Outlook for PWA Experiments

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Frank Zimmermann

CERN, BE Department, ABP Group

KET Meeting Dortmund

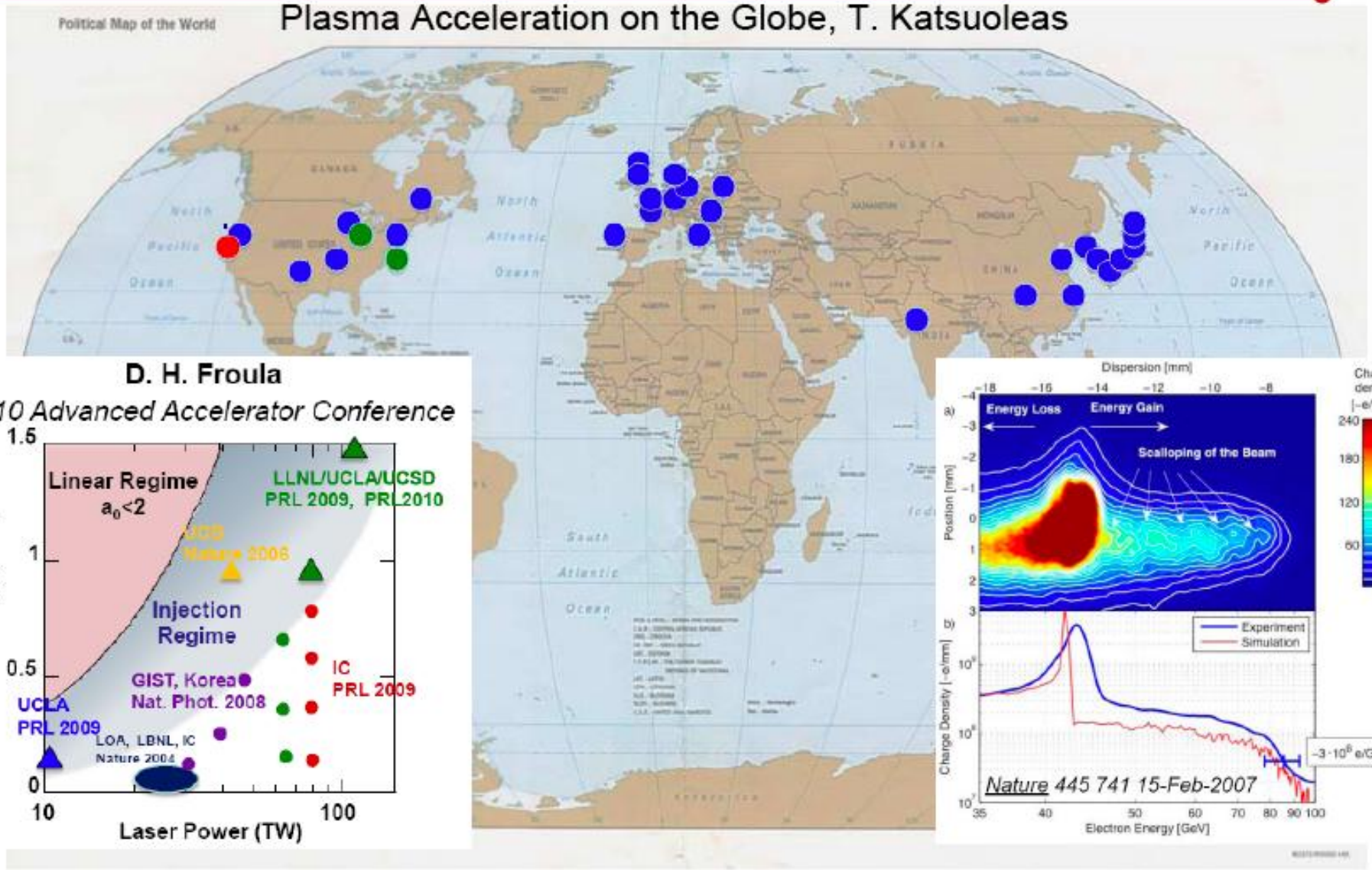
25 October 2010

themes

community interest and potential

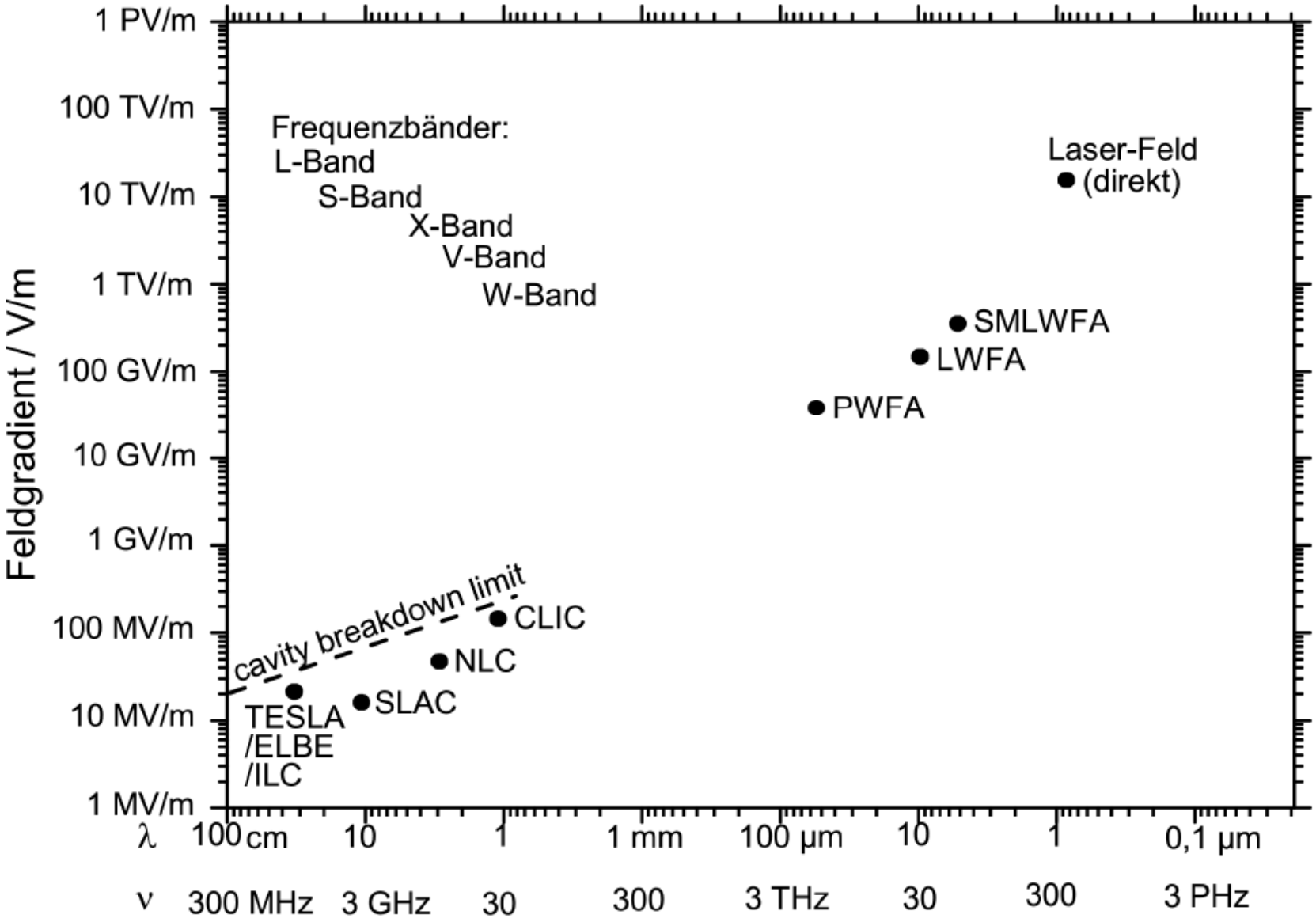
first demonstration experiment for proton-driven plasma wakefield acceleration (PDPWA) at CERN

World-Wide Interest in Plasma Acc.



