STATUS AND PLANS FOR THE AWAKE EXPERiMENT

AWAKE status report

V. Bencini, A. Caldwell, S. Doebert, J. Farmer, E. Granados, E. Gschwendtner, E. Guran, S. Mazzoni, P. Muggli, A. Pukhov, A. Sublet, M. Wing, G. Zevi Della Porta

on behalf of AWAKE

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

AWAKE Collaboration: 23 Institutes World-Wide

- University of Oslo, Oslo, Norway
- CERN, Geneva, Switzerland
- University of Manchester, Manchester, UK
- Cockcroft Institute, Daresbury, UK
- Lancaster University, Lancaster, UK
- Oxford University, UK
- Max Planck Institute for Physics, Munich, Germany
- Max Planck Institute for Plasma Physics, Greifswald, Germany
- UCL, London, UK
- UNIST, Ulsan, Republic of Korea
- Philipps-Universität Marburg, Marburg, Germany
- Heinrich-Heine-University of Düsseldorf, Düsseldorf, Germany
- University of Liverpool, Liverpool, UK
- ISCTE - Instituto Universitéario de Lisboa, Portugal
- Budker Institute of Nuclear Physics SB RAS, Novosibirsk, Russia
- Novosibirsk State University, Novosibirsk, Russia
- GoLP/Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico, Universidade de Lisboa, Lisbon, Portugal
- TRIUMF, Vancouver, Canada
- Ludwig-Maximilians-Universität, Munich, Germany
- University of Wisconsin, Madison, US
- Uppsala University, Sweden
- Wigner Institute, Budapest
- Swiss Plasma Center group of EPFL, Lausanne, Switzerland

✧Driving wakefields in plasma with a proton (p^+) bunch

✧Accelerating externally-injected electrons (e^-) to GeV (SPS) to TeV (LHC) energy scale

✧Relativistic proton (p^+) bunches with tens to hundreds of kJ are available

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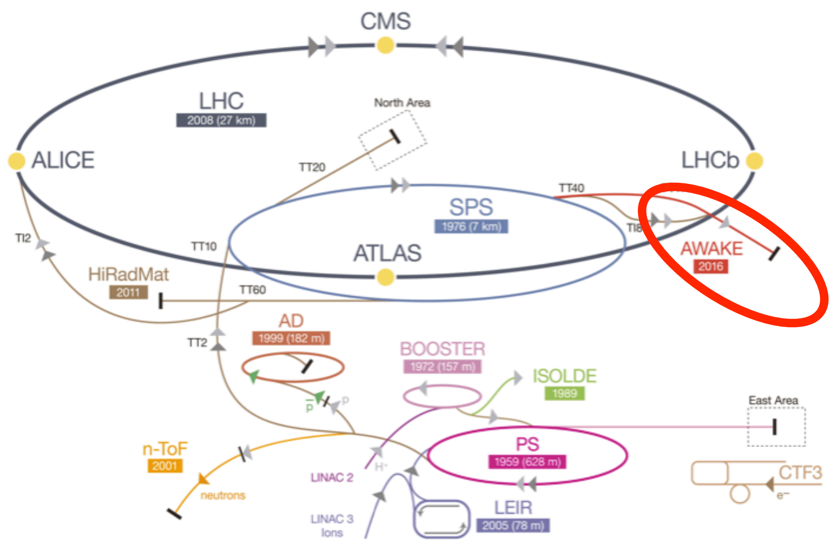

