New technologies for colliders
Overview of recent progress of plasma based acceleration

Jorge Vieira

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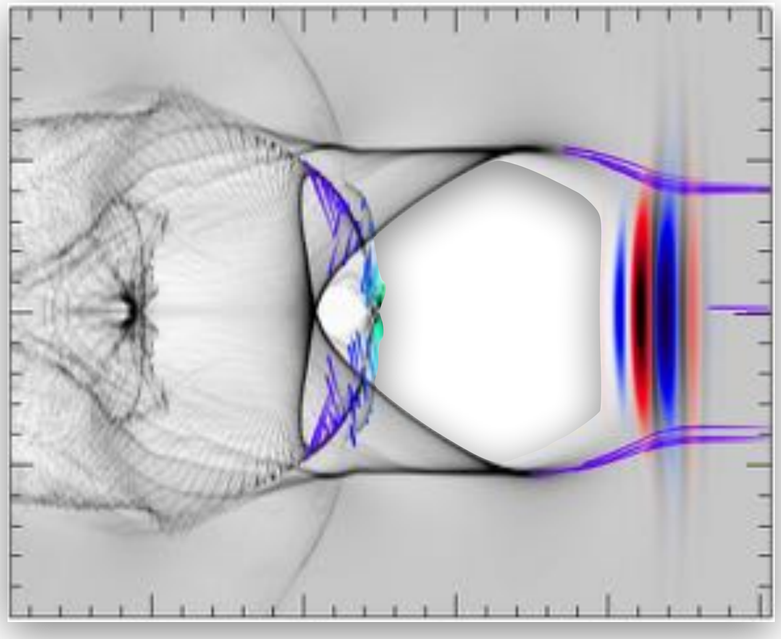

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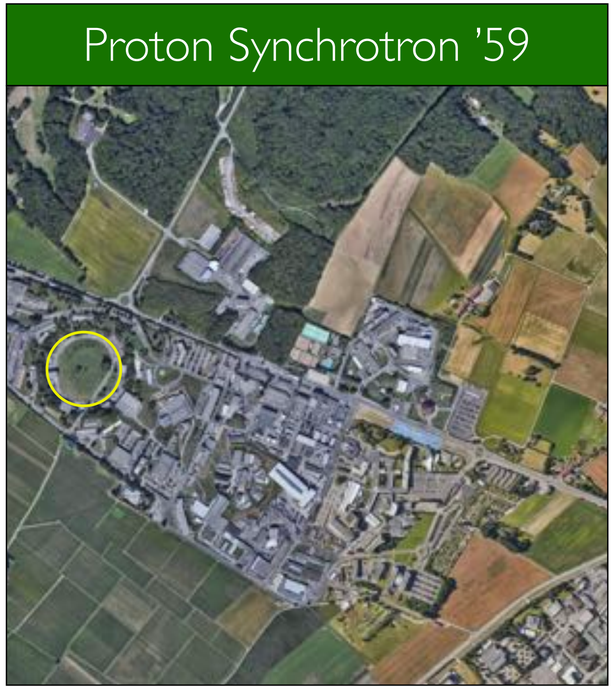
Particle accelerators: why plasma?



Particle accelerators: why plasma?

Proton Synchrotron '59

Super PS '76

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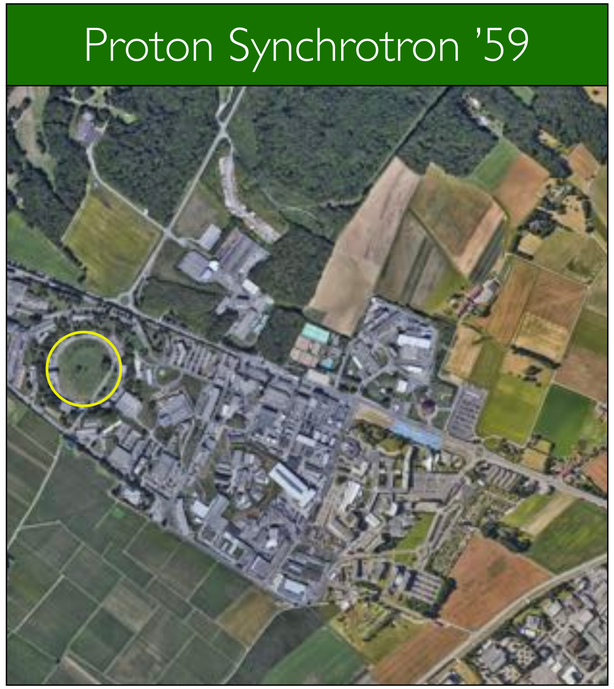

