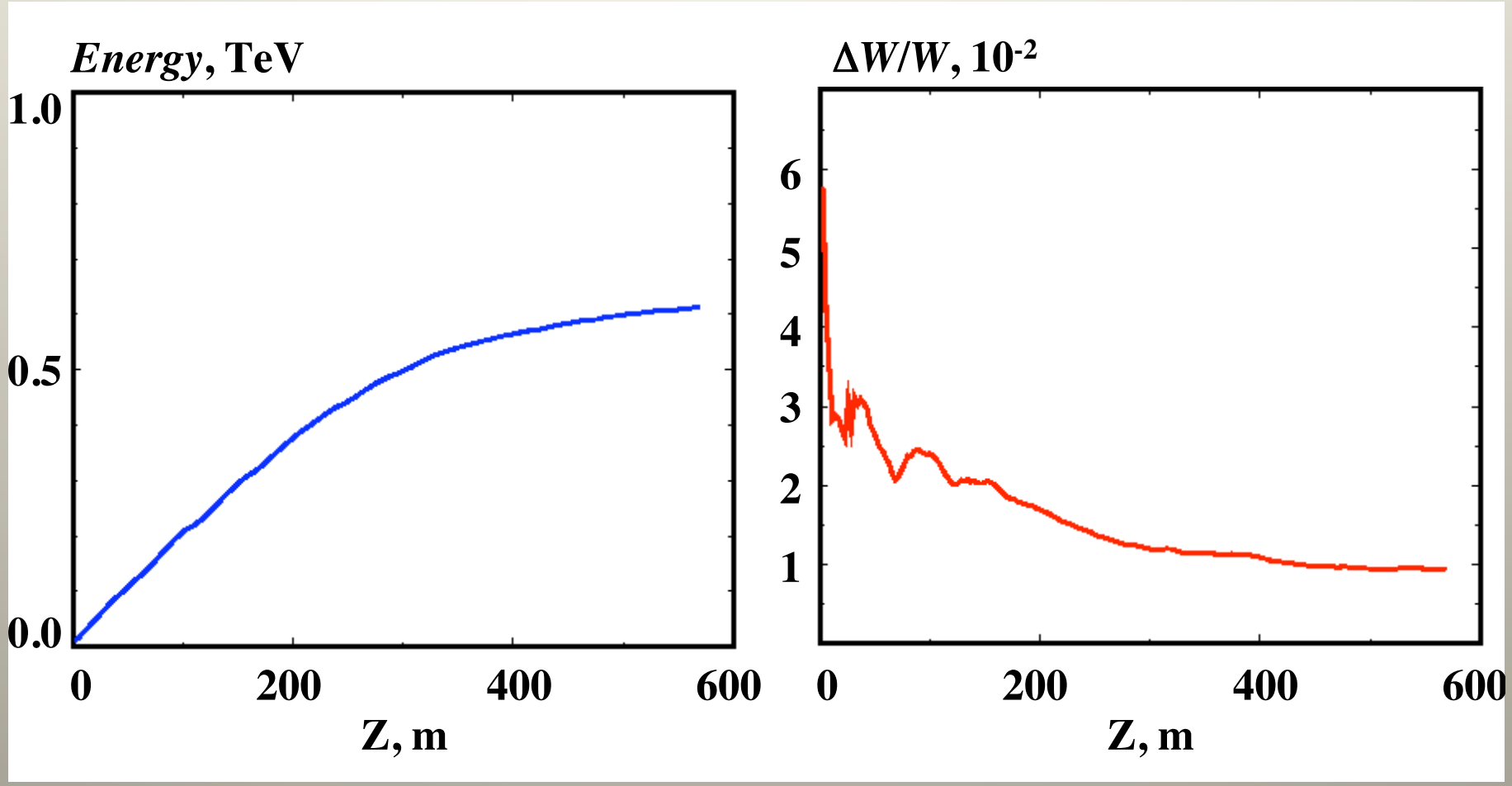


A. Caldwell, K. Lotov, A. Pukhov, F. Simon *Nature Physics* ***5, 363 - 367 (2009)***

Simulation

Table 1: Table of parameters for the simulation.