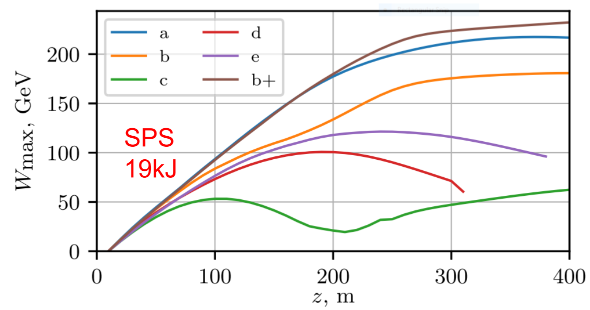

P. Tuev, K. V. Lotov, PPFC 63, 125027 (2021)

SPS driver (19kJ):
~200GeV in ~200m
~10^9 e^-

2D numerical simulation results

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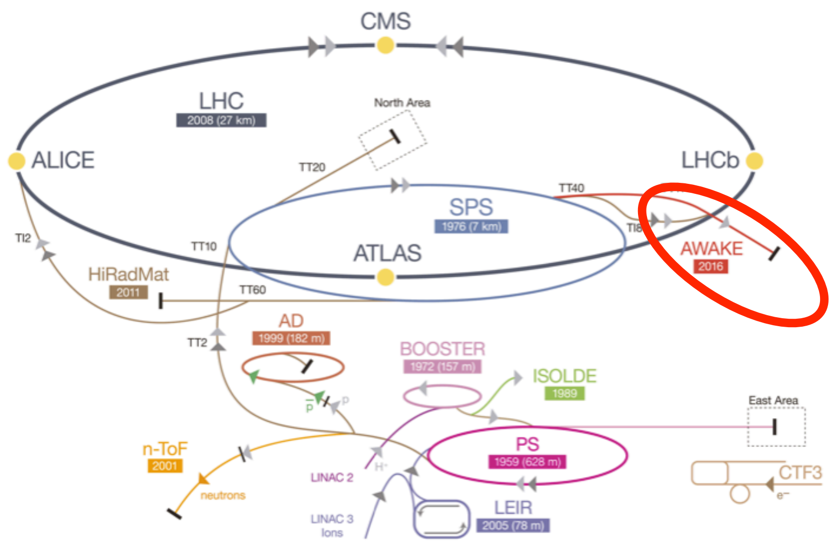

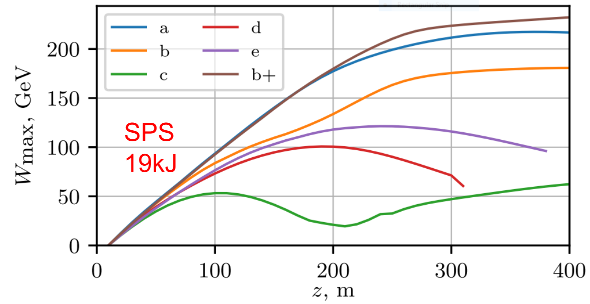

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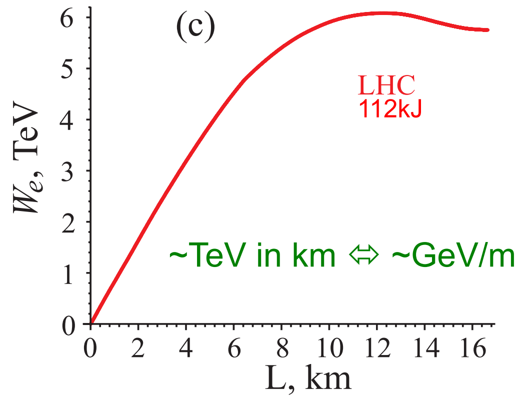


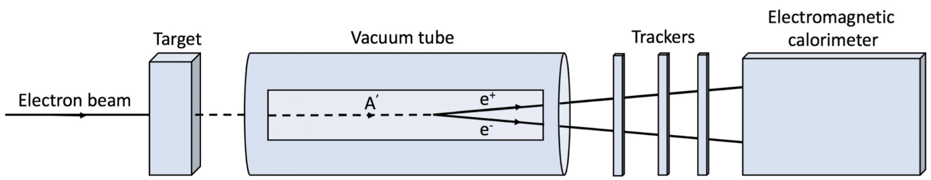
A. Caldwell, K. V. Lotov, Phys. Plasmas **18**, 13101 (2011)

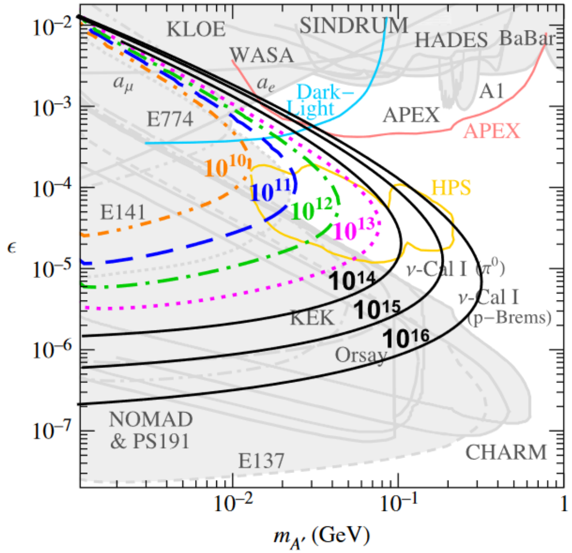
LHC driver (119kJ):
~5TeV in ~7km
~10^9 e^-

APPLICATIONS TO PARTICLE PHYSICS

M. Wing, Phil. Trans. Royal Soc 377,20180185 (2019)
AWAKE collaboration, Symmetry 2022, 14(8), 1680

- 20-200Gev e^-, SPS p^+ bunch as driver:
  - Fixed target, beam-dump experiments: search for dark photons
  - Nonlinear QED: e^-/photon collisions
  - ep or eA collisions, QCD, structure of matter
  - …