Slide: T. Raubenheimer, ICHEP

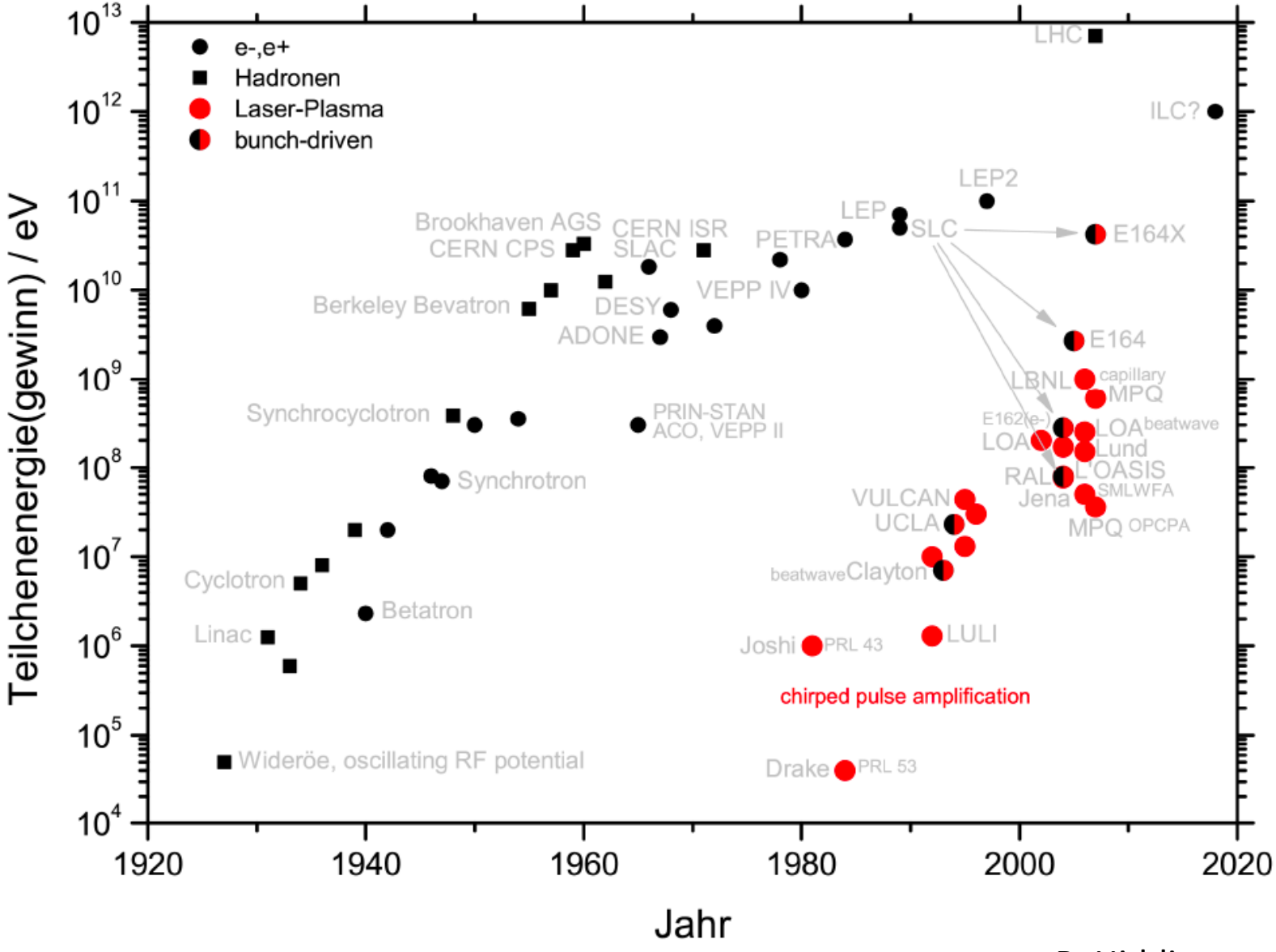
Gradient vs Plasma Wavelength



R. Assmann

B. Hidding

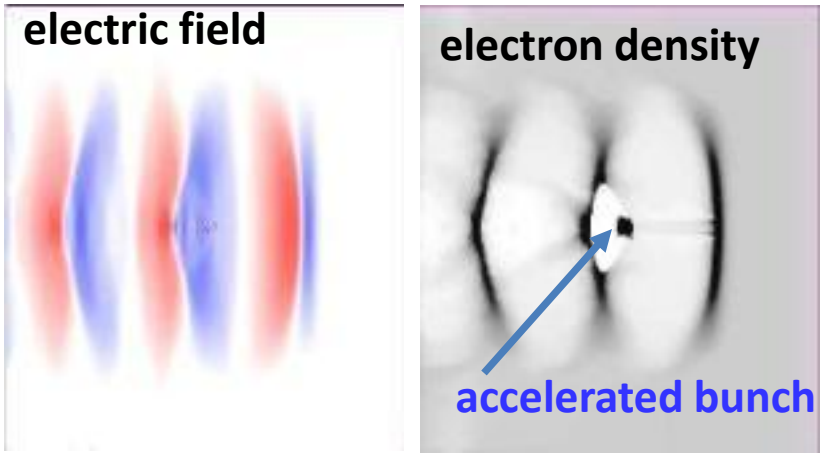
The New Livingston Plot

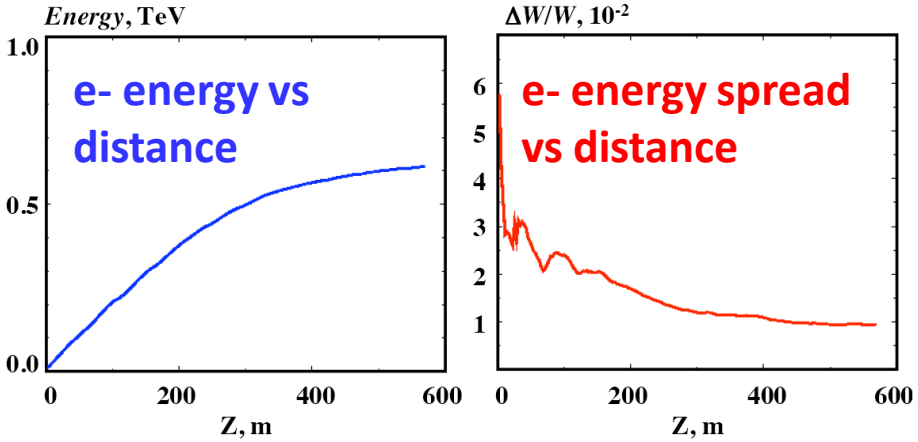


B. Hidding

new scheme: PDPWFA

simulation





TeV p-bunches are available from conventional accelerators

PDPWA accelerates e- in the wake of such p bunches to TeV energy over a few 100 m

electric fields = 100 x ILC or CLIC

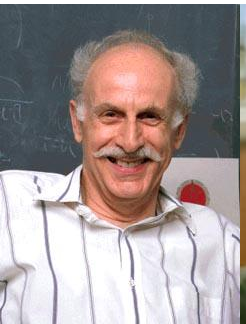
Allen Caldwell, K. Lotov, A. Pukhov, F. Simon, Nat. Phys. 5 (2009) 363.

ICFA & ICUIL interest

(ICFA=International Committee for Future Accelerators)

*"A **joint task force** between ICFA and the International Committee on Ultra-High Intensity Lasers (ICUIL) has been set up to study the laser acceleration of particles.*

A first workshop has already been held [in Darmstadt], and a technical report will be written on such accelerators and the technical challenges that still need to be overcome."



Summary of 63rd ICFA meeting
24 July 2010

EuCARD interest

(EuCARD = European Coordination for Accelerator Research and Development)

"[New] associate network on laser and plasma acceleration in EuCARD-WP4 (R.Assmann et al)

…

ESGARD will monitor the outcome of the laser/plasma network … to include such R&D field in EuCARD2."

Jean-Pierre Koutchouk
EuCARD Project Coordinator
12 October 2010

EuCARD network PWAN

(PWAN=Plasma Wakefield Acceleration Network)

Coordinator Ralph Assmann (CERN),
deputy Jens Osterhoff (DESY), +
Scientific Steering Board, Network Coordination
web site: https://espace.cern.ch/pwfa-network

generation and acceleration of GeV-class e-/e+ beams

1) **comparison of different methods**
2) **description of required R&D**
3) **roadmap towards PWFA test facility with first test applications**
4) **roadmap towards high energy physics applications**
5) **coordination of European expertise**

in short, PWAN = community organizer for plasma acceleration

CERN interest

(CERN = European Organization for Nuclear Research)

"CERN is very interested in following and participating in novel acceleration techniques, and has as a first step agreed to make protons available for the study of proton-driven plasma wakefield acceleration."

Steve Myers
CERN Director of Accelerators & Technology
4 October 2010

PDPWA:
several meetings, workshops, and site visit at CERN

CERN COURIER

Feb 24, 2010

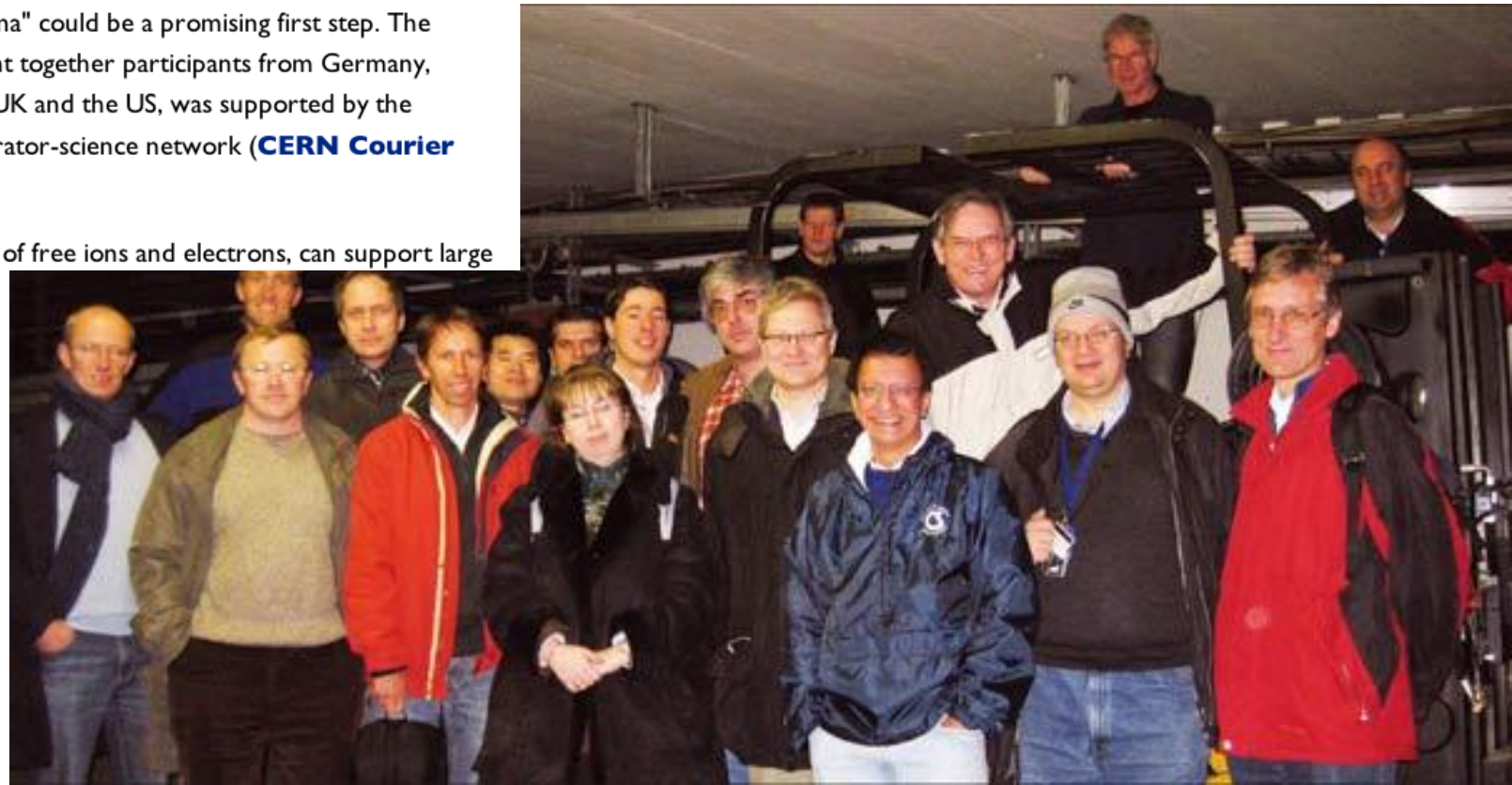
Workshop pushes proton-driven plasma wakefield acceleration