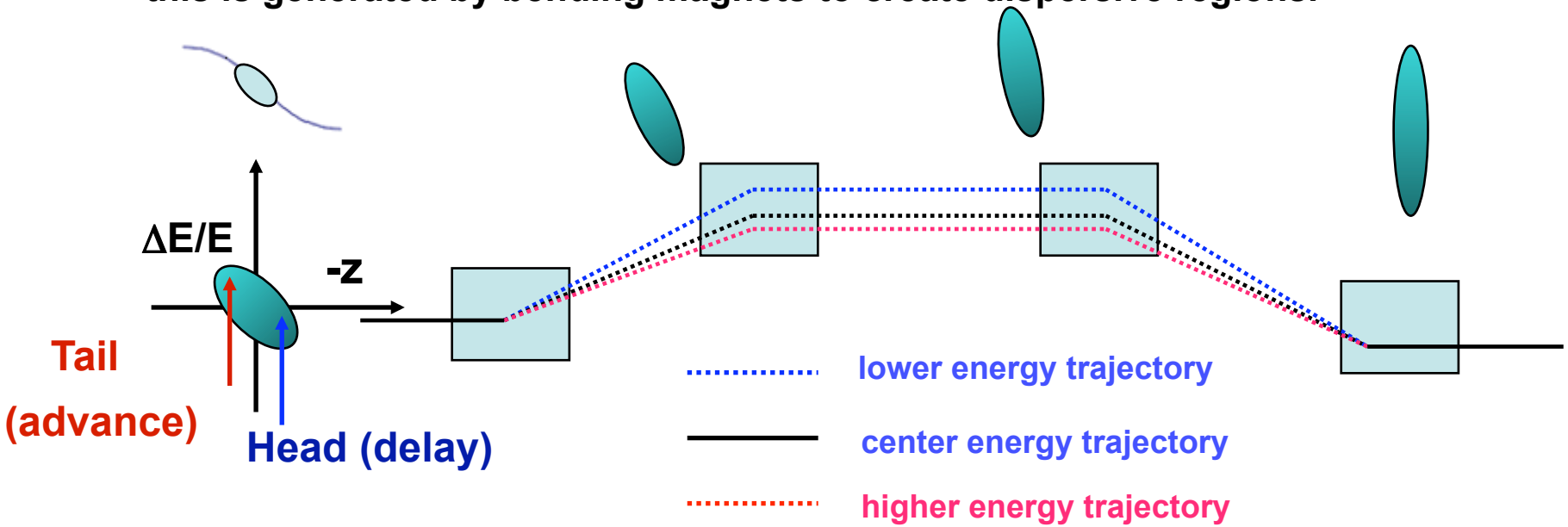
Parameter	Symbol	Value	Units
Protons in Drive Bunch	N_P	10^{11}	
Proton energy	E_P	1	TeV
Initial Proton momentum spread	σ_p/p	0.1	
Initial Proton longitudinal spread	σ_Z	100	μm
Initial Proton bunch angular spread	σ_θ	0.03	mrad
Initial Proton bunch transverse size	$\sigma_{X,Y}$	0.4	mm
Electrons injected in witness bunch	N_e	$1.5 \cdot 10^{10}$	
Energy of electrons in witness bunch	E_e	10	GeV
free electron density	n_p	$6 \cdot 10^{14}$	cm^{-3}
Plasma wavelength	λ_p	1.35	mm
Magnetic field gradient		1000	T/m
Magnet length		0.7	m



A 1 TeV proton beam, compressed to 100 microns but with 10% momentum spread, would allow to create a 600 GeV electron beam.