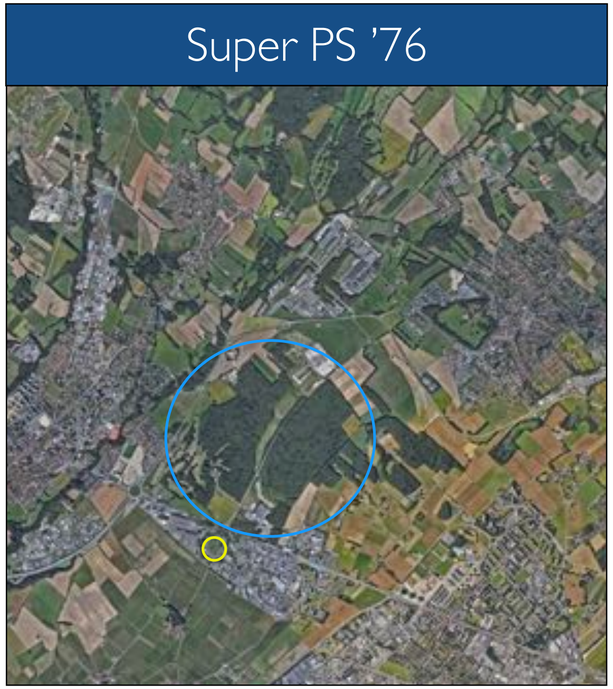

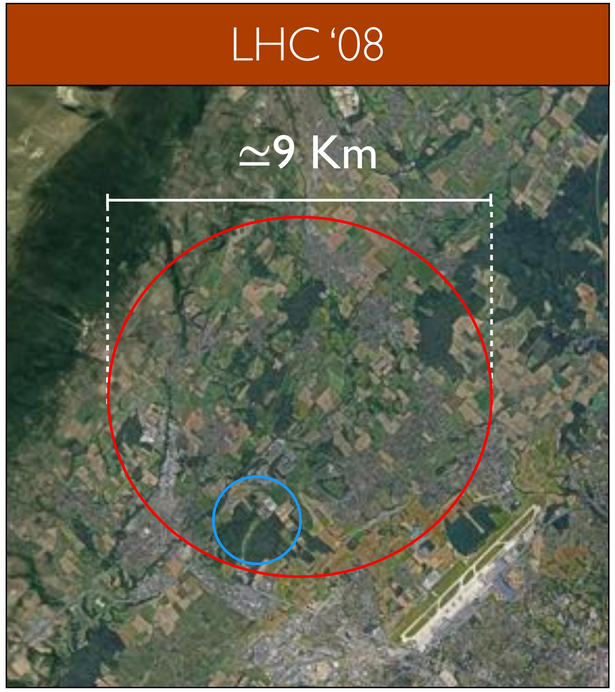

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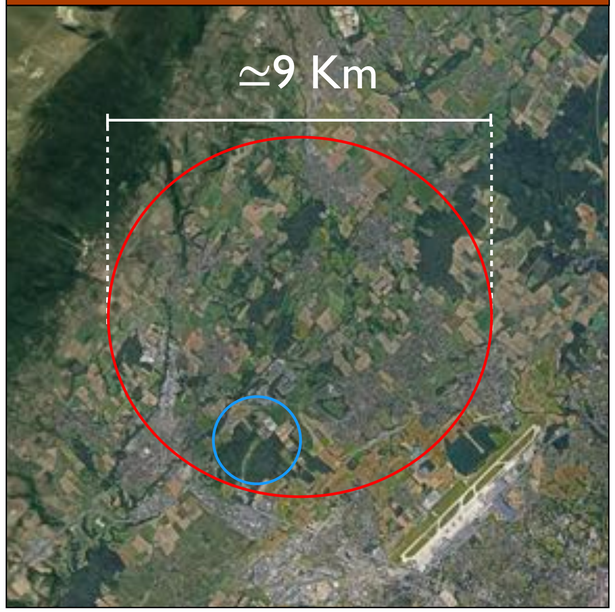
LHC '08



Burton Richter, Nobel prize '76

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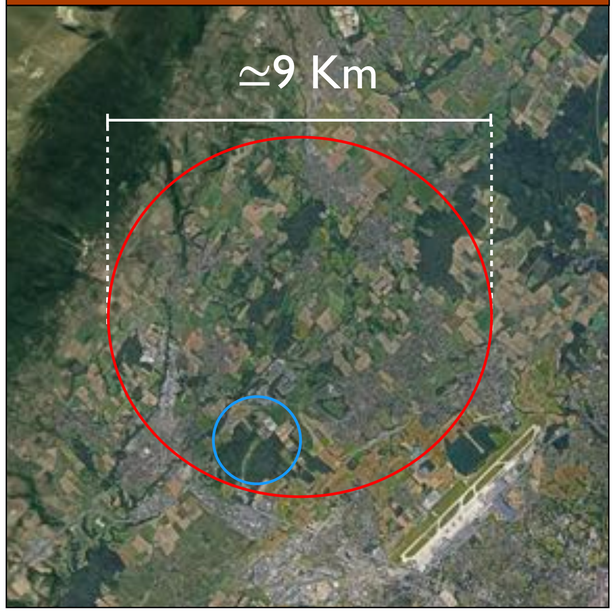
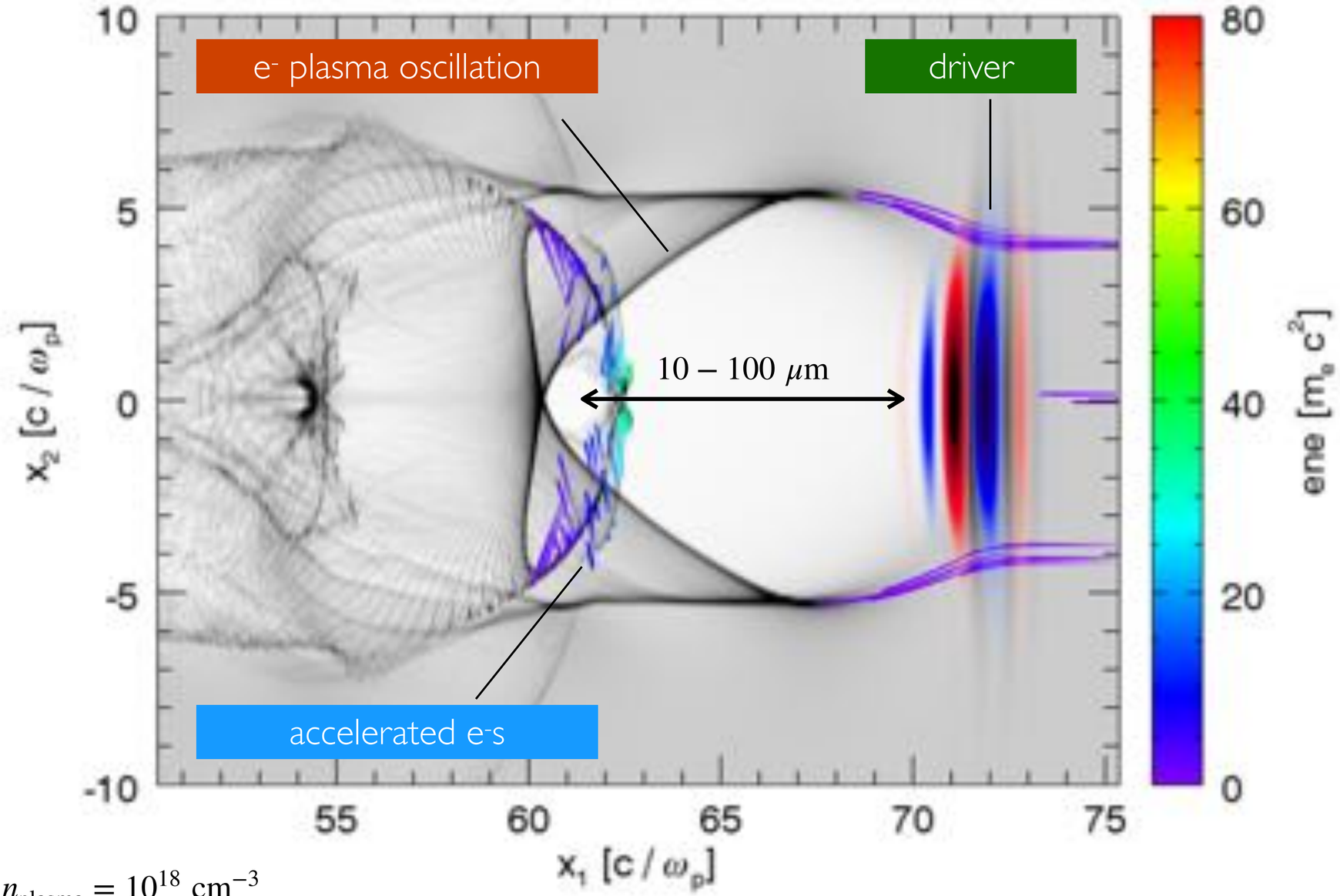