PPA09

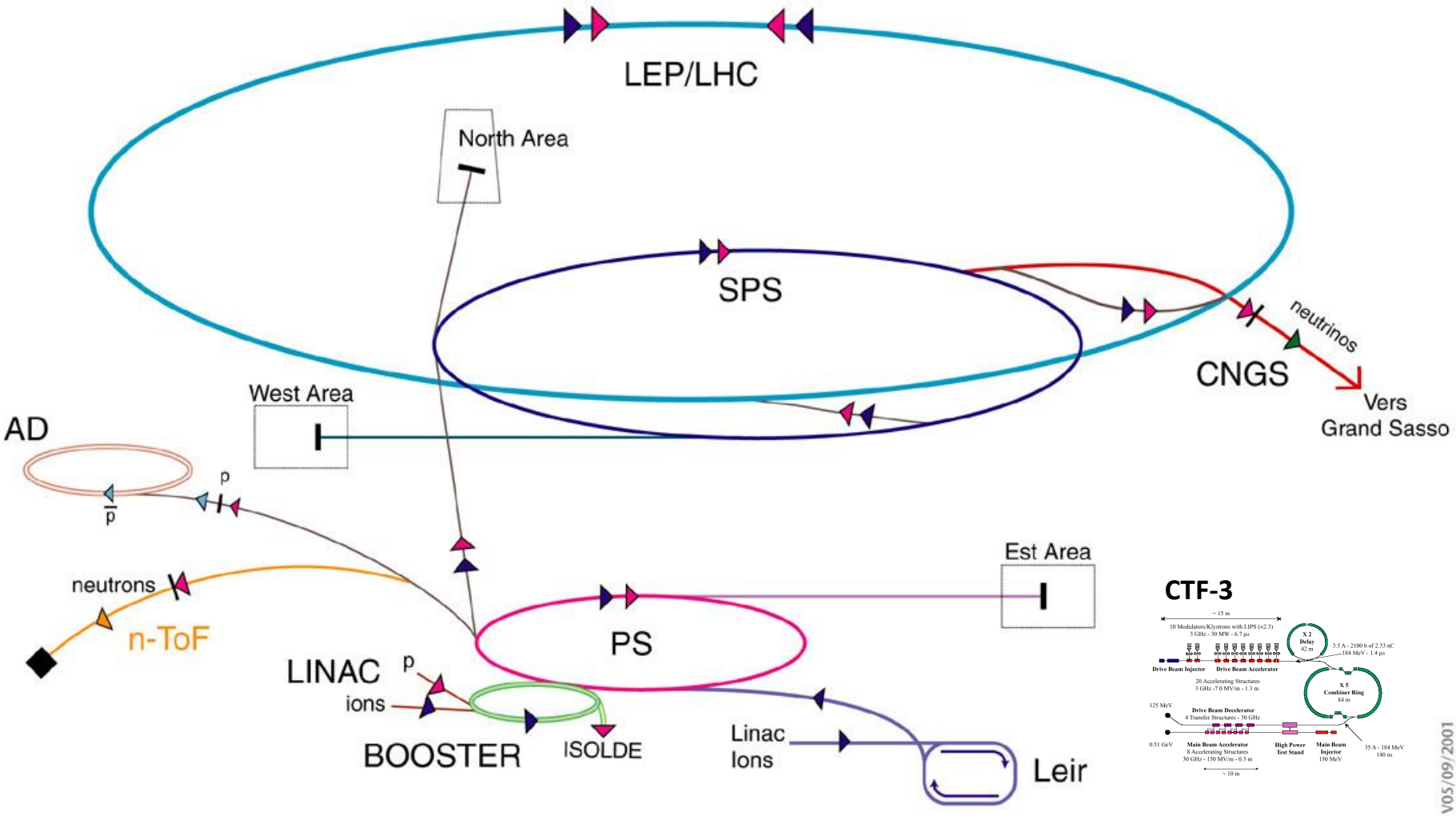
PPA09, a workshop held at CERN on proton-driven plasma wakefield acceleration, has launched discussions about a first demonstration experiment using a proton beam. Steve Myers, CERN's director for Accelerators and Technology, opened the event and described its underlying motivation. Reaching higher-energy collisions for future particle-physics experiments beyond the LHC requires a novel accelerator technology, and "shooting a high-energy proton beam into a plasma" could be a promising first step. The workshop, which brought together participants from Germany, Russia, Switzerland, the UK and the US, was supported by the EuCARD AccNet accelerator-science network (**CERN Courier** November 2009 p16).

Plasmas, which are gases of free ions and electrons, can support large

http://cerncourier.com/cws/article/cern/41714



Accelerator chain of CERN (operating or approved projects)



parameters for experiments at CERN with available PS, SPS or LHC *p* beams

Parameter	PS	SPS-LHC	SPS-TOTEM	LHC
E_p (GeV)	**24**	**450**	**450**	7000
N_p (10^{10})	**13**	**11.5**	**3.0**	11.5
σ_p (MeV)	12	135	80	700
σ_z (cm)	20	12	8	7.6
σ_r (μm)	400	200	100	100
σ_θ (mrad)	0.25	0.04	0.02	0.005
β^* (m)	1.6	5	5	20
ε(mm-mrad)	**0.1**	**0.008**	**0.002**	$5 \cdot 10^{-4}$
n_0 (10^{15} cm^{-3})	0.16	0.63	2.5	2.5
eE_0 (GeV/m)	1.28	2.55	5.1	5.1
c/ω_b (m)	2.4	4.0	3.3	13
$eE_{z,max}$(GeV/m)	**0.08**	**0.3**	**0.3**	**1.2**
α	0.05	0.12	0.06	0.24
$L_{dephase}$ (m)	11	330	240	4260
$W_{\beta*}$ (GeV)	0.13	1.4	1.5	23
$W_{dephase}$ (GeV)	**0.9**	**100**	**74**	**5100**

$$E_{z,\max} \approx 0.1(\mathrm{GV/m}) \cdot \left(\frac{N}{10^{10}}\right)\left(\frac{100\mu\mathrm{m}}{\sigma_r}\right)^2$$

upper limit from σ_r

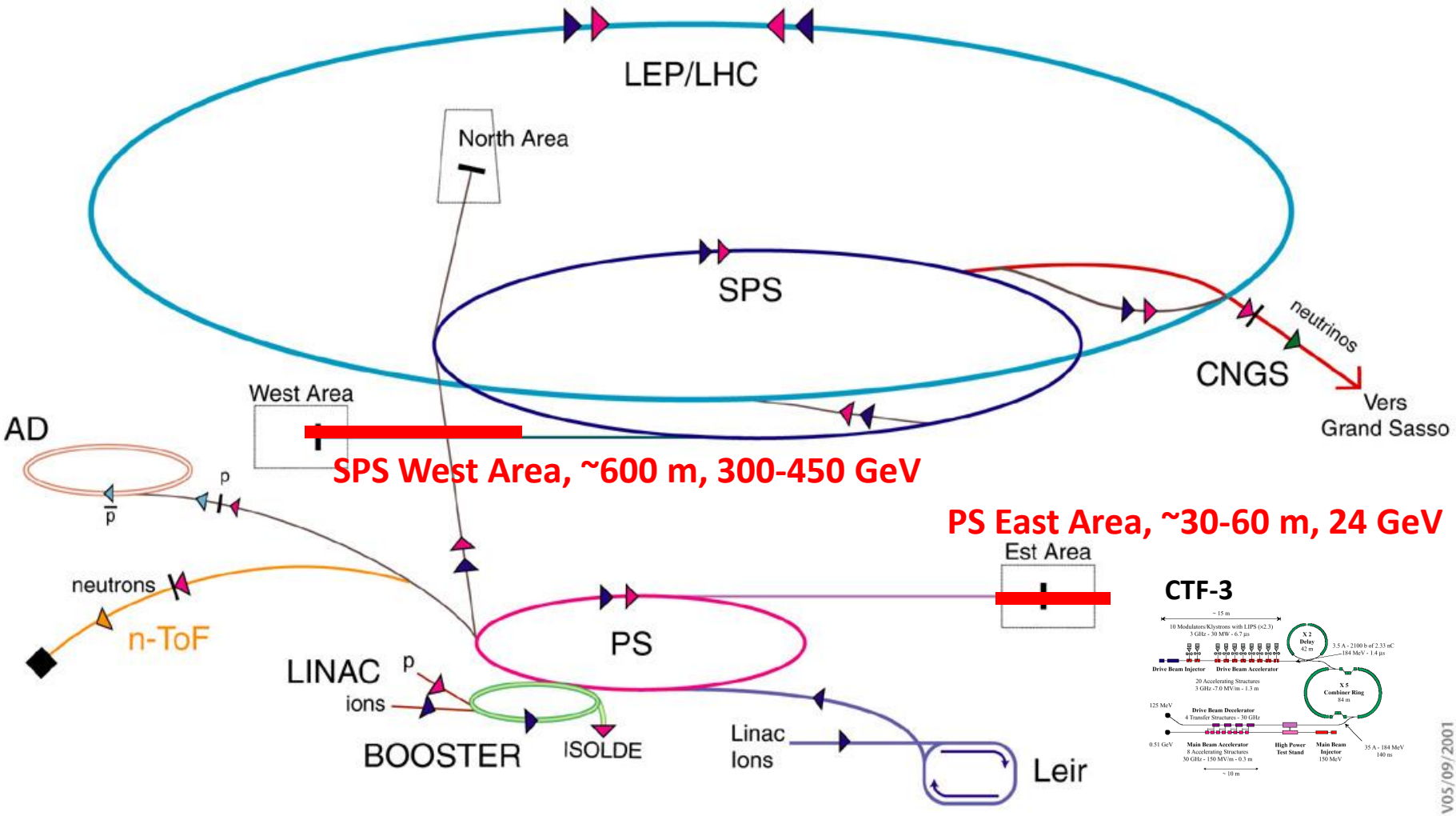
wave breaking field

estimated gradient

max. energy gain w/o focusing

max. energy gain with focusing

Accelerator chain of CERN (operating or approved projects)