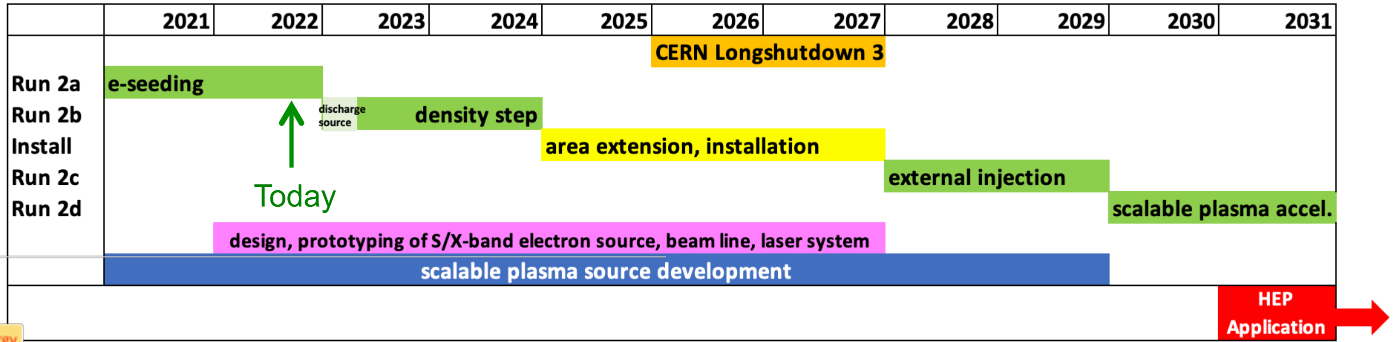
- TeV e^-, LHC p^+ bunch as driver:
  - High energy ep or eA collider

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

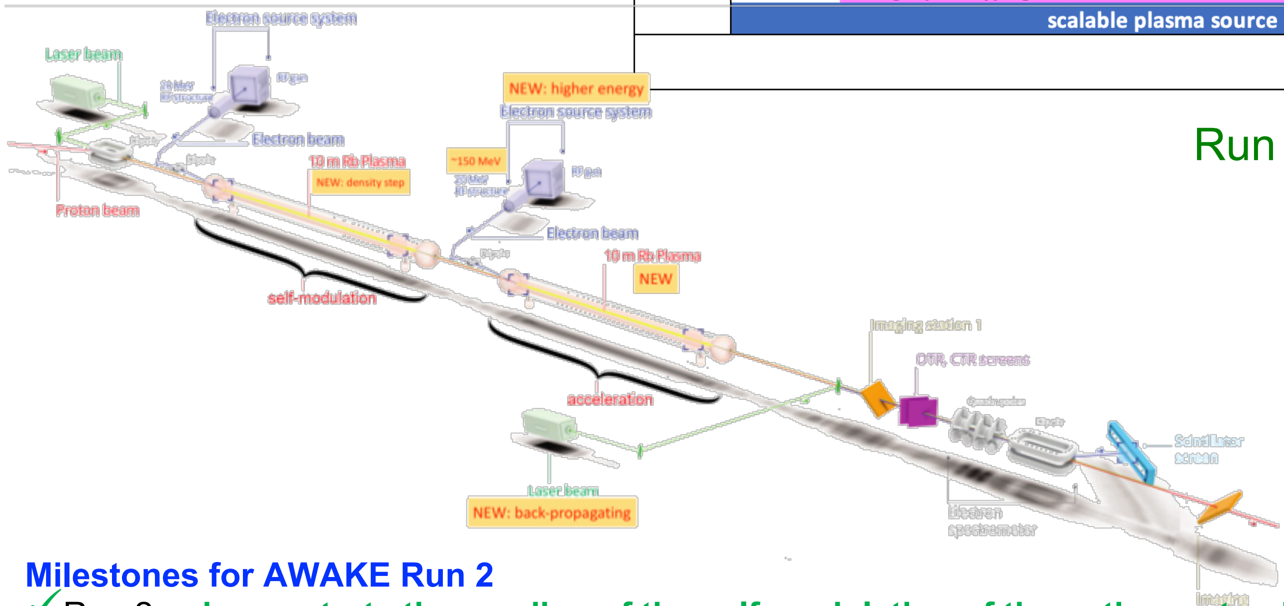
- Luminosity of collider applications limited by single use of low rep-rate p^+ bunch production

CLEAR TIME LINE TOWARDS AN ACCELERATOR

Run 1 +



Run 2



L. Verra et al. (AWAKE Collaboration), Phys. Rev. Lett. 129, 024802 (2022)

Milestones for AWAKE Run 2

✓ Run 2a: **demonstrate the seeding of the self-modulation of the entire proton bunch with an electron bunch**

Run 2b: maintain large wakefield amplitudes over long plasma distances by introducing a step in the plasma density

Run 2c: demonstrate electron acceleration and emittance preservation of externally injected electrons.