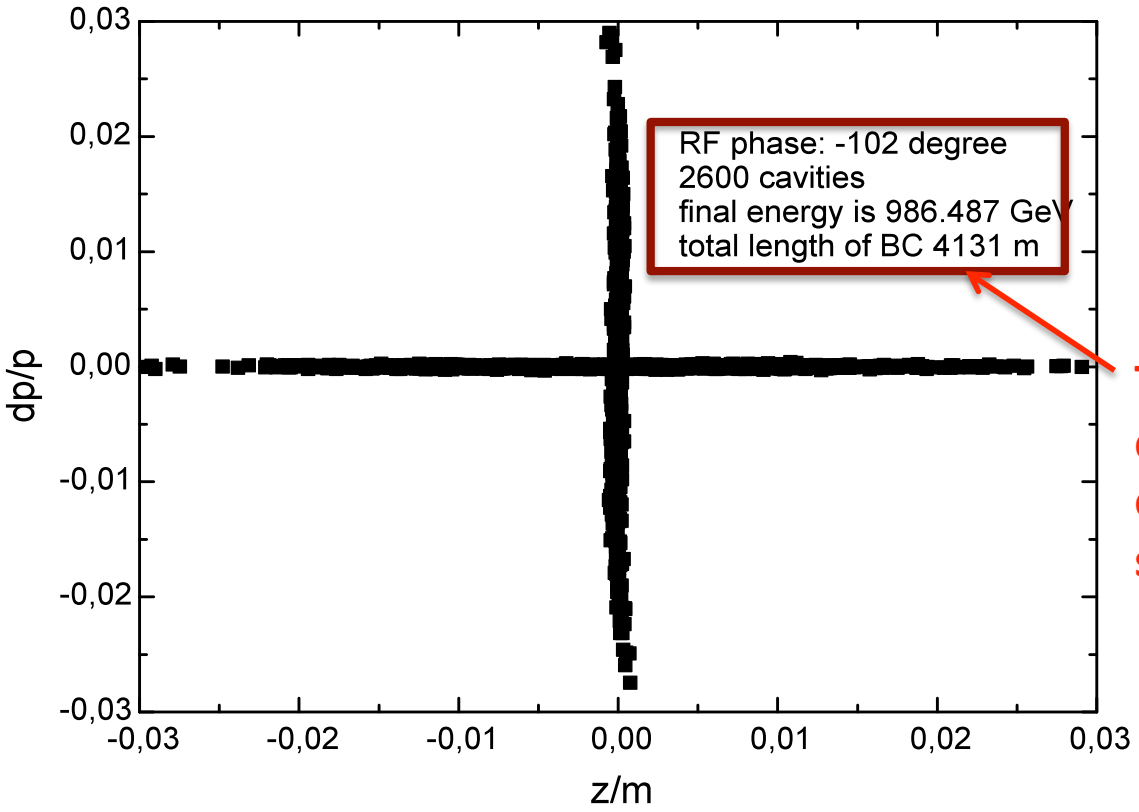
Magnetic bunch compression (BC)

- **Beam compression can be achieved:**
  - **(1) by introducing an energy-position correlation along the bunch with an RF section at zero-crossing of voltage**
  - **(2) and passing beam through a region where path length is energy dependent: this is generated by bending magnets to create dispersive regions.**



- **To compress a bunch longitudinally, trajectory in dispersive region must be shorter for tail of the bunch than it is for the head.**

Phase space of beam



Too long – use in combination with other compression schemes

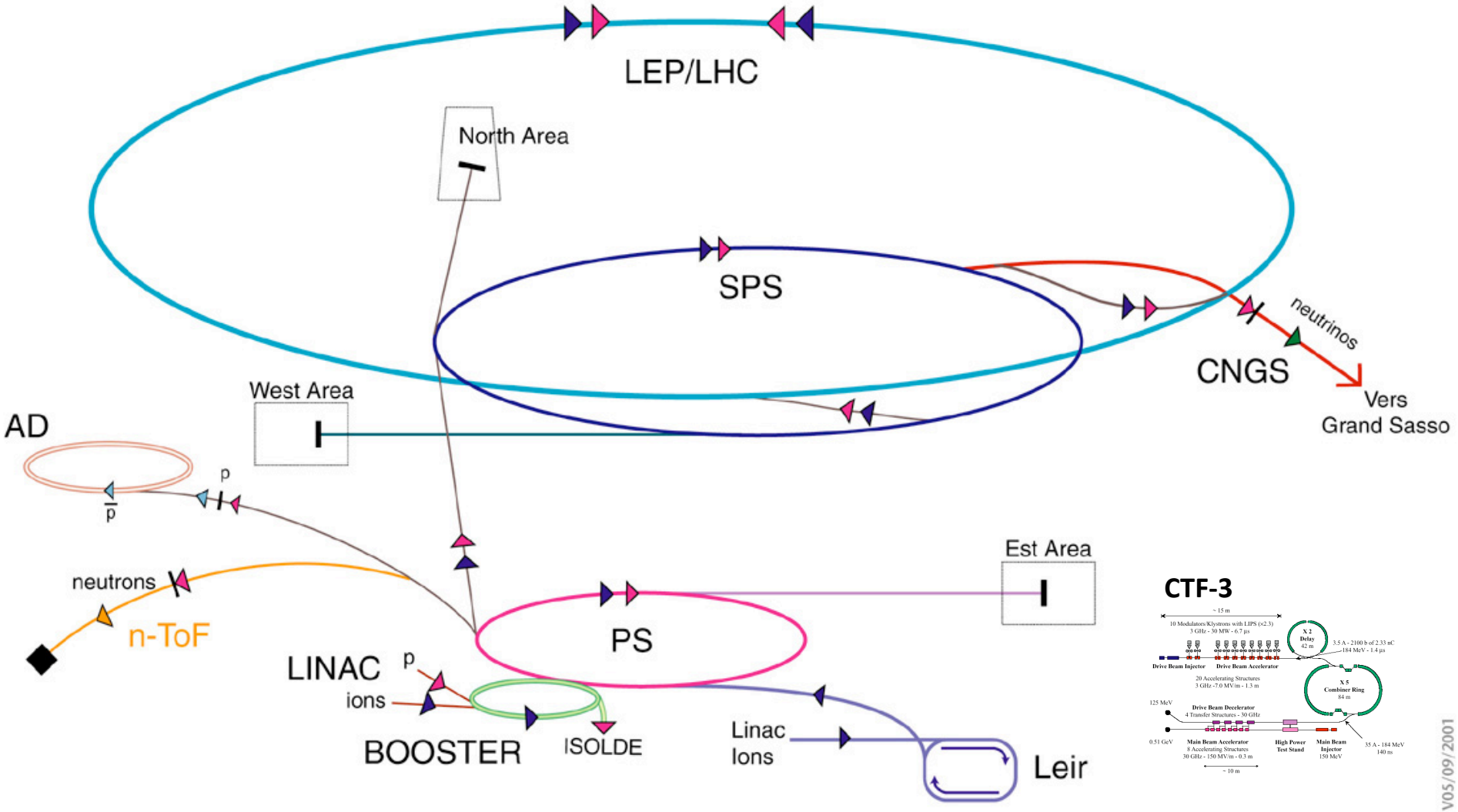
See A. Caldwell, G. Xia et al., Preliminary study of proton driven plasma wakefield acceleration, Proceedings of PAC09, May 3-8, 2009, Vancouver, Canada