1000x **smaller** (Tajima, Dawson PRL '79)

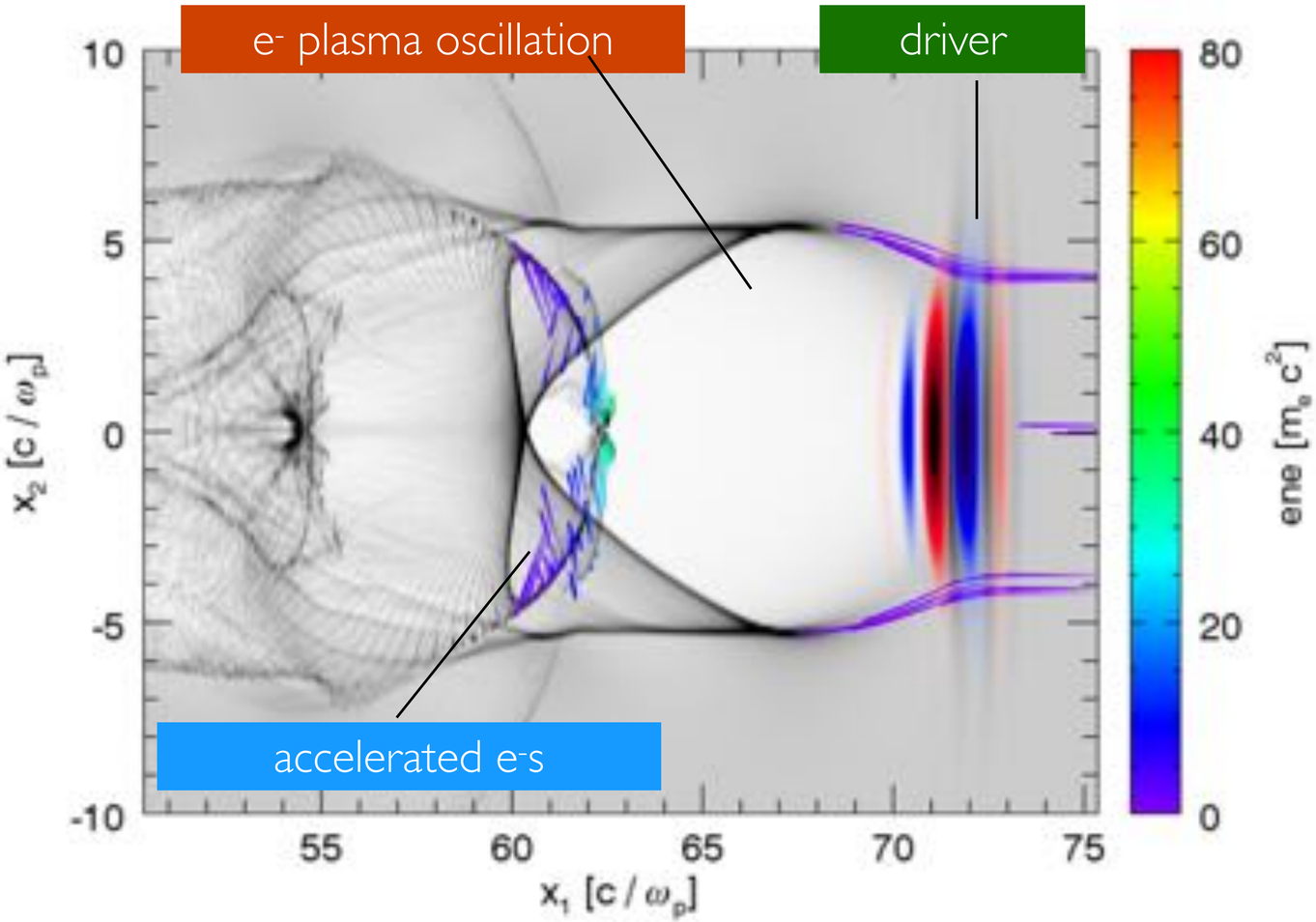
Burton Richter, Nobel prize '76

What is a plasma accelerator?



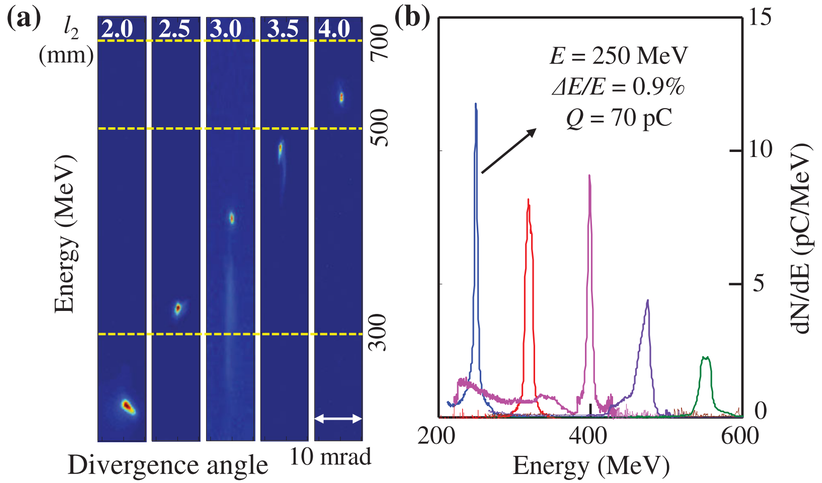
$E_{\text{accel}} \sim \mathbf{100\ GV/m}$ for $n_{\text{plasma}} = 10^{18}\ \text{cm}^{-3}$

What is a plasma accelerator?