Run 2d: development of scalable plasma sources to 100s meters length with sub-% level plasma density uniformity.

➔ **Propose first applications for particle physics experiments with 50-200 GeV electron bunches**

OUTLINE

- ✧Introduction to AWAKE and to the self-modulated plasma wakefield accelerator (PWFA)
- ✧Topics addressed in 2022 in the experiment (Run 2a):
  - ✧Seeding of self-modulation (SM) with an electron bunch

    Verra, (AWAKE Coll.), Phys. Rev. Lett. 129, 024802 (2022)
  - ✧Hosing studies
  - ✧Plasma light studies

    } Preliminary
    - ✧Plasma density ramp
    - ✧Propagation in very-low-density plasma
    - ✧SM of a wide proton bunch
    - ✧SMI/RIF-SSM transition
- ✧Run plan for 2023-4 (Run 2 b)
- ✧Beam time request
- ✧Summary

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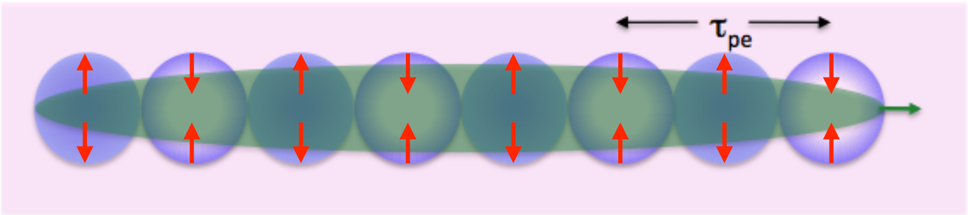
on behalf of

AWAKE

SELF-MODULATiON

Long driver (p^+), dense plasma, $\sigma_t >> 1/\omega_{pe}$, $\sigma_t \sim c/\omega_{pe}$



(1)

$$\omega_{pe} = \left(\frac{n_{e0}e^2}{\epsilon_0 m_e}\right)^{1/2}$$

Plasma e^- angular frequency

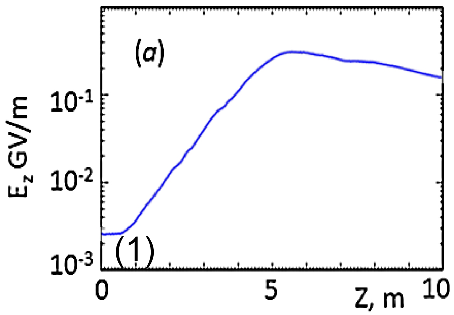
<u>Growth mechanism:</u>

Initial (transverse) wakefields

Periodic focusing/defocusing

(1)

Pukhov, PRL107 145003 (2011)



SELF-MODULATION

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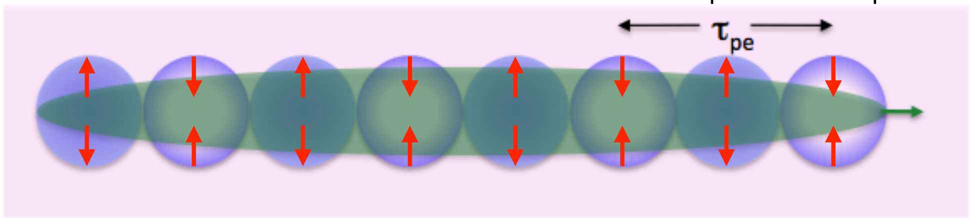
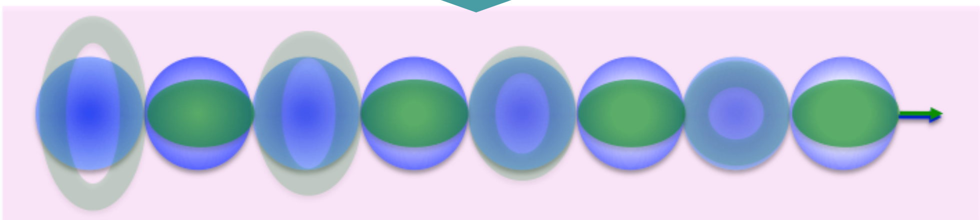