Simulation studies will continue

Also, concept for proton bunch compression needs to be worked out – this is the key for the long term success.

But, we also want to start an experimental program and perform a demonstration experiment at CERN

Accelerator chain of CERN (operating or approved projects)



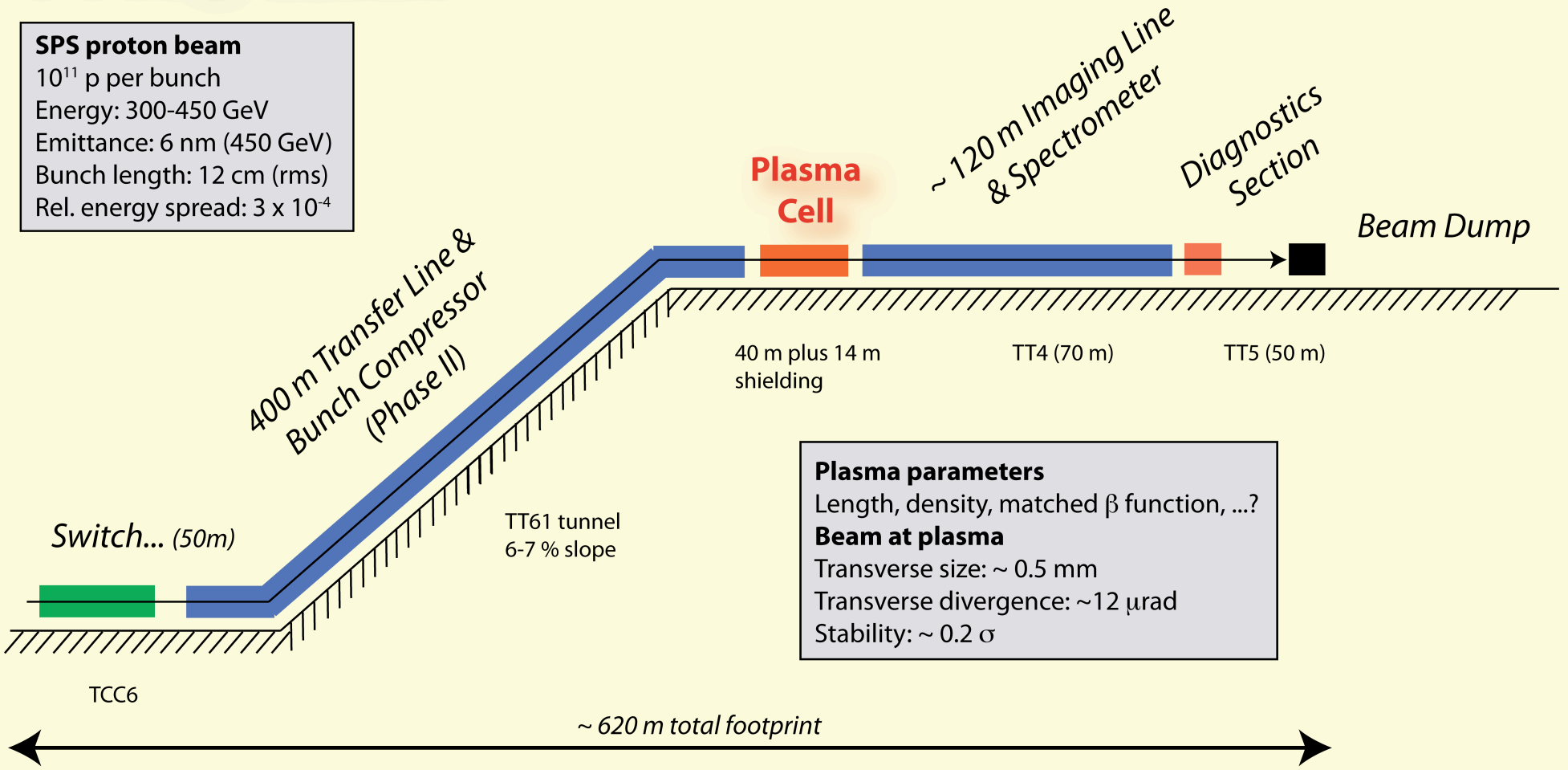
TT61 tunnel

Status today – after partial dismantling of the old line

- Services and infrastructure still in place from the old beam line
- However the power supplies have been dismounted and used as spares for the SPS North Area
- Steep slope 6-7%

PPA@CERN

SPS proton beam
10^{11} p per bunch
Energy: 300-450 GeV
Emittance: 6 nm (450 GeV)
Bunch length: 12 cm (rms)
Rel. energy spread: 3×10^{-4}



Plasma parameters
Length, density, matched β function, ...?
Beam at plasma
Transverse size: ~ 0.5 mm
Transverse divergence: ~12 μrad
Stability: ~ 0.2 σ

Demonstration experiment – possible sequence

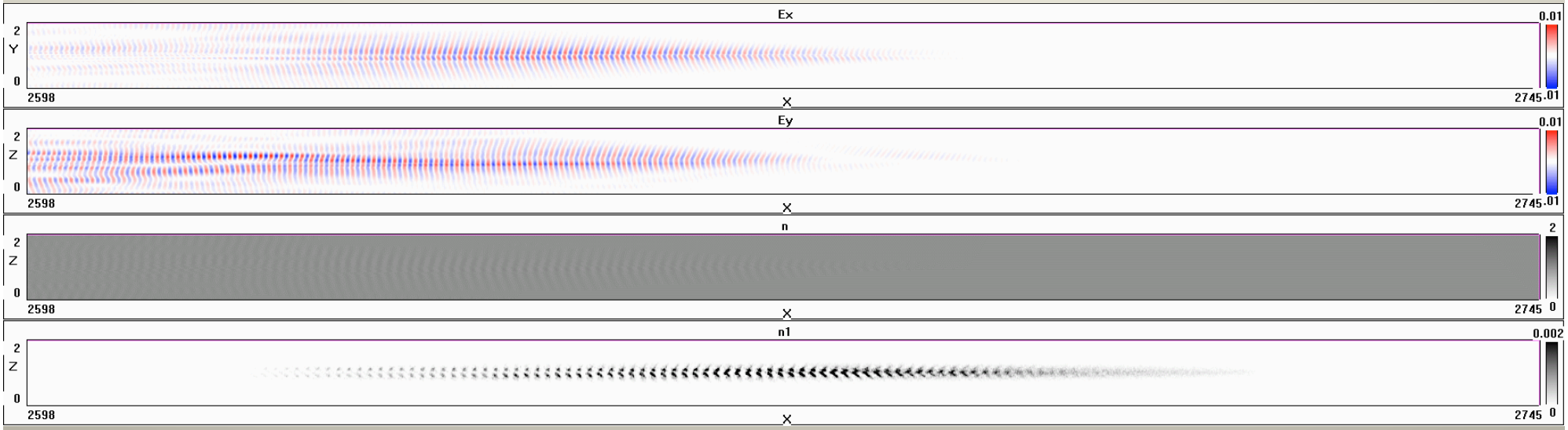
1. Plasma cell + diagnostics: expect to see **modulation of proton bunch** by plasma