PS East Area

Beam line for PWA

Ilias Efthymiopolous

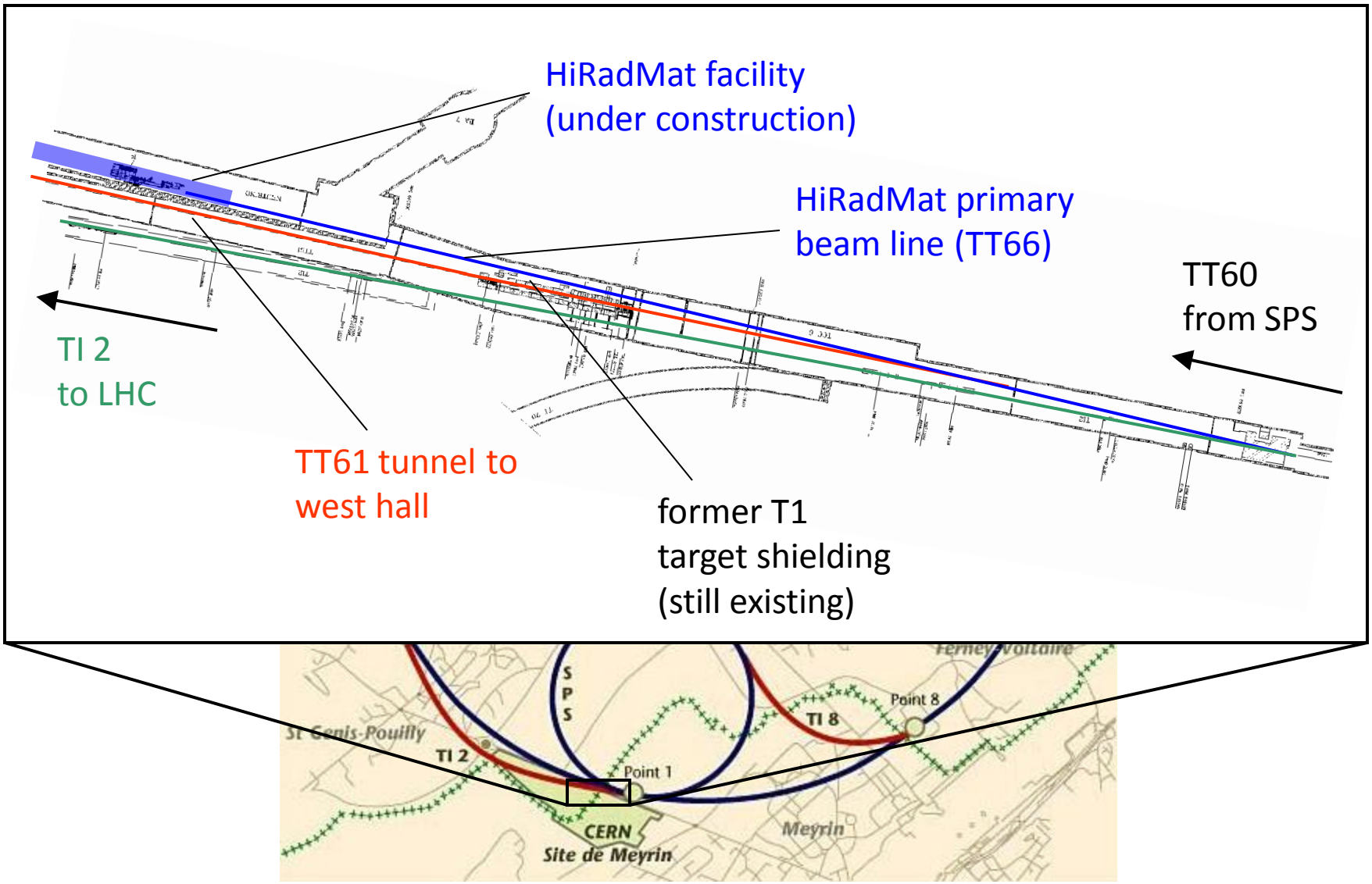
PS beam line (DIRAC)

semi-fast extraction from PS machine

<u>issues to clarify:</u>

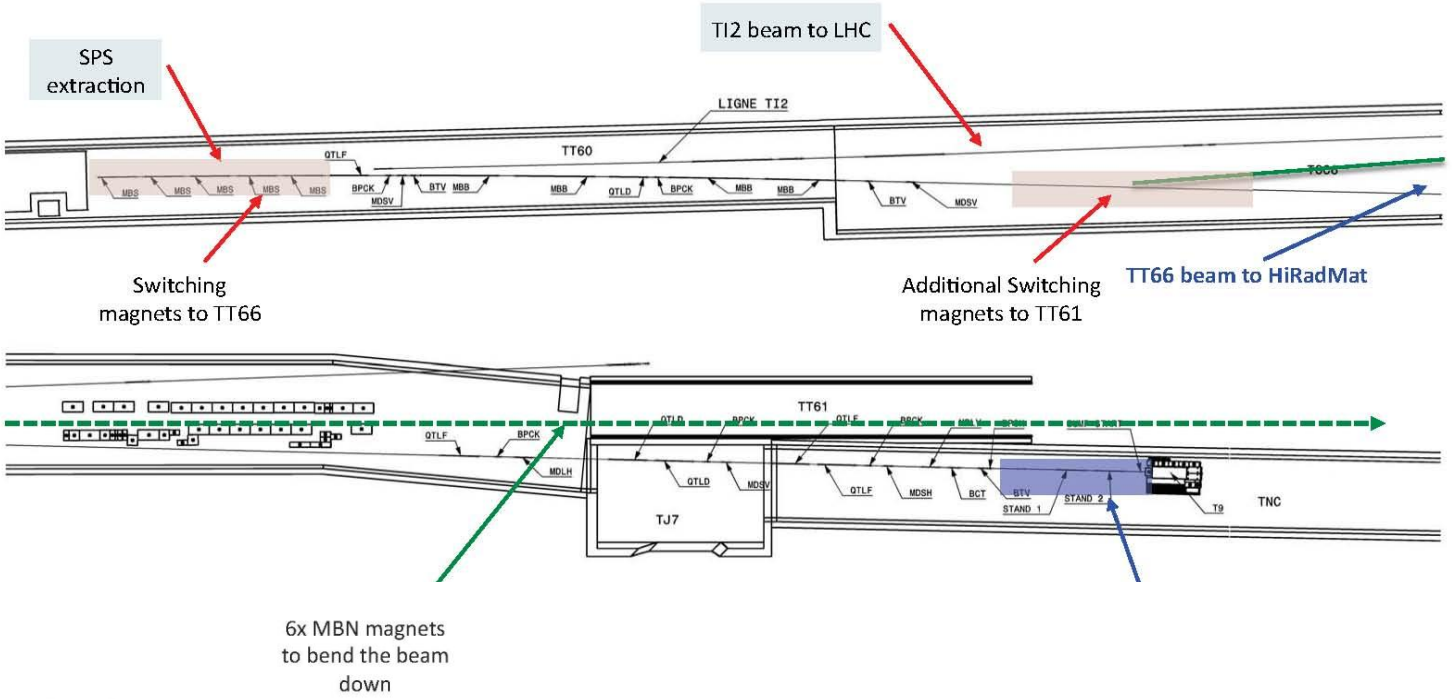
- removal of the DIRAC experiment – when?
- even after DIRAC removal there is a strong interest to `reuse the area for electronics irradiation facility
- total length for experimental area ~30m, difficult to prolong it – beam dump ~6m
- a proposal is under study to renovate the East Hall Exp. Area
- time scale: earliest in 2012, or during the long shutdown in 2013/2014

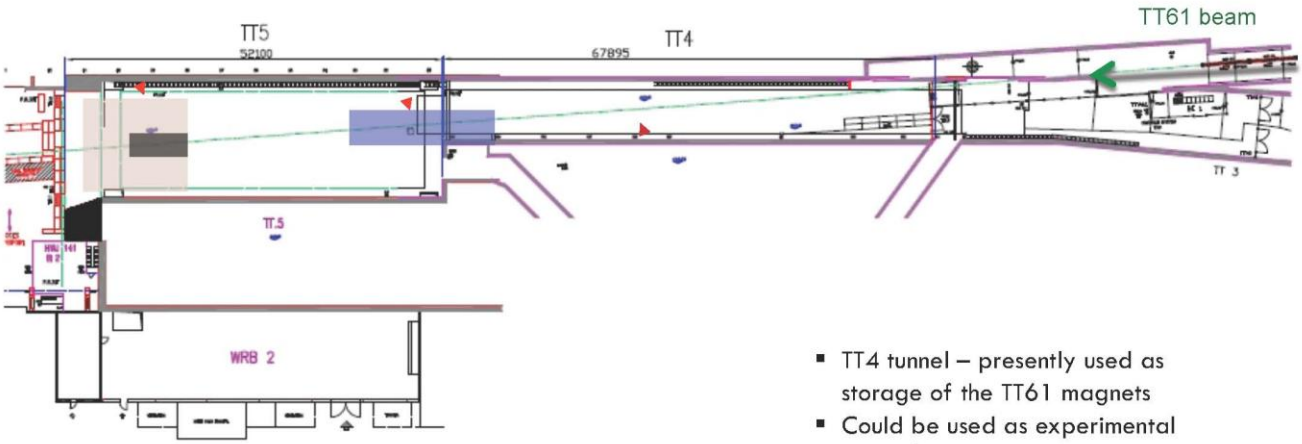
Beam Line in SPS West Area



Christoph Hessler, TE/ABT, CERN

SPS West Area





- TT4 tunnel – presently used as storage of the TT61 magnets
- Could be used as experimental area (67m long)