(1)

Self-modulation



(2)

Growth mechanism:

Initial (transverse) wakefields

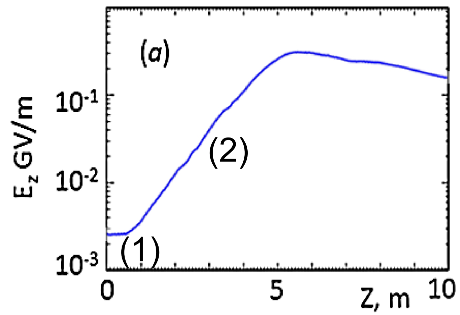
(1)

Periodic focusing/defocusing

(2)

Density modulation

Pukhov, PRL107 145003 (2011)



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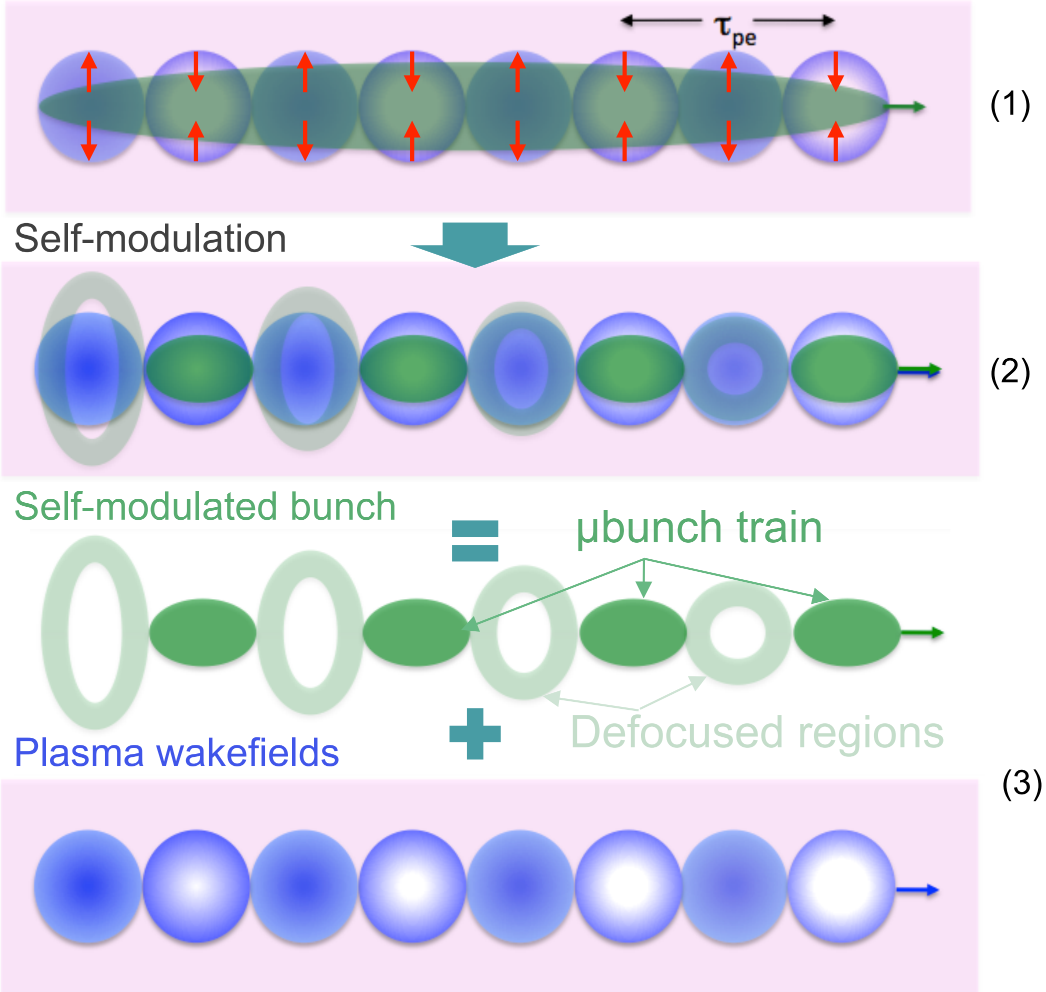

Growth mechanism:

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(1)

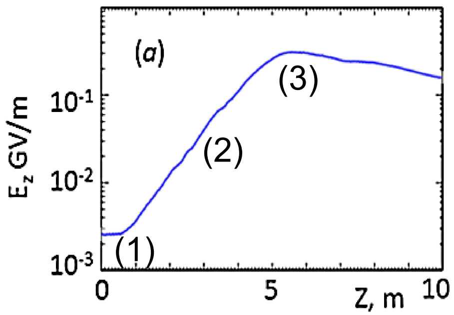
Periodic focusing/defocusing

(2)

