

# PASAIG:



## AF6 White Paper Plan

# p<sup>+</sup>-Driven PWFA for Early Applications to Particle Physics

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✧ White paper draft

<https://www.overleaf.com/read/gjgdxfgyfjnp>

# White Paper: AWAKE, Plasma Wakefield Acceleration of Electron Bunches for Near and Long Term Particle Physics Applications

P. Muggli<sup>1,\*</sup>

(AWAKE Collaboration)

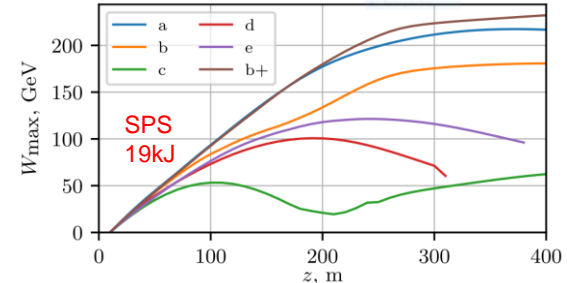
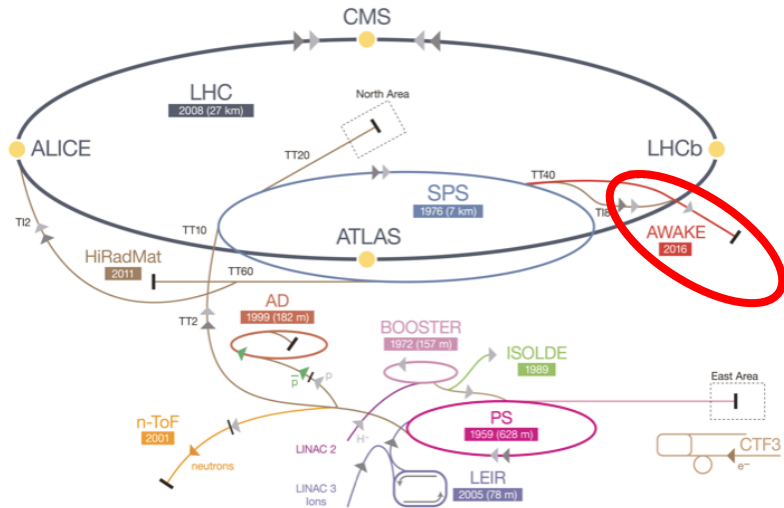
<sup>1</sup>*Max Planck Institute for Physics, Munich, Germany*

(Dated: February 14, 2022)

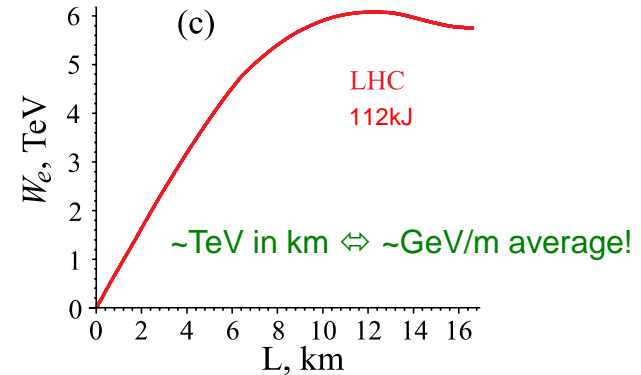
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- ✧ Relativistic proton ( $p^+$ ) bunches with tens to hundreds (CERN-SPS) of kJ (LHC) exist!
- ✧ Driving wakefields in plasma with a proton ( $p^+$ ) bunch
- ✧ Accelerating externally-injected electrons ( $e^-$ ) to GeV (SPS) to TeV (LHC) energy scale



P. Tuv, K. V. Lotov, *PPFC* 63, 125027 (2021)



✧ 20-200 GeV  $e^-$ , SPS  $p^+$  bunch as driver:

- ✧ Fixed target, beam-dump experiments: searches for dark photons
- ✧ Nonlinear QED:  $e^-$  /photon collisions
- ✧ ep or eA collisions, QCD, structure of matter
- ✧ ...