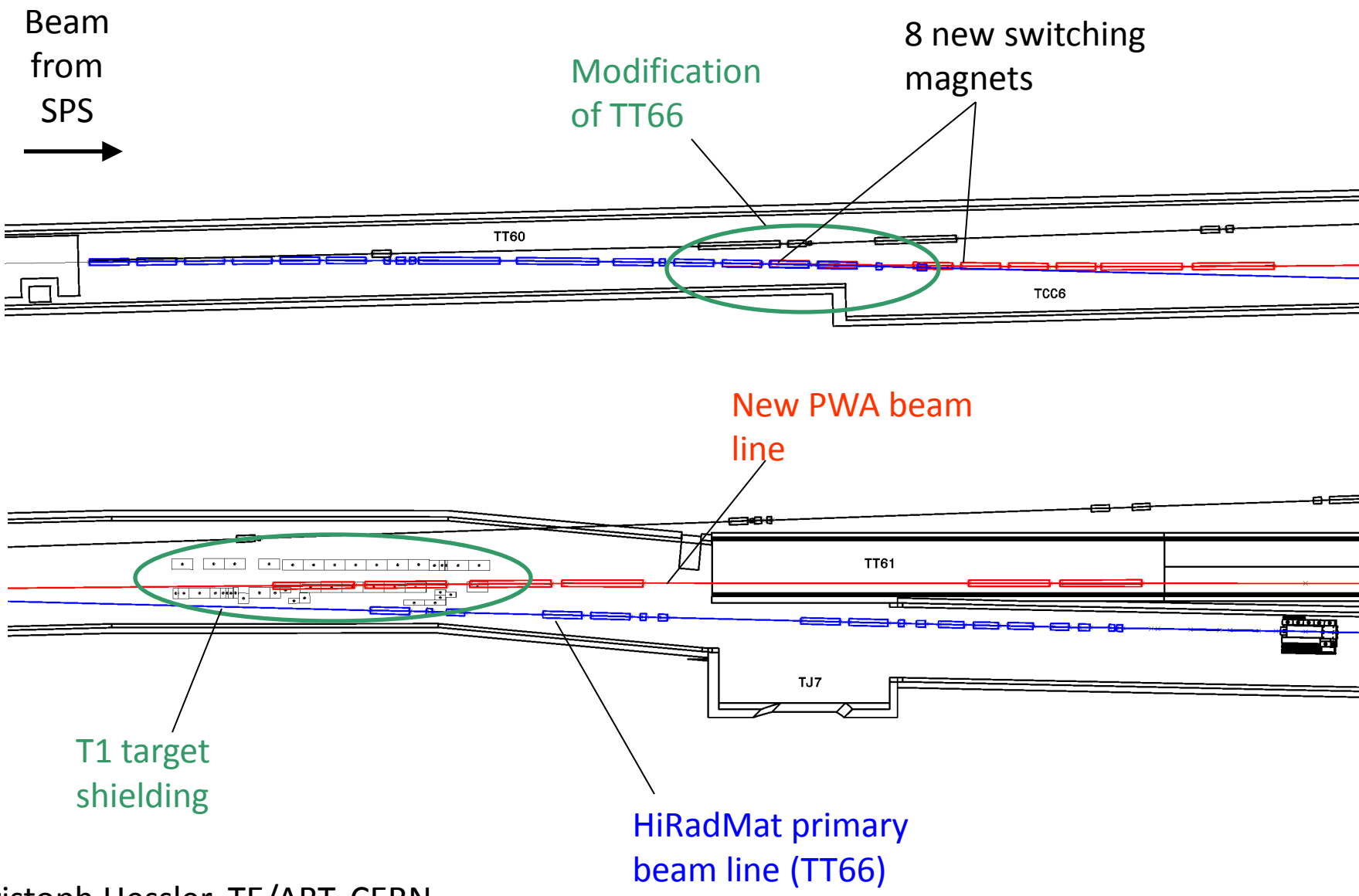
Ilias Efthymiopolous

SPS beam line (TT61, TT4)

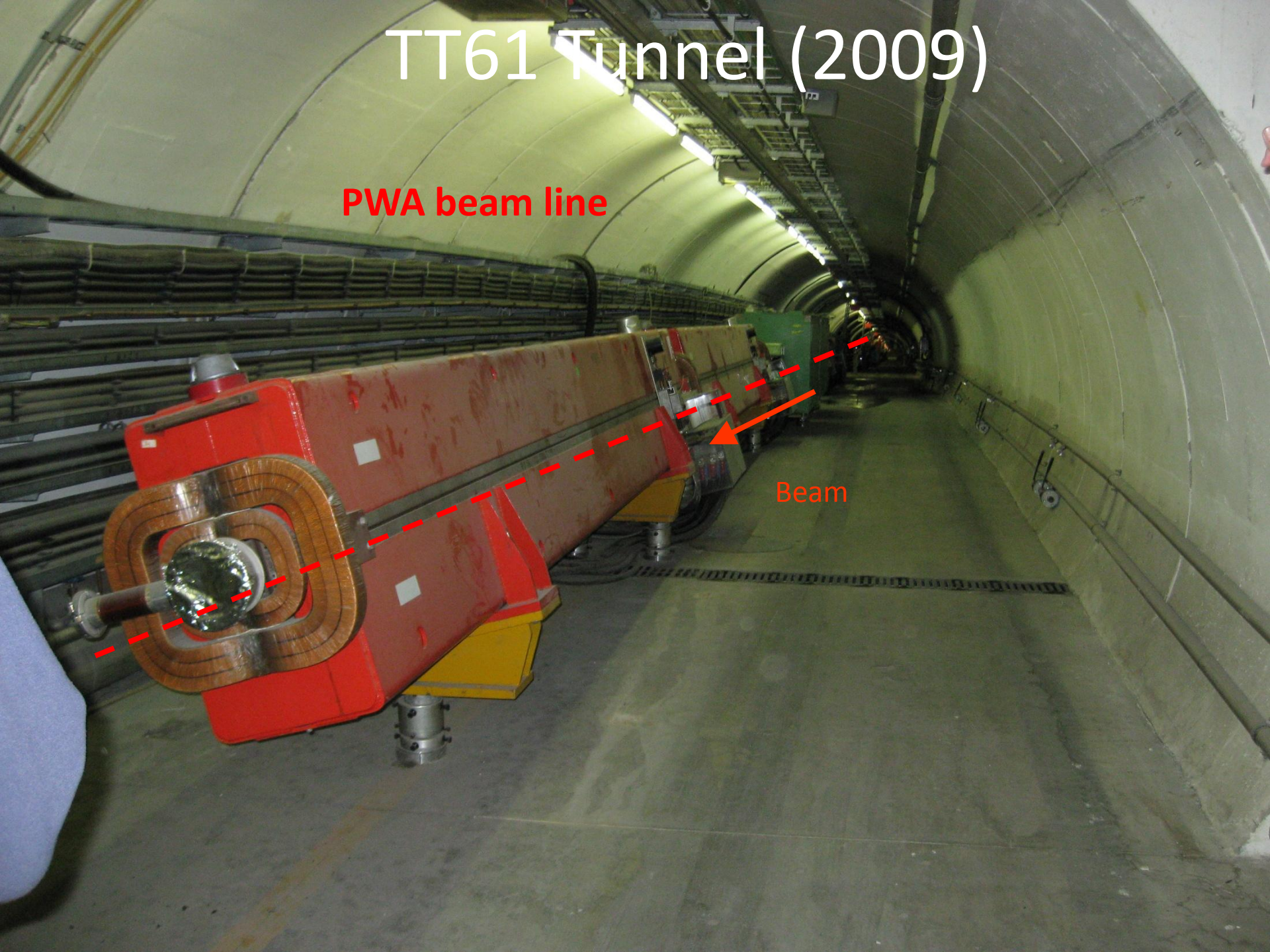
- status of the available infrastructure, i.e. ventilation, services, electricity, etc.
- highly radioactive T1 target shielding needs to be removed
- large slope of 8.5%
- the line is long: availability of magnets and power supplies?
- except for the switching magnets, the rest should be available from old installations, BUT…
- former H3 beam line designed for 250 GeV/c
  → are TT61 tunnel geometry & old magnets suitable for 450 GeV beams? or can we have 250 GeV beams in this line?