Density modulation

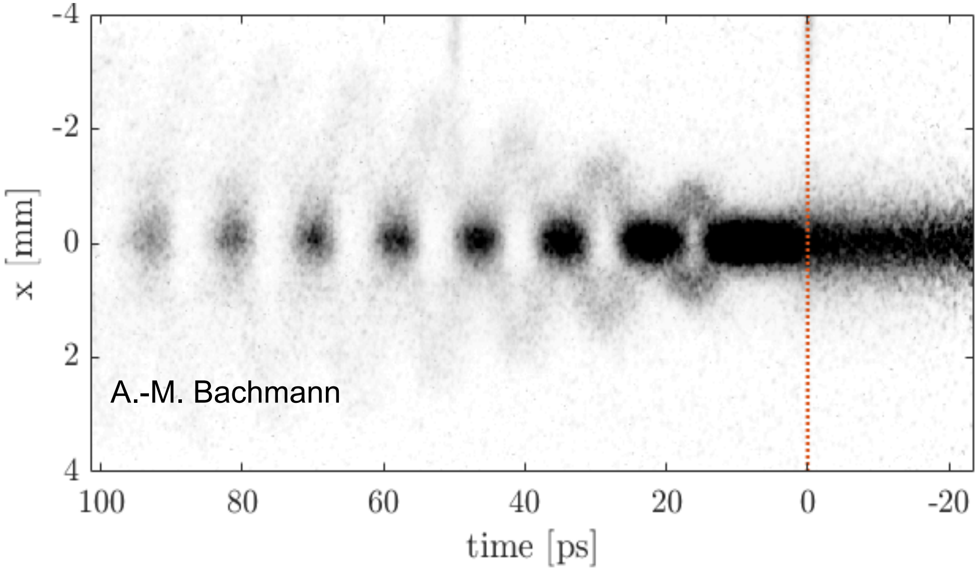
Full modulation - bunch train (3)

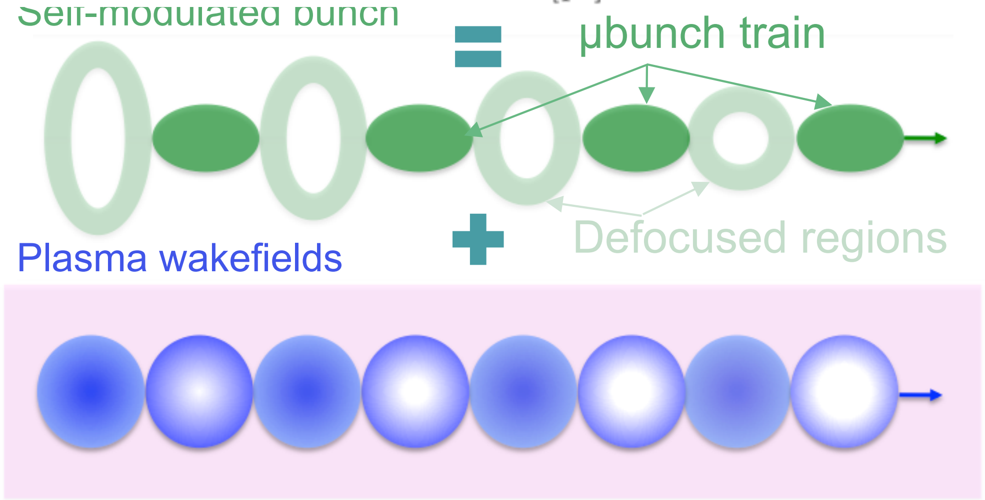
Pukhov, PRL107 145003 (2011)



(3)
- ✧Train period $\sim\tau_{pe}=2\pi/\omega_{pe}$
- ✧µbunch length $< \tau_{pe}$
- ✧Resonantly drives wakefields to large amplitude
- ✧Self-modulation necessary to drive ~GV/m accelerating fields in $\sim 10^{14}cm^{-3}$ density plasma

SELF-MODULATION





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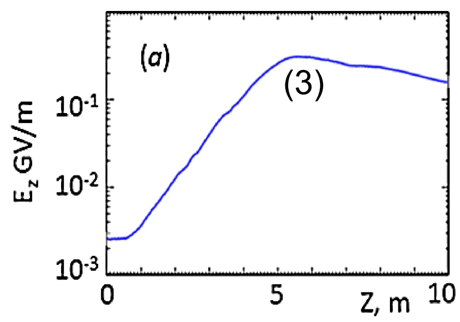