2. Plasma cell + seeded modulation to add **reproducibility and stronger fields**

3. Plasma cell + bunch compression: generation of **GeV/m fields**, demonstration of **scaling principles with protons**

4. Plasma cell + bunch compression + electron injection: **demonstration of electron acceleration**

Plasma modulation of SPS beam

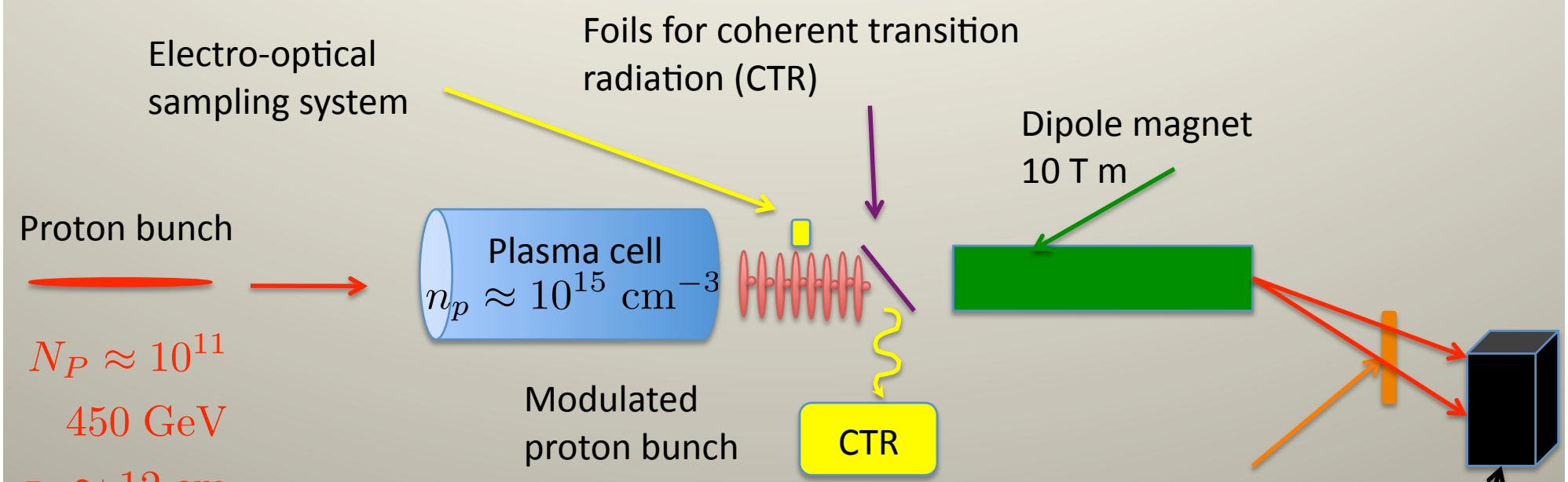


Simulation by A. Pukhov, U. Düsseldorf

r_b=1 mm, n_p=1 10^{11}, σ_z=12 cm, E_p=450 GeV, n_0= 1 10^{14} cm^{-3} (λ_p=3mm)