GeV class e- with sub-percent energy spread

W. Wang *et al.* PRL **117**, 124801 (2016)



8 GeV peak energy gain in a laser driven plasma accelerator (Gonçalves, PRL **122**, 084801 (2019)

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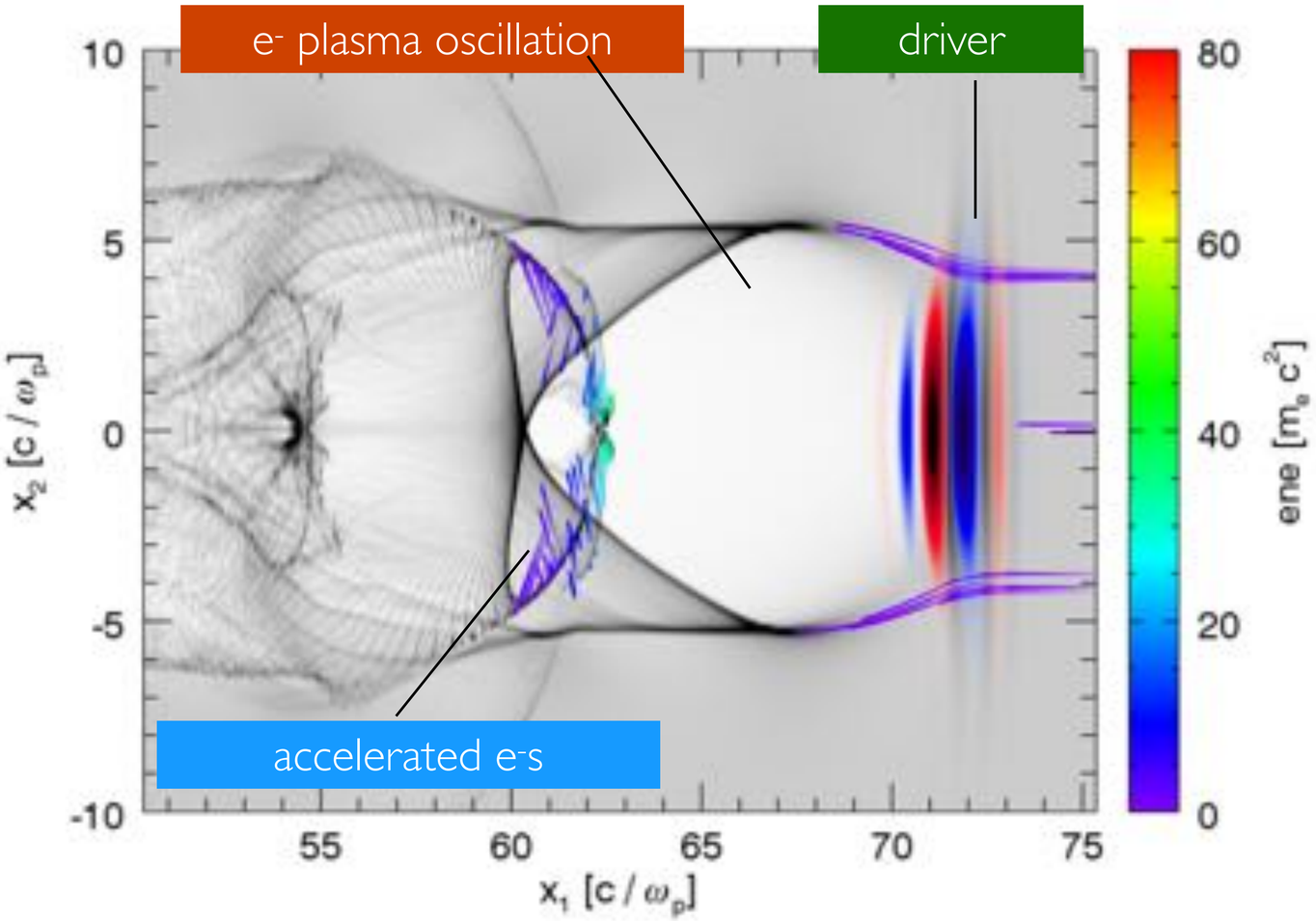
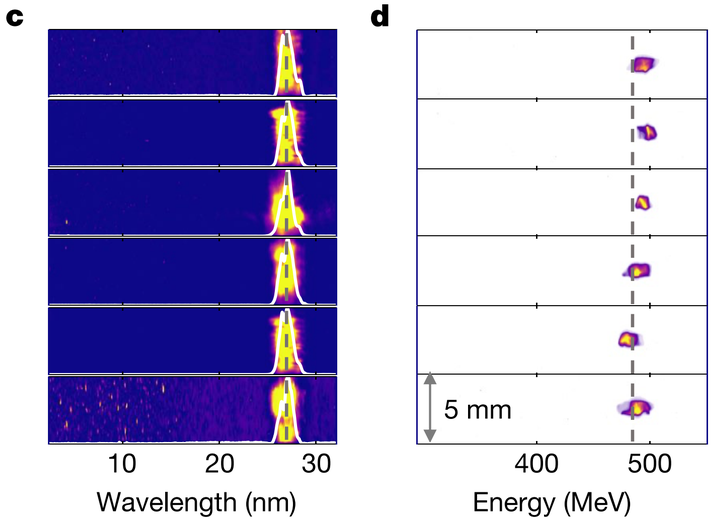