Ilias Efthymiopolous, Christoph Hessler

Compatibility with TT66 Beam Line

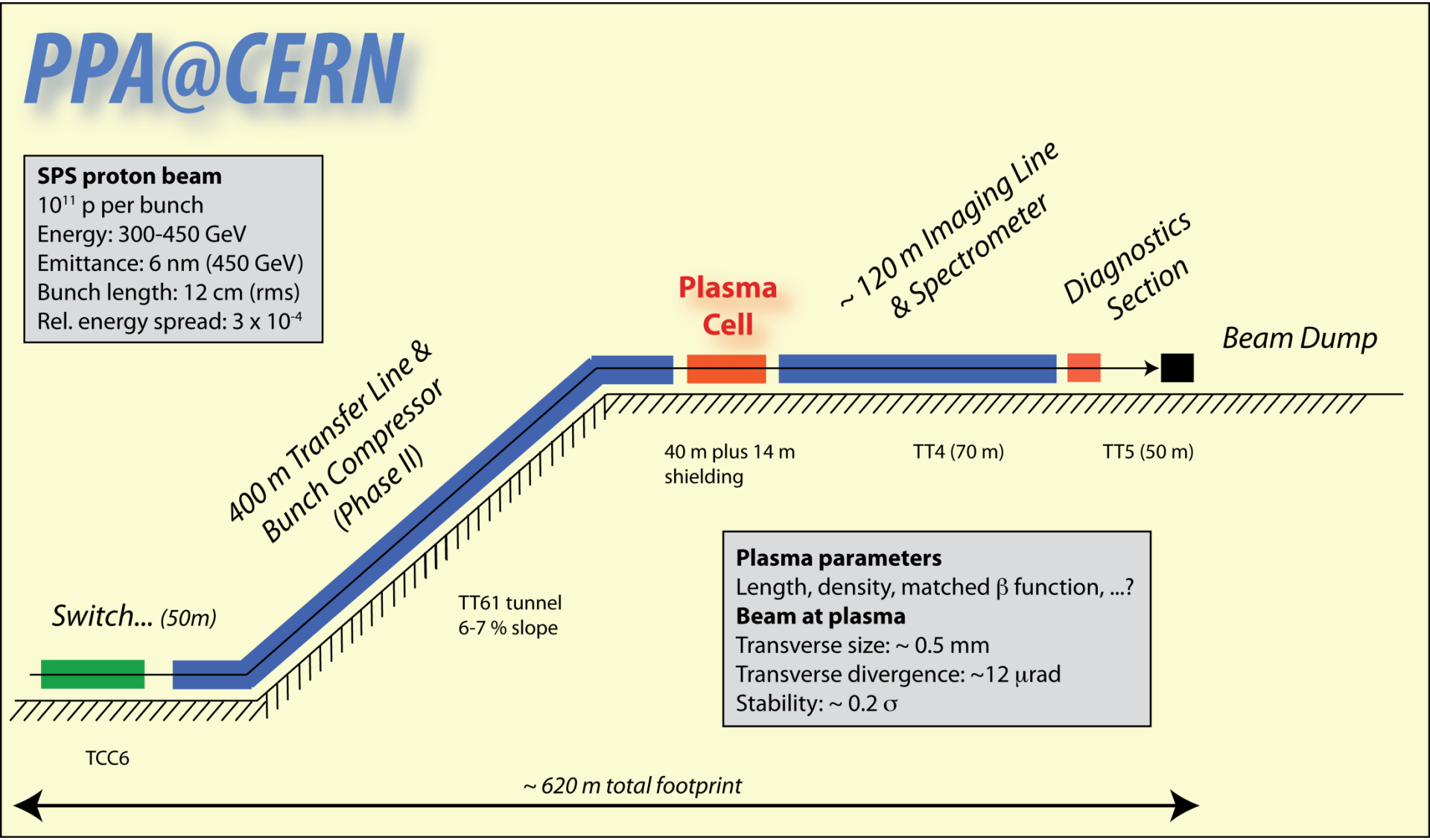


TT61 Tunnel (2009)



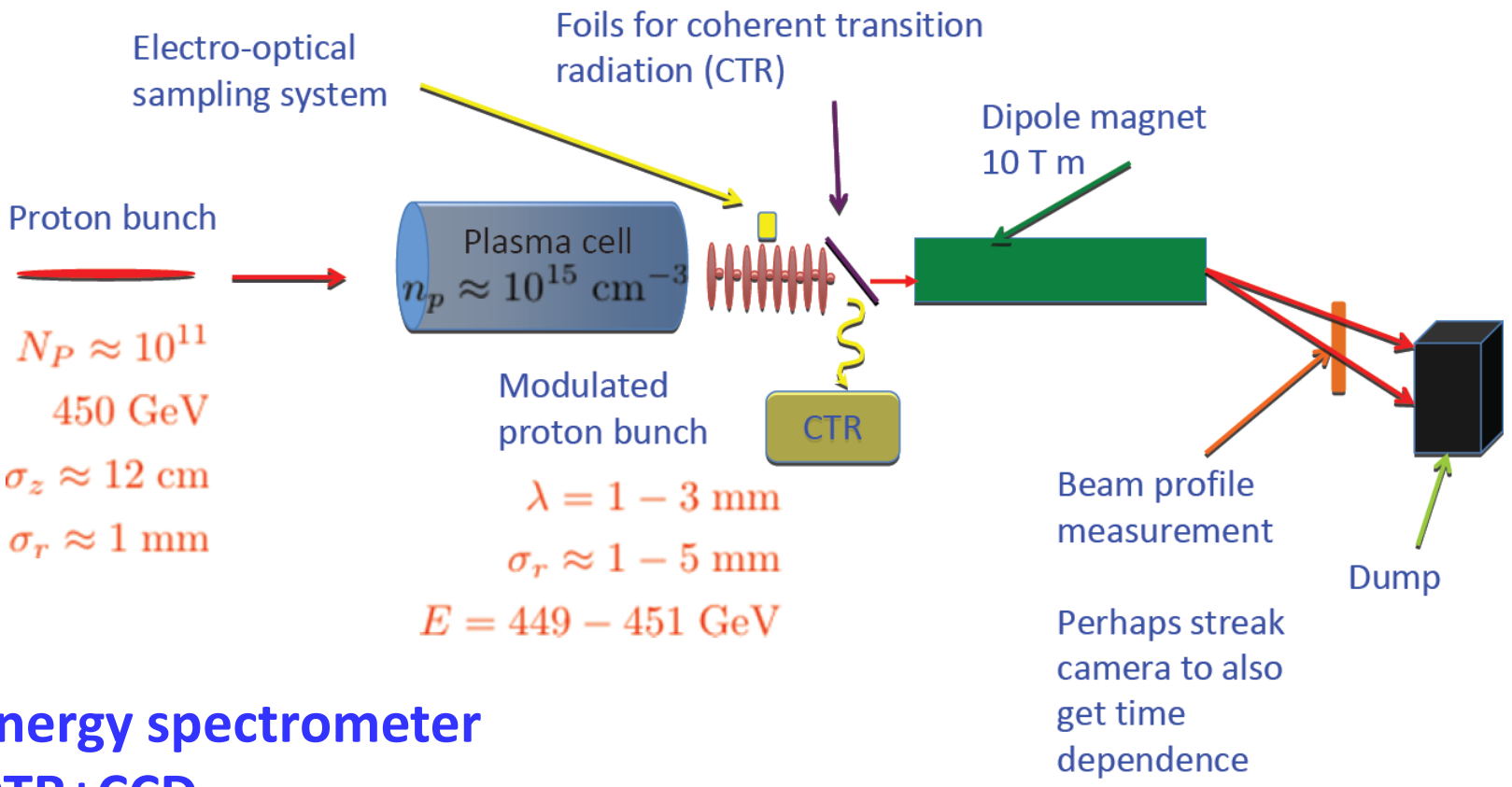
TT61 Tunnel (2009)

sketch of PDPWA experiment in SPS TT60 line



R. Assmann

diagnostics for PDPWA experiment



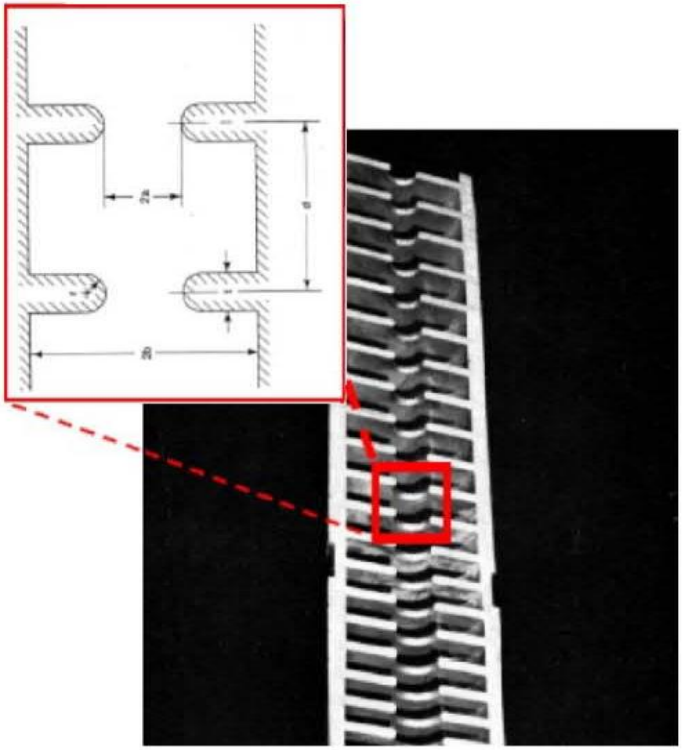
energy spectrometer
OTR+CCD
electro-optic sampling
streak camera
transverse deflecting cavity
frequency domain holography

collimators
crystal detectors
wire scanners
beam current transformers

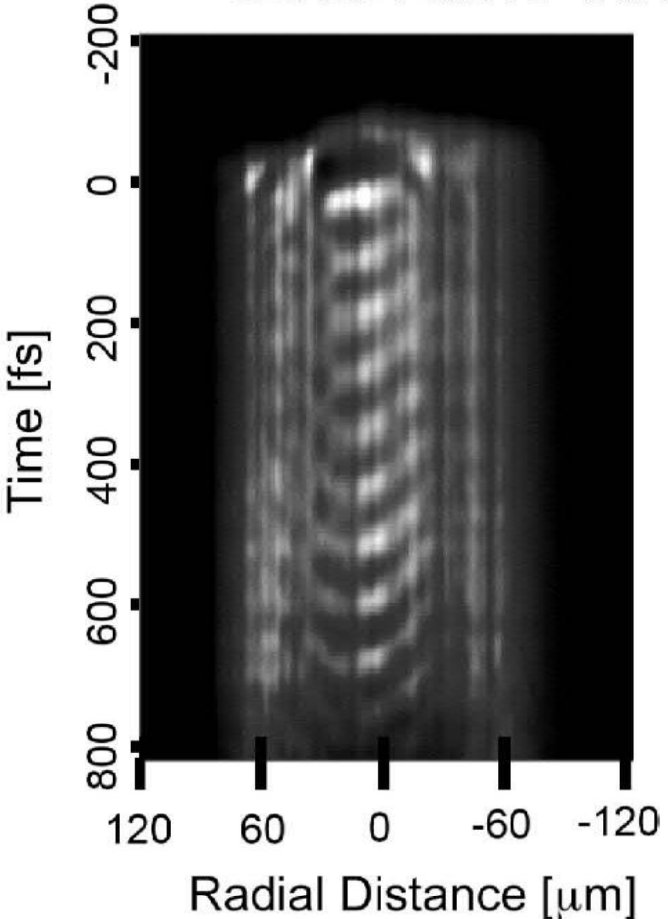
C. Joshi

Plasma Accelerating Structure Visualized Using Frequency Domain Holography

Conventional Accelerator Cavity



Plasma Accelerator Cavity



M.Downer: U.Texas Austin

possible experimental phases

(1) observe the energy variation of the proton driver; self-modulation; demonstrate 1 GeV in less than 5 m of plasma; beam matched to plasma? – *medium term goal*