Length of simulation=8.4 m

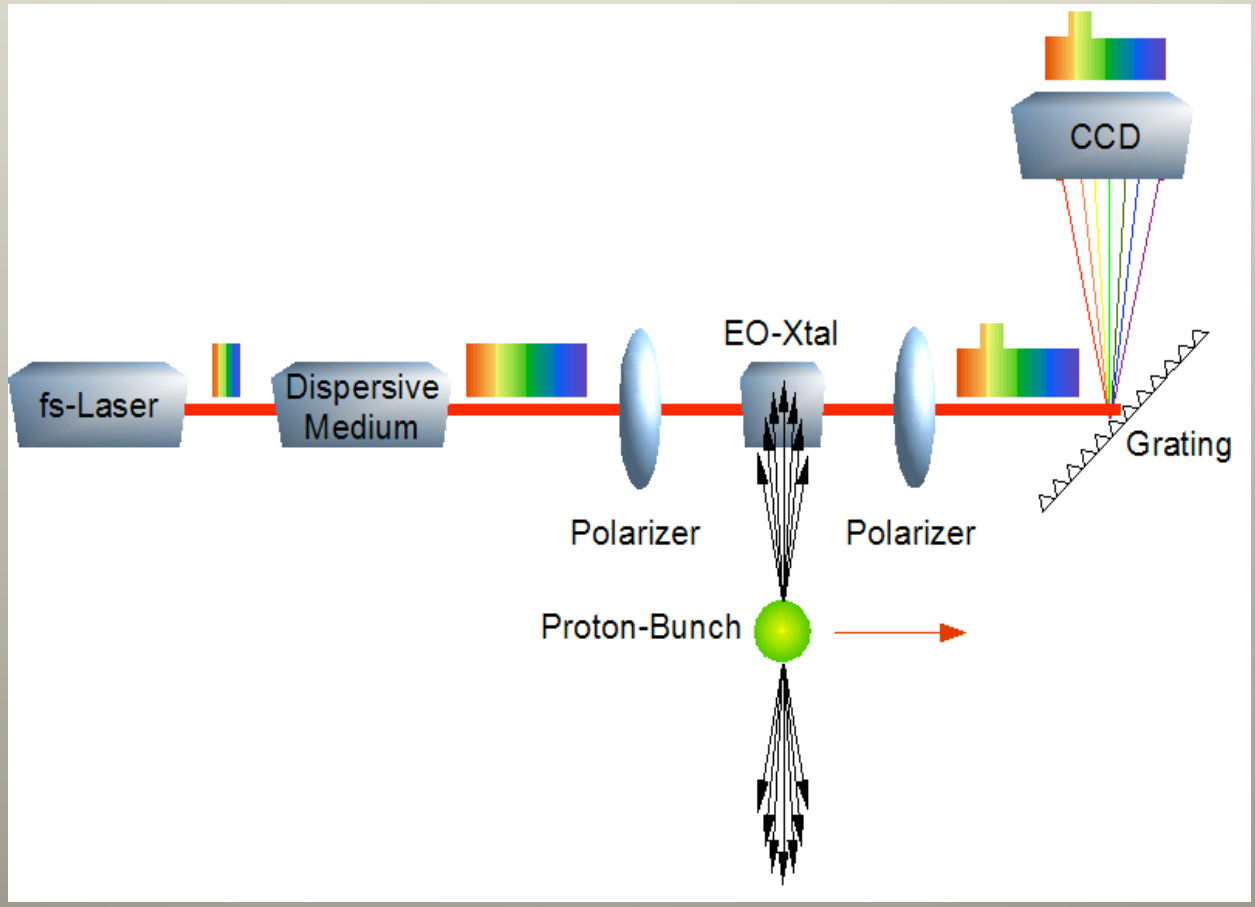
Possible Experimental Layout



Coherent transition radiation (CTR) ➔ frequency domain
Electrooptical sampling ➔ time domain information