M. Wing, Phil. Trans. Royal Soc 377,20180185 (2019)  
AWAKE collaboration, to be submitted

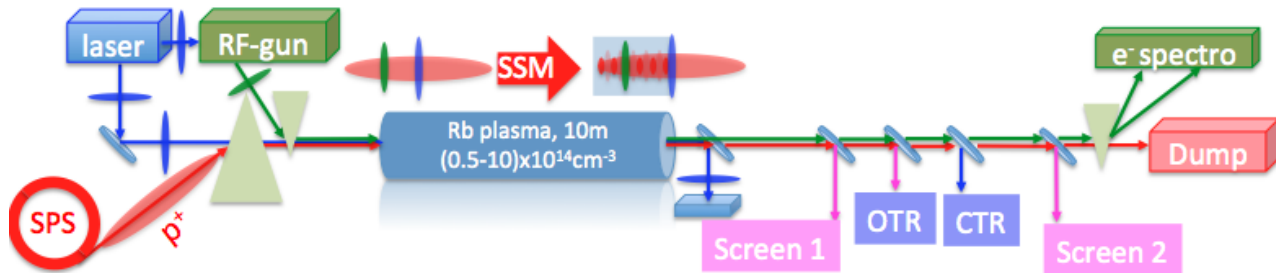
✧ TeV  $e^-$ , LHC  $p^+$  bunch as driver:

- ✧ High-energy ep or eA collisions
- ✧ Very-high-energy ep or eA collider

A. Caldwell and M. Wing, The European Physical Journal C76, (2016)

✧ Luminosity of collider applications limited by single use of low rep-rate  $p^+$  bunch production

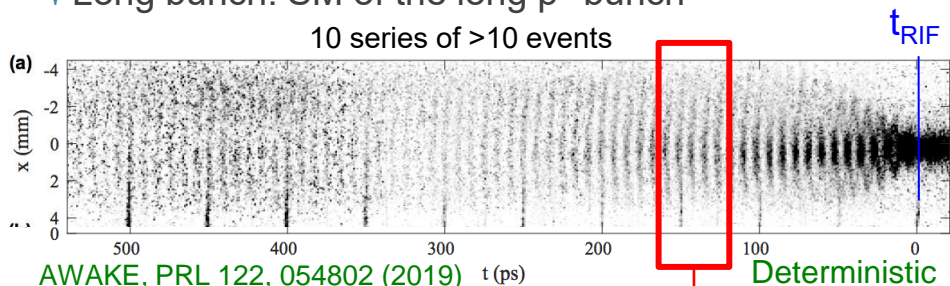
- Long p+ bunch ~10cm
- Single, 10m-long, rubidium plasma
- $n_{e0} = (0.5-10) \times 10^{14} \text{cm}^{-3}$



N. Kumar, PRL104, 255003 (2010)

- Long bunch: SM of the long p+ bunch

10 series of >10 events

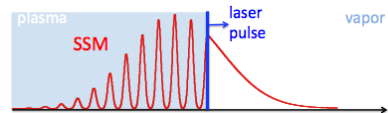


AWAKE, PRL 122, 054802 (2019)

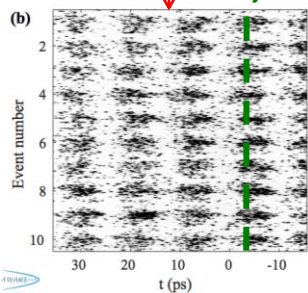
Turner et al. PRL 122, 054801 (2019)

Braunmueller, PRL 125, 264801 (2020)