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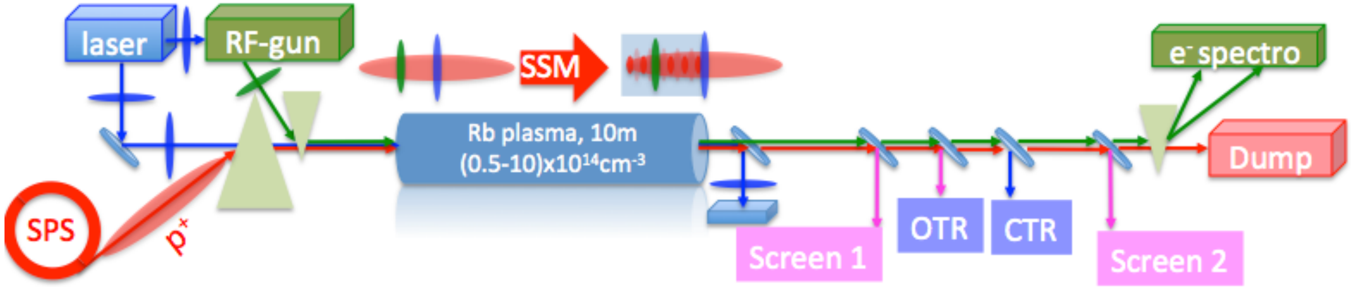
SUCCESSFUL RUN 1

✧Single, 10m-long, rubidium plasma

✧$n_{e0}=(0.5\text{-}10)\times10^{14}cm^{-3}$



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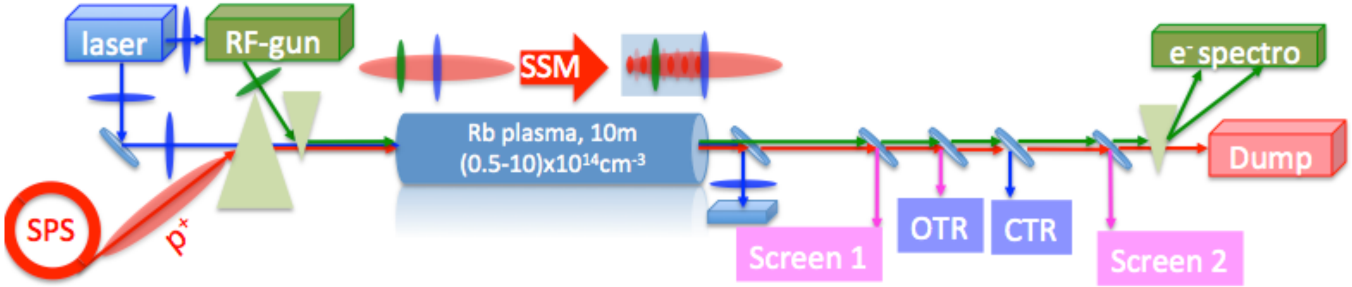
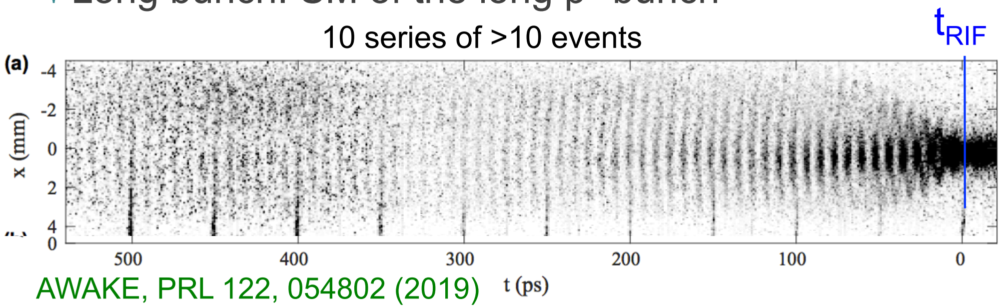
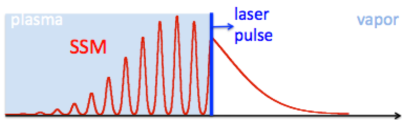