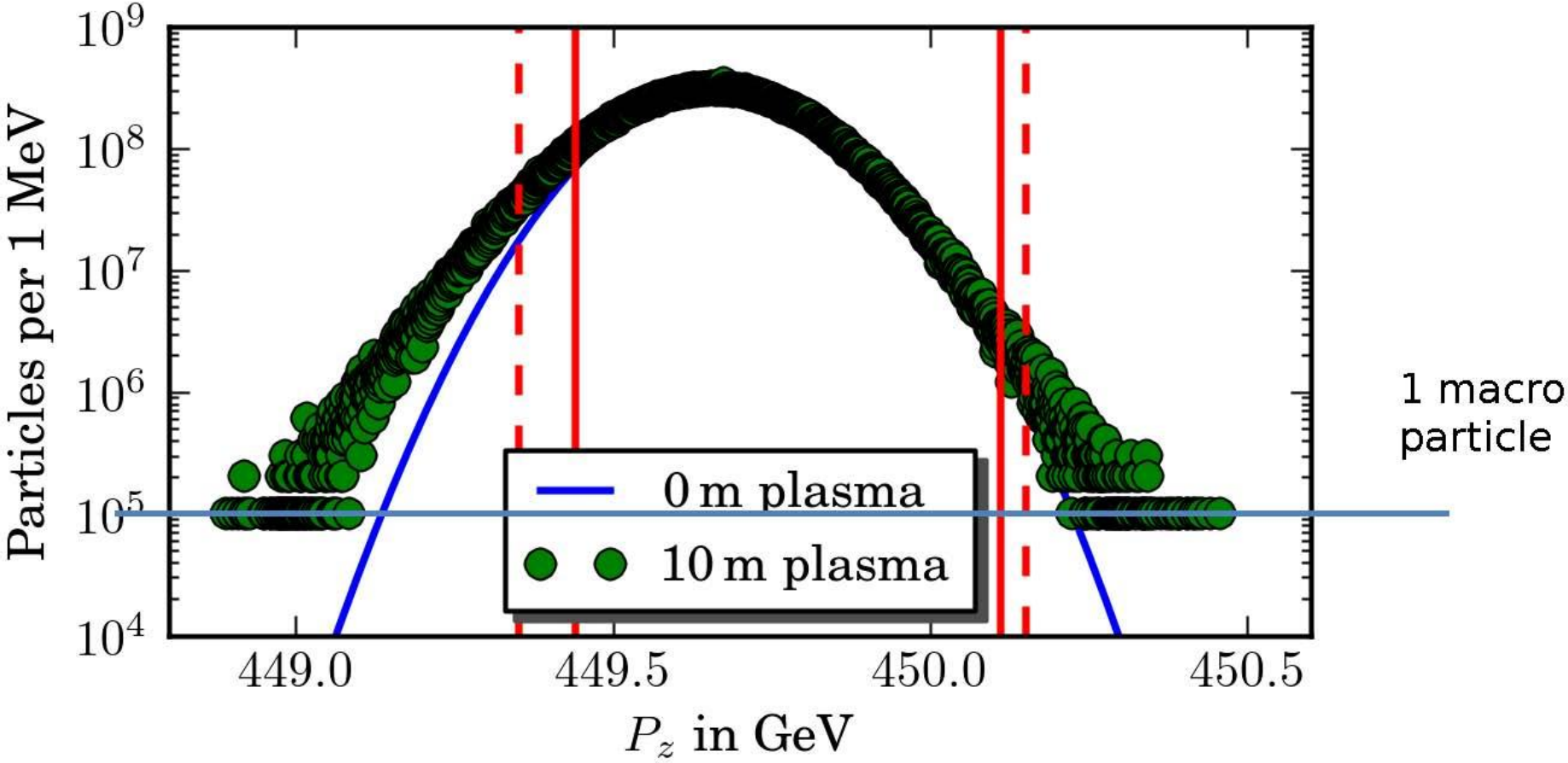
(2) push gradient: shorter bunch→ nonlinear regime, “hard-cut” beam, plasma density step up – *next medium term goal*

(3) demonstrate e- acceleration based on PDPWA by injecting e- – *advanced goal*

(4) reach 100 GeV over 100 m of plasma; produce TeV-scale e- beams – *ultimate goal*

momentum distribution after 10 m plasma

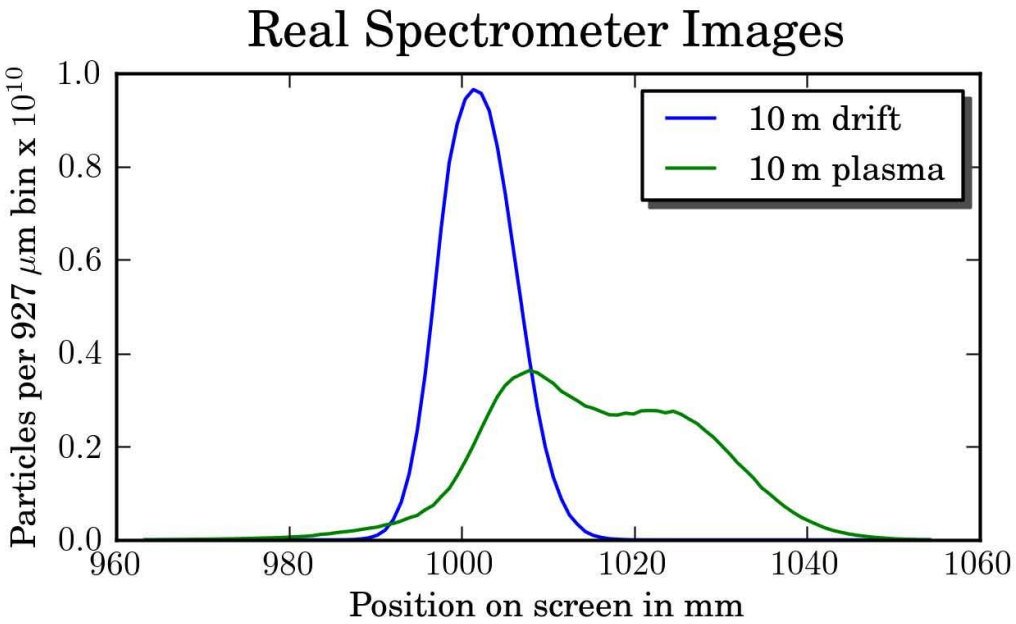
(K. Lotov)

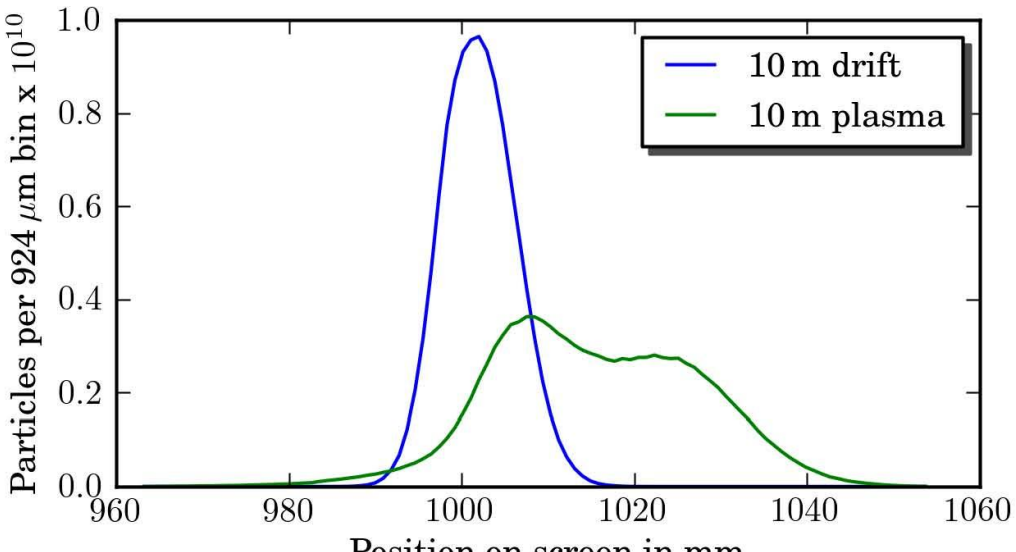


Steffen Hillenbrand

simple spectrometer: 10-m long 1.5-T dipole, followed bv 100 m drift and screen

S. Hillenbrand





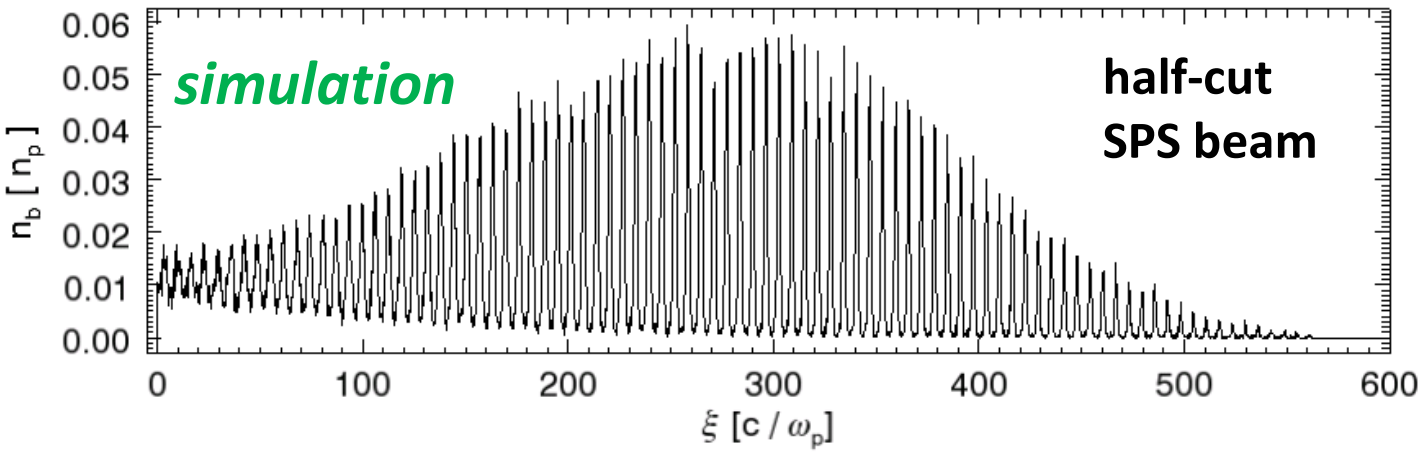
Upper Figure:
All values from data

Lower Figure:
p_z = 450GeV
for all particles
(i.e. energy modulation was „turned off')

Result:
The change due to the energy modulation is heavily overshadowed by the effect of the transverse momentum!