Lasing at 27 nm using laser plasma accelerators

W. Wang *et al.* Nature **595**, 516 (2021)



Roadmap for a plasma based linear collider

Particle physics strategy update

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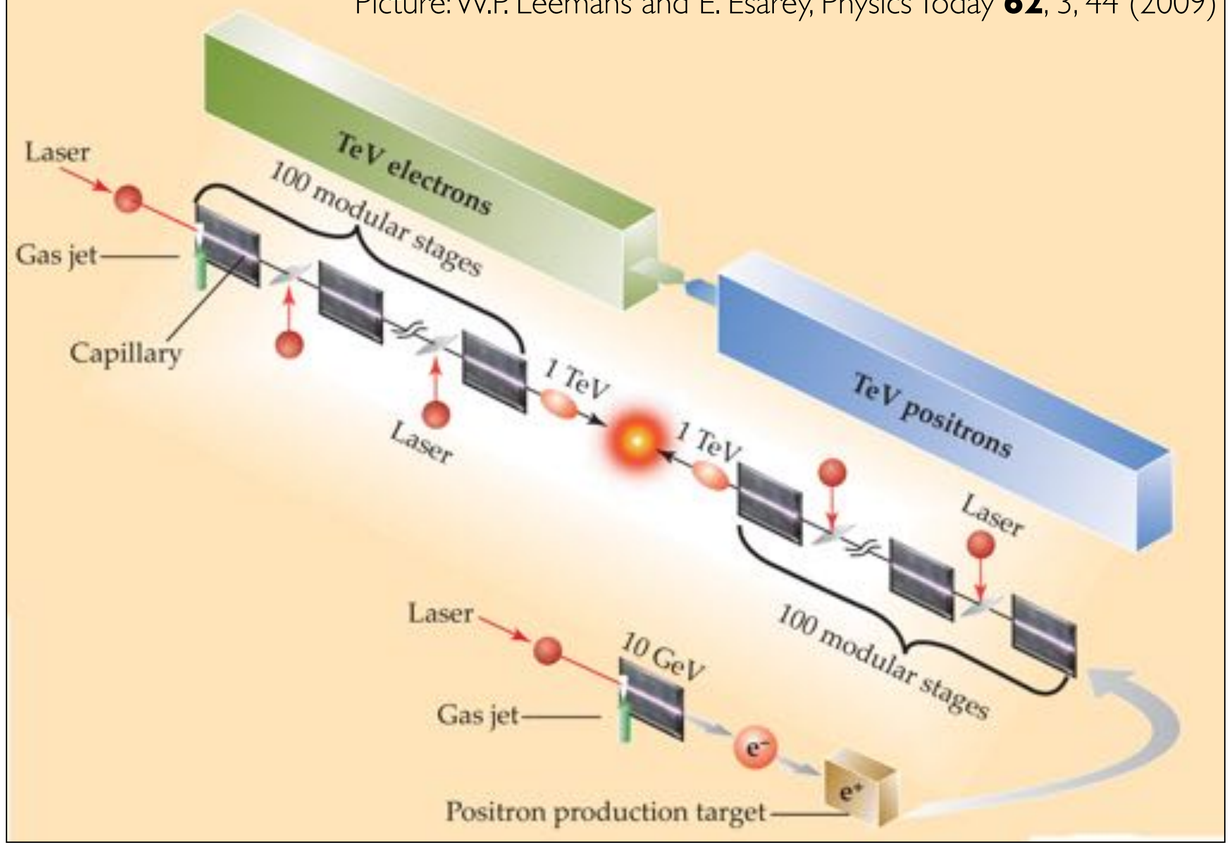
Particle physics strategy update

Concept of a plasma based linear collider

Picture: W.P. Leemans and E. Esarey, Physics Today **62**, 3, 44 (2009)



What are the requirements for a particle physics collider?

Parameter	Units	CLIC-like (e-/e+)	ILC-like (e-/e+)
bunch charge	pC	833	3200
polarization	-	80% e-	80% e- / 30% e+
initial energy	GeV	**175**	**235**
final energy	GeV	**190**	**250**
initial relative energy spread	%	0,6	1
final relative energy spread	%	0,35	0,1
initial bunch length	µm	70	300
final bunch length	µm	70	300
initial normalized emittance H/V	µm / nm	0.890 / 19	9.5 / 25
emittance growth budget H/V	µm / nm	0.010 / 1	0.5 / 5
final normalized emittance H/V	µm / nm	0.900 / 20	10 / 30
bunch separation	ns	0,5	554
number of bunches per train	-	352	1312
rep rate	Hz	50	5
beamline length	m	250	600
Efficiency: wall-plug to drive beam	%	58	-
Efficiency: drive beam to main beam	%	22	-
Luminosity	10^34 cm-2 s-1	1,5	1,8

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- ✓ 15 GeV stages
- ✓ Up to 190 GeV
- ✓ High gradients have been established

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Open questions

- ✳ Average power ($\simeq 100$ MW)*
- ✳ Emittance ($\simeq 10$ nm) and emittance growth
- ✳ Positrons

* C.B. Schroeder et al, PRSTAB 13 101301 (2010)

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A hybrid, asymmetric, linear Higgs factory based on plasma-wakefield and radio-frequency acceleration

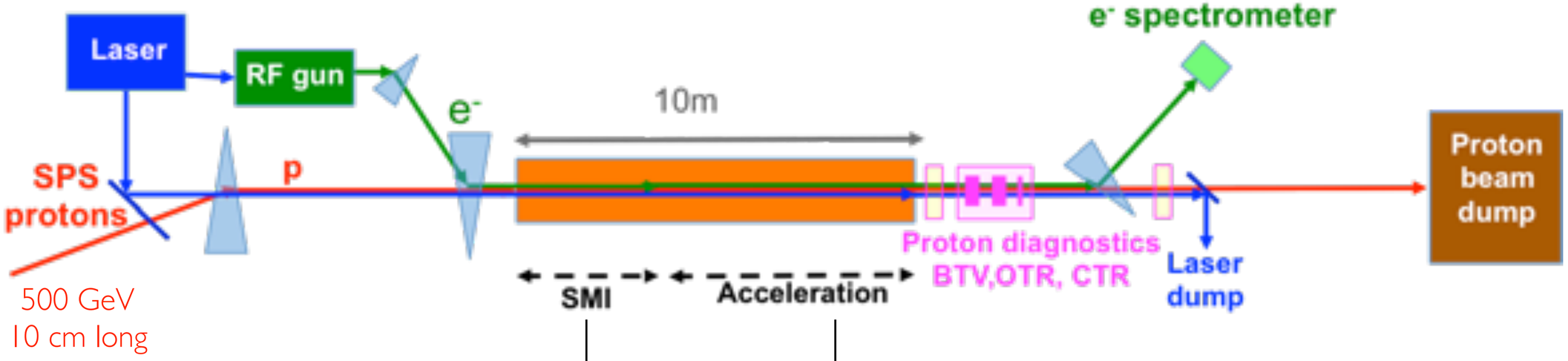
B. Foster,[1,*] R. D'Arcy,[2] and C. A. Lindstrøm[3]