✧Long bunch: SM of the long p⁺ bunch

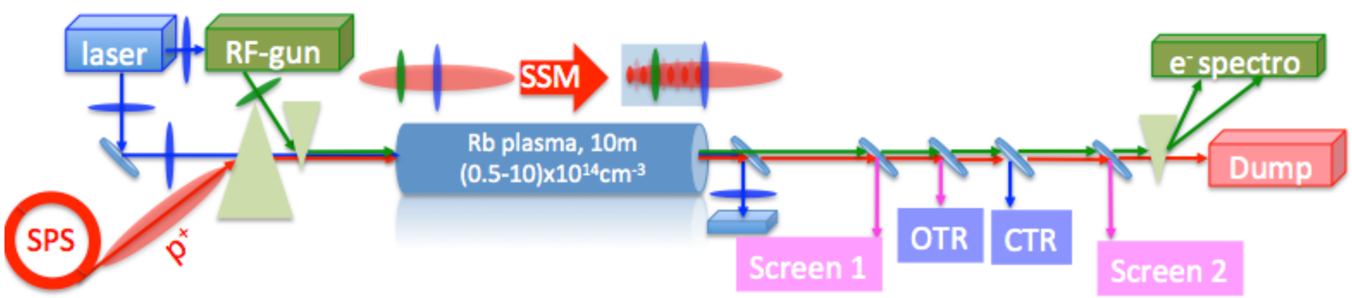


AWAKE, PRL 122, 054802 (2019)
Turner, (AWAKE coll.), PRL 122, 054801 (2019)
Braunmueller, (AWAKE coll.), PRL 125, 264801 (2020)



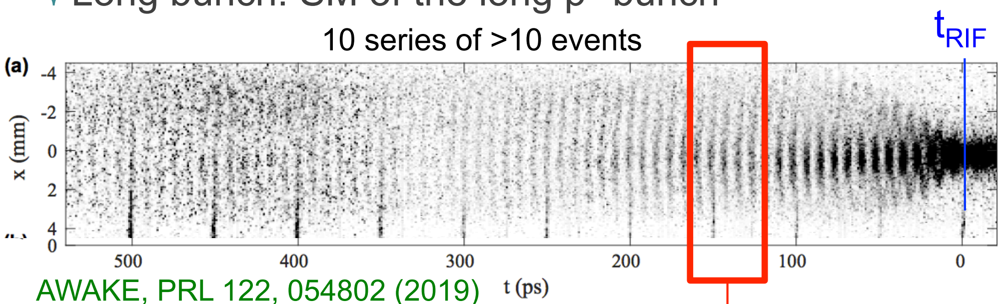
SUCCESSFUL RUN 1

- Single, 10m-long, rubidium plasma
- n_{e0}=(0.5-10)x10^{14}cm^{-3}



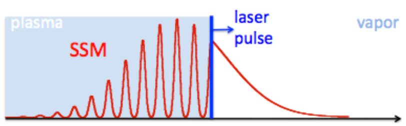
- Long bunch: SM of the long p⁺ bunch

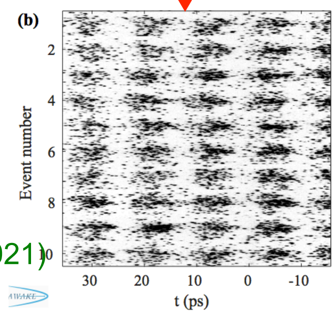
10 series of >10 events



AWAKE, PRL 122, 054802 (2019)
Turner, (AWAKE coll.), PRL 122, 054801 (2019)
Braunmueller, (AWAKE coll.), PRL 125, 264801 (2020)

- RIF seeding of SM





Batsch, (AWAKE coll.), PRL126, 164802 (2021)

SUCCESSFUL RUN 1

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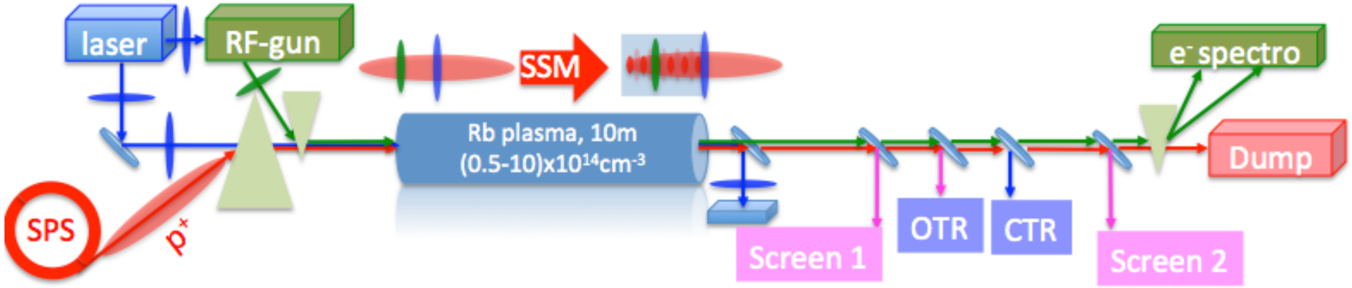