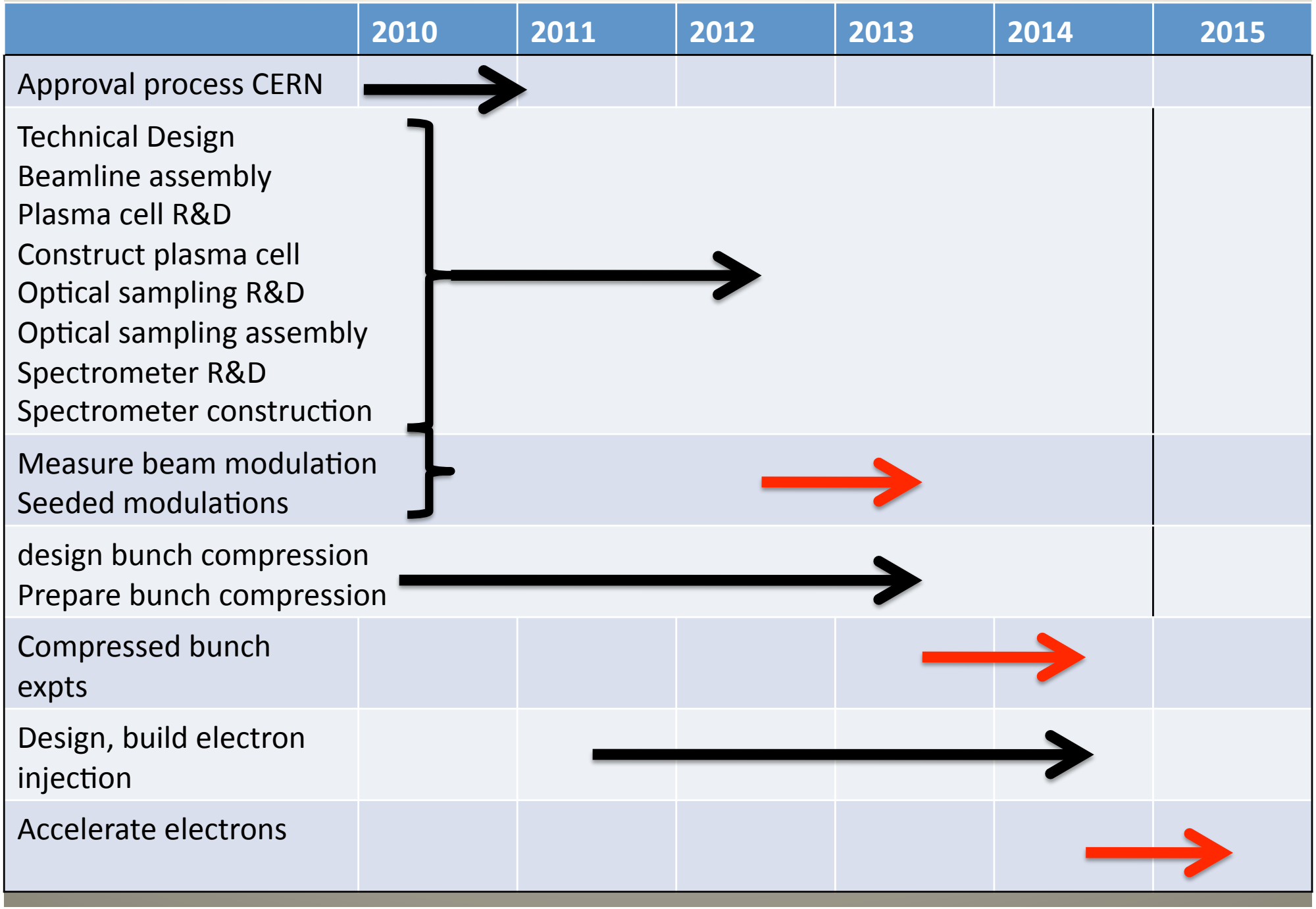
Because of large bunch-bunch time jitter and the very long acquisition times (low rep-rate) -> Single-shot sampling