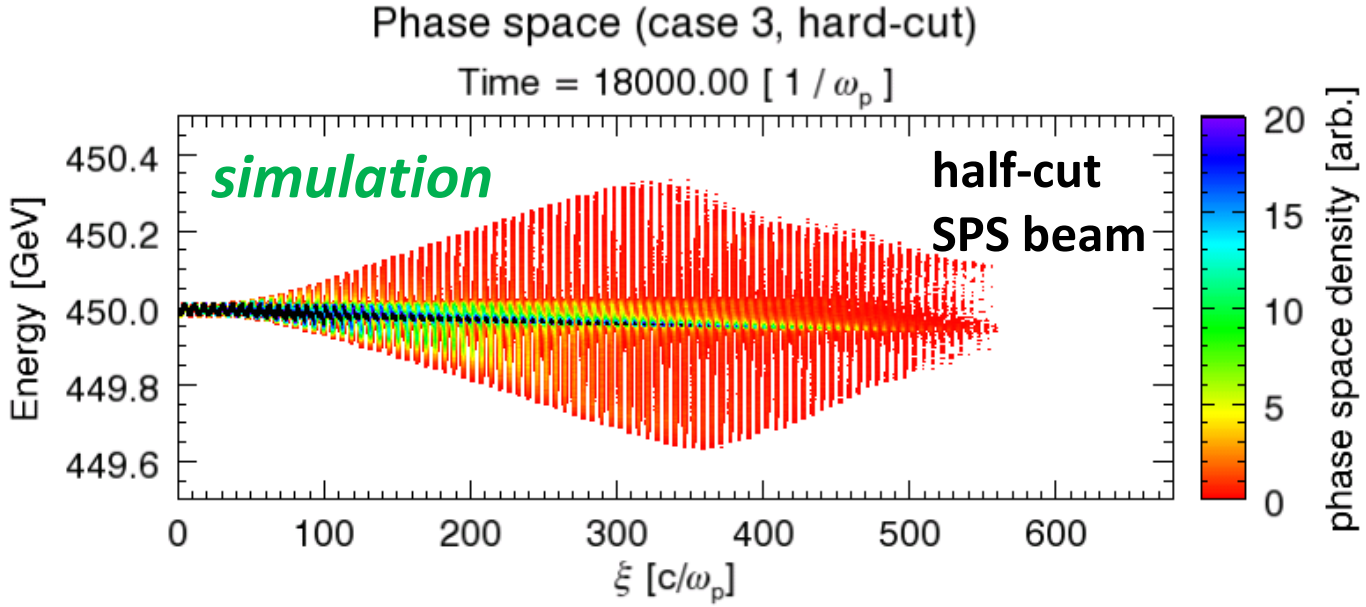
need for achromatic optics!

p-bunch self modulation



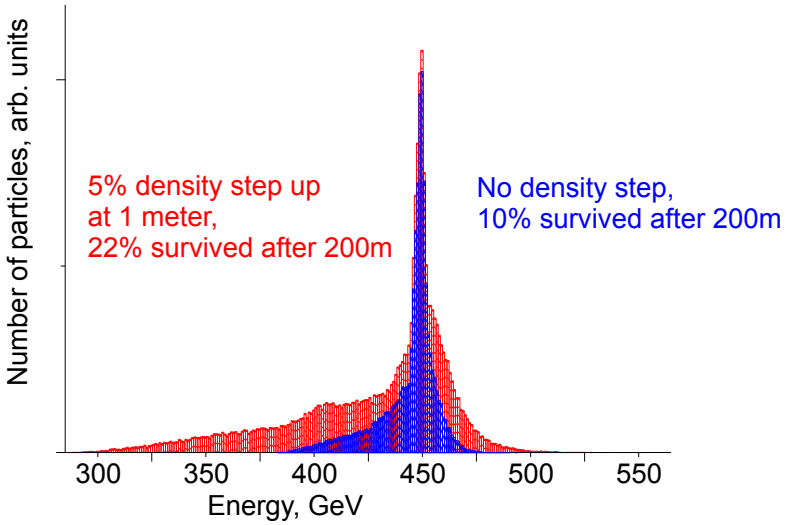
how to make a half-cut bunch?

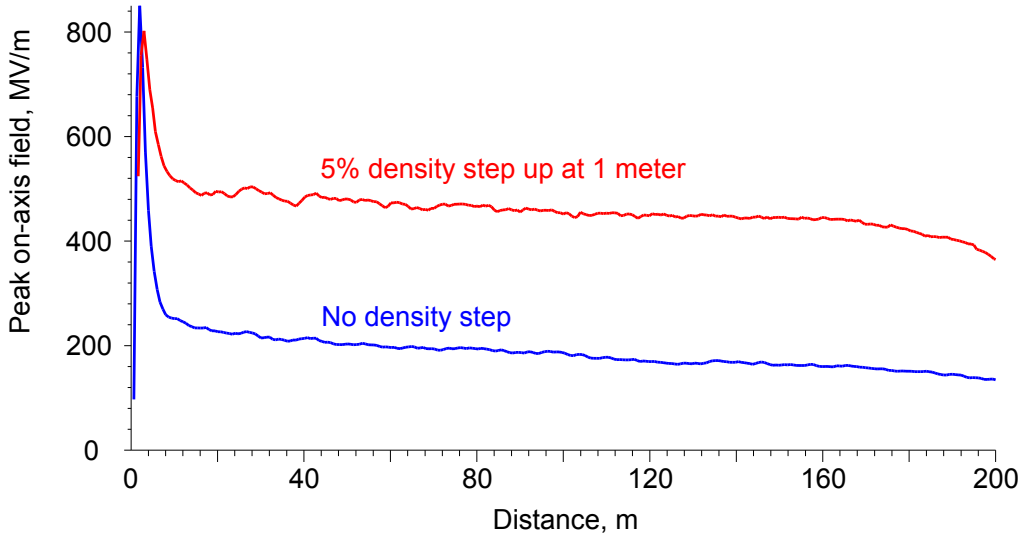
on-axis beam density profile after 4.8 m propagation in plasma



energy variation after 9.6 m propagation in plasma

5% plasma ***density step up*** after 1 m (K. Lotov)





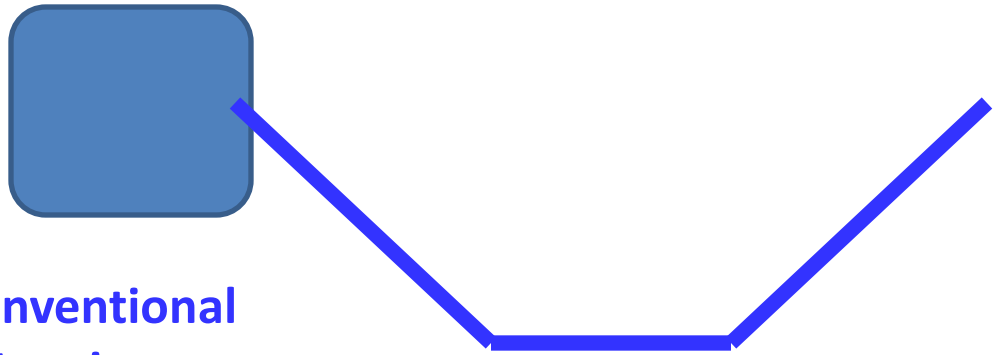
increase plasma density at the moment of instability development

→

stable bunch train over long distance

how to shorten the *p* bunch?

option 1: conventional bunch compression [SLC, CTF-2/3, G. Xia]

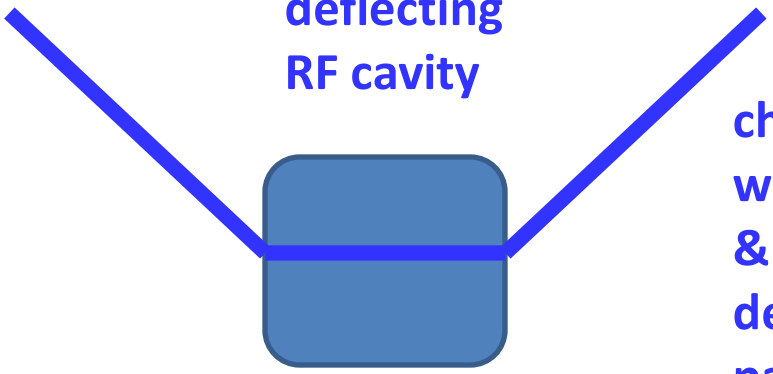


conventional RF cavity

chicane/arc with momentum dependent path length

option 2: *x-z* emittance exchange [P. Emma, 2002; for LCLS]

deflecting RF cavity



chicane with dispersion & momentum dependent path length

SPS:

ε_z~4 μm

$\varepsilon_{x,y}$~8 nm

might option 2 need a lower voltage?

PDPWA collaboration

CERN: beam, vacuum pipes, magnets, collimators, standard diagnostics, beam dump, manpower

MPP Munich: manpower + special diagnostics (EOS)

UCLA: laser based Li/Cs plasma source

IPP Greifswald: helicon-discharge based Ar plasma source

Letter of Intent in preparation, to be submitted to CERN SPSC

(G. Xia et al)

thank you for your attention!