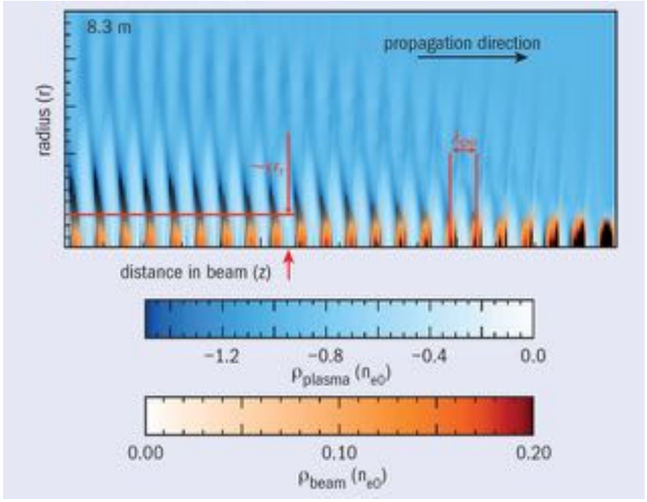
[1] *John Adams Institute for Accelerator Science at University of Oxford, Oxford, UK*
[2] *Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany*
[3] *Department of Physics, University of Oslo, Oslo, Norway*

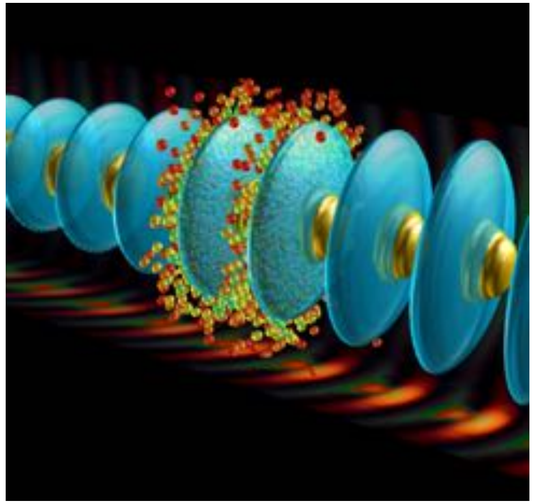
(Dated: March 28, 2023)

* C.B. Schroeder et al, PRSTAB 13 101301 (2010)

AWAKE experiment







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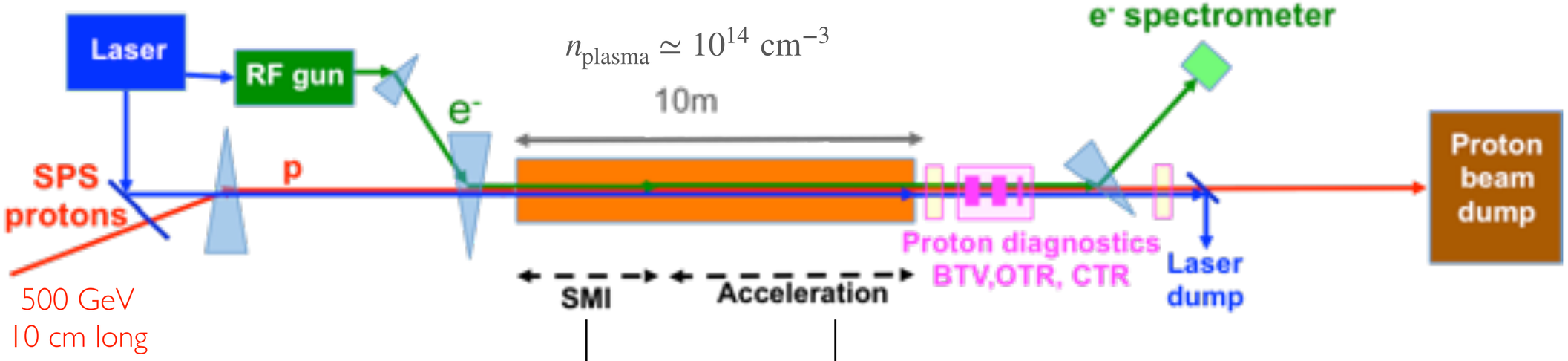
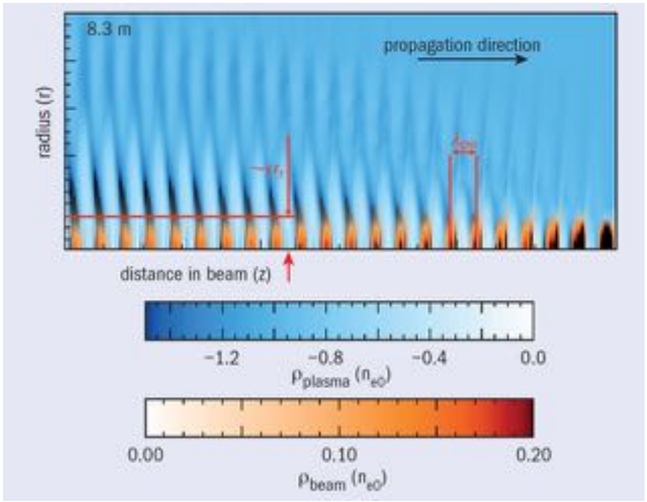
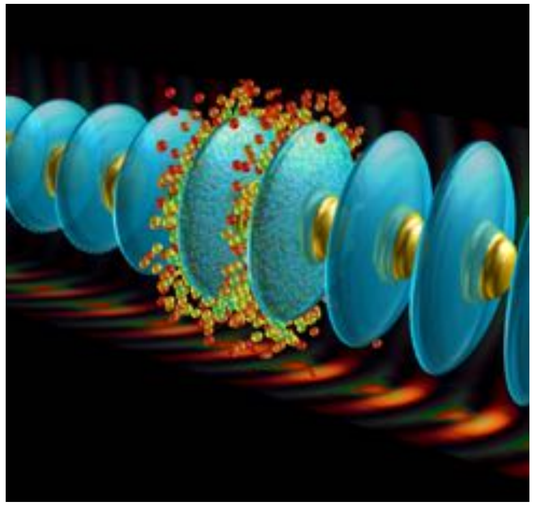


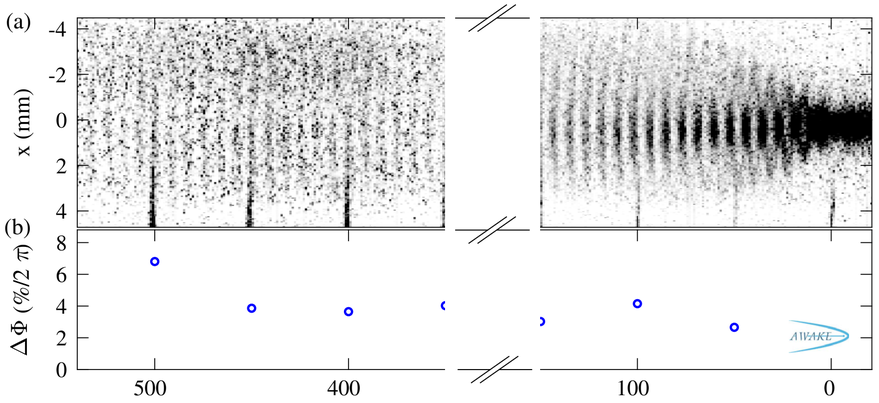




Electron acceleration at the AWAKE experiment

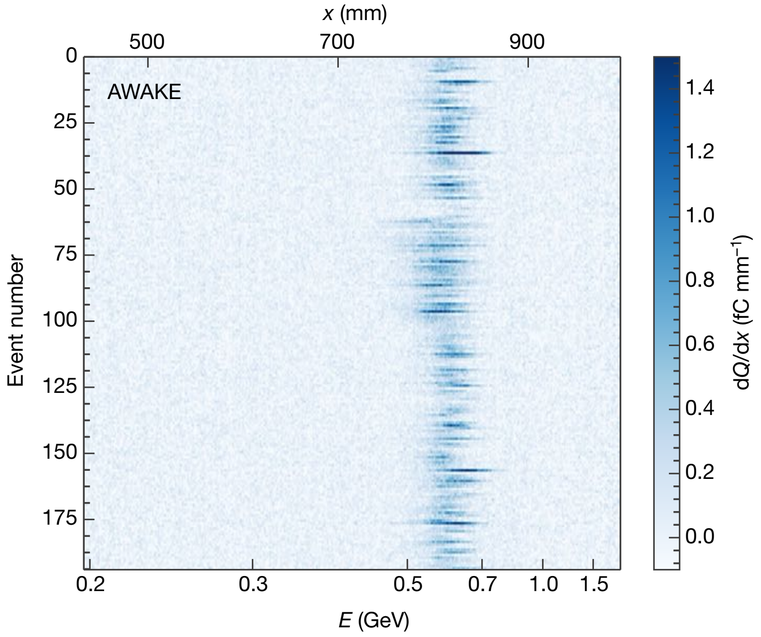
Seeded self-modulation instability

F. Batsch *et al.* (AWAKE collaboration)
PRL **126**, 164802 (2021)



Electron acceleration

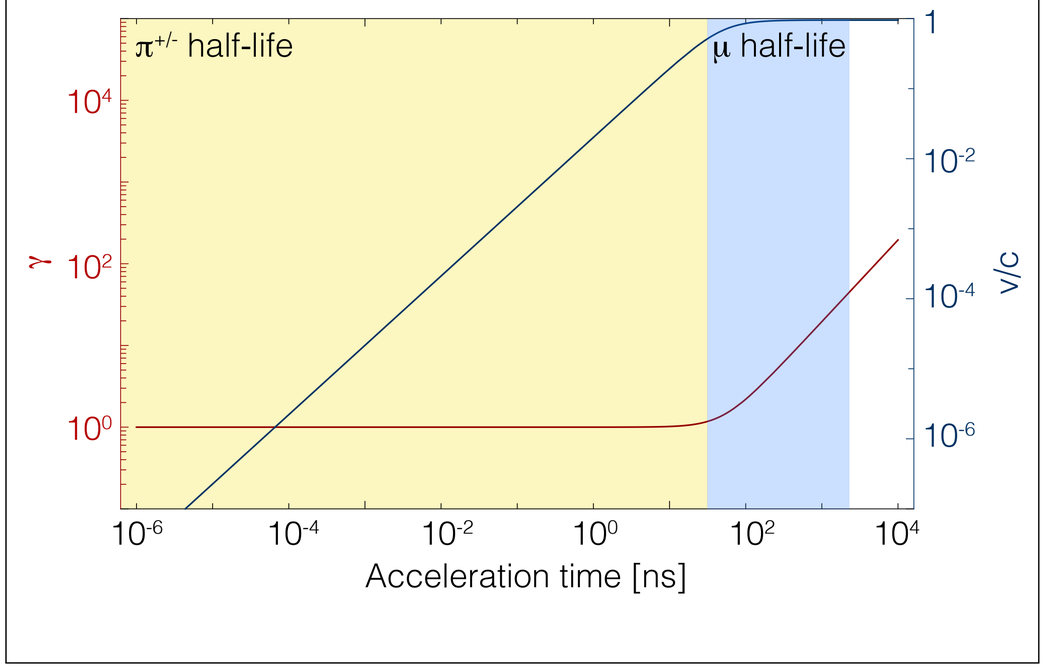
E. Adli *et al.* (AWAKE collaboration)
Nature **561, 363** (2018)



Acceleration of unstable particles

C. Badiali *et al.* in preparation (2023)

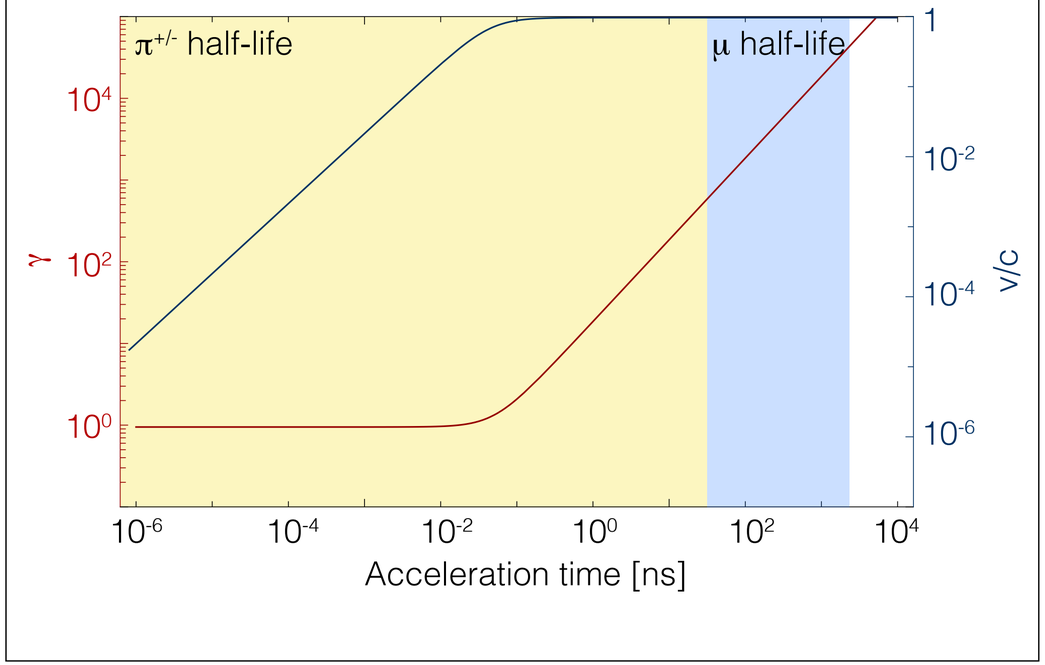
Assuming $E_{\text{accel}} \simeq 10$ GV/m…



Acceleration of unstable particles

C. Badiali *et al.* in preparation (2023)

Assuming $E_{\text{accel}} \simeq 100$ GV/m…



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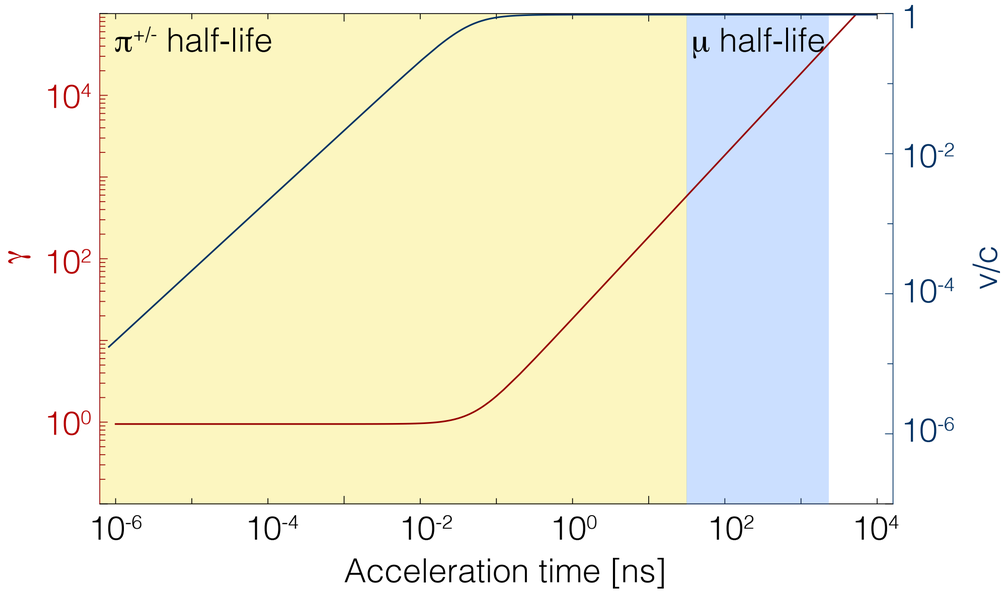
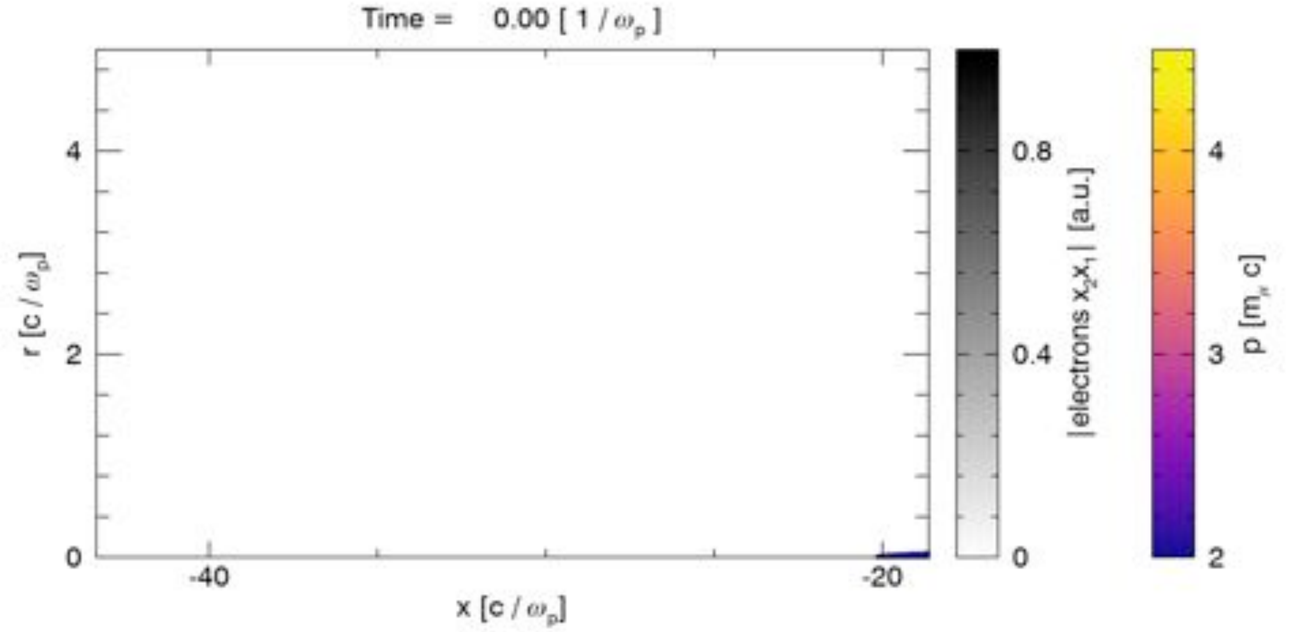


Muon acceleration in a plasma accelerator

Initial velocity: **0.9c**
Final velocity: **0.98c**



Conclusions

Open PhD position!

Email jorge.vieira@tecnico.ulisboa.pt

Strong recent progress in plasma based accelerators research

Sub-% energy spread, mm-mrad normalized emittance, good for XUV/soft x-ray FEL

Challenges

Emittance preservation in staging, tolerances, power dissipation

New perspectives for HEP

Use extremely high electric fields to accelerate unstable particles

Thank you!