- Using a (linear) chirped femtosecond laser pulse as sampling signal
- The pulse is stretched (up to 10ps?) in a dispersive medium
- Strong relation between time and wavelength



- The output spectrum is modulated in time by the electric field from the beam
- The output signal is split using a grating and detected by a CCD

Possible Timeline



The path to approval at CERN goes through the SPSC

- Submit ca 10 page Letter of Intent. Contents:
  - motivation
  - sketch of experiment
  - beam needs
  - estimated cost
  - estimate of manpower
  - collaboration & task assignment

- LoI should be submitted 2-4 weeks prior to an SPSC meeting
- Times of next meetings: April 13,14 June 29,30
- SPSC assigns referees & discussions ensue
- In case of positive evaluation by referees & committee, request detailed proposal
- Detailed proposal:
  - Comprehensive description of project
  - timeline
  - financial contributions from participating institutes

This meeting:

- agree on what we want to accomplish with a first round of experiments
- list the subprojects involved and allocation of people to subprojects
- get some idea of the timeline
- set a target date for the LoI submission
- discuss ideas on bunch compression
- set parameter ranges for beam, plasma cell, diagnostics, …

A first set of questions:

1. How long can the plasma cell be ?
2. What density range is possible for the plasma ?
3. Interesting length for modulation studies ?
4. Long plasma cell may require quadrupole focusing – compatible with beamline ?
5. Most promising plasma cell concept – follow more than one ?
6. What are the possibilities to shape the proton beam ? (hard edge)
7. Can the proton bunch be pre-modulated ? How ?
8. Ideas on proton bunch compression – can we vary SPS parameters (compaction factor, RF) during down times of LHC ?
9. What diagnostics should be there at the beginning ?
10. Which locations are available for equipment – what are the space/ power/… restrictions ?
11. What types of beam requirements do we anticipate (# bunches/min at maximum), total number/day, number/year
12. What are the limits set by radiation protection ?

PPA09 Workshop @ CERN

Thursday December 17

9:00-9:15	Introduction & goal of meeting	A. Caldwell
9:15-10:00	Overview of Plasma Wakefield Generation	C. Joshi
10:00-10:45	Experiments in beam driven PWA	P. Muggli
10:45-11:15	Coffee	
11:15-11:45	Experimental techniques at FLASH	B. Schmidt
11:45-12:15	PS & SPS beamlines at CERN	I. Efthymiopoulos
12:15-12:45	Possible Layout of Experiment at the SPS	R. Assmann
12:45-14:15	Lunch	
14:15-14:45	Accelerator physics, optics and instrumentation challenges	F. Zimmermann
14:45-15:15	Comments on transfer line work	B. Goddard + M. Meddahi
15:15-17:00	visit SPS beamline	
17:00-18:30	Coffee/Discussion	

Friday December 18

9:00-9:45	Proton Driven PWA, simulations for PS & SPS	A. Pukhov
9:45-10:30	Proton Bunch Compression	G. Xia
10:30-11:00	coffee	
11:00-11:45	Plasma wakefields via modulation	K. Lotov
11:45-12:15	Plasma cell design & operation at SLAC	C. Joshi
12:15-12:45	Helicon plasma cell concept	O. Grulke
12:45-14:15	lunch	
14:15-16:00	Discussion on task list, preparation of LoI	