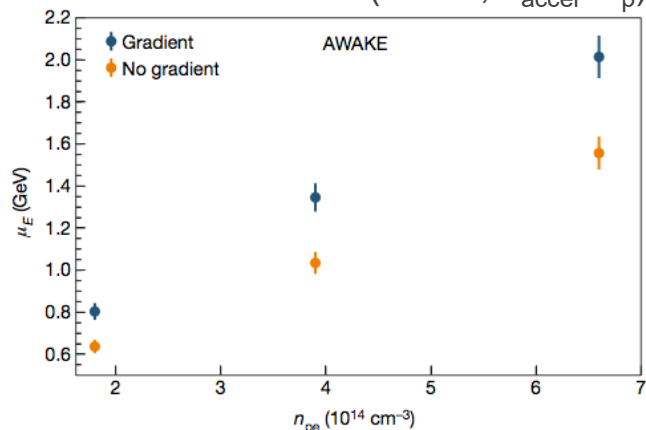
- RIF seeding of SM



F. Batsch, PRL126, 164802 (2021)

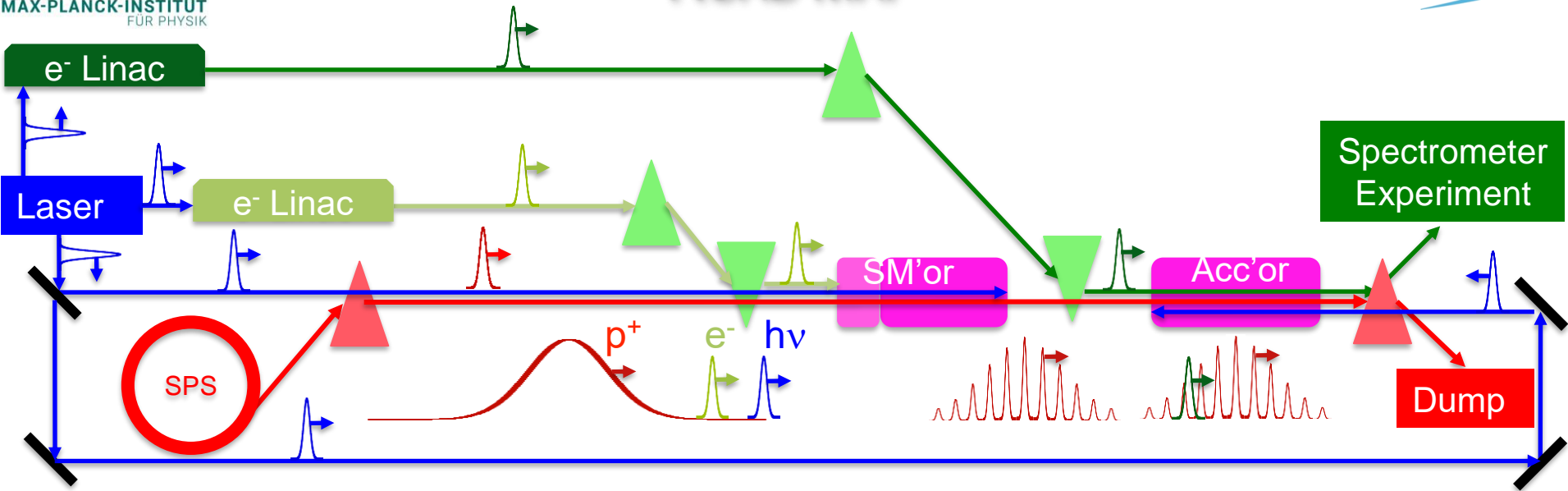


- Acceleration of externally-injected e-
- 19MeV -> 2GeV (test e-,  $L_{\text{accel}} < L_p$ )



AWAKE, Nature 561, 363 (2018)

# ROAD MAP



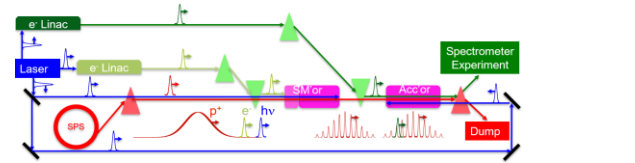
Based on state-of-the-art:

- ✧ Separate self-modulation and acceleration
- ✧ Two plasmas
- ✧ Bunch quality sufficient for applications (TBD)

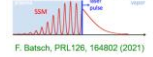
P. Muggli, *Journal of Physics: Conference Series* 1596, 012008(2020).

Four milestones:

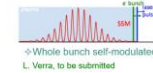
- ❖ e-bunch seeding of SM (2021-2)
- ❖ Plasma density step in the SM'or (2023-4)
- ❖ External injection of e-bunch (~10GeV)
- ❖ Scalable (accelerator) plasma source



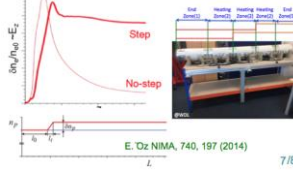
Run 1: Relativistic ionization front (RIF) seeding



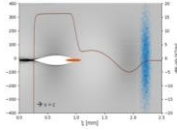
Run 2a: e-bunch seeding



Caldwell, POP 18, 103101 (2011)

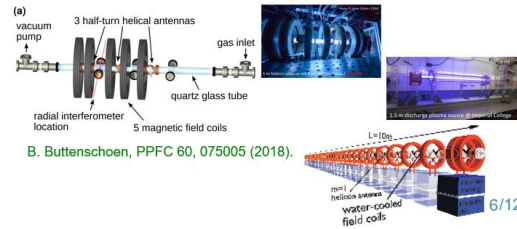


SM'or Acc'or  
V. K. Berglyd Olsen, PR-AB 21, 011301 (2018)



Quality preservation: Q, E,  $\Delta E/E$ ,  $\epsilon$   
 ❖ Blow-out  
 ❖ Beam loading  
 ❖ Matching

❖ Helicon source, discharge source



- ❖ Early 2030: ready to propose/build first particle physics experiment(s)
- ❖ Continue develop the concept towards TeV e-bunches

White paper draft

<https://www.overleaf.com/read/gjgdxfgyfjnp>

White Paper: AWAKE, Plasma Wakefield Acceleration of  
Electron Bunches for Near and Long Term Particle Physics  
Applications

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- AWAKE has a clear roadmap towards (early and long-term) applications to particle physics
- Accelerator and particle physics case(s) developed in parallel
- Draft of White Paper exists, ready to be “integrated” in AF6 White Paper submissions



# Thank you to my collaborators



# Thank you!

<http://www.mpp.mpg.de/~muggli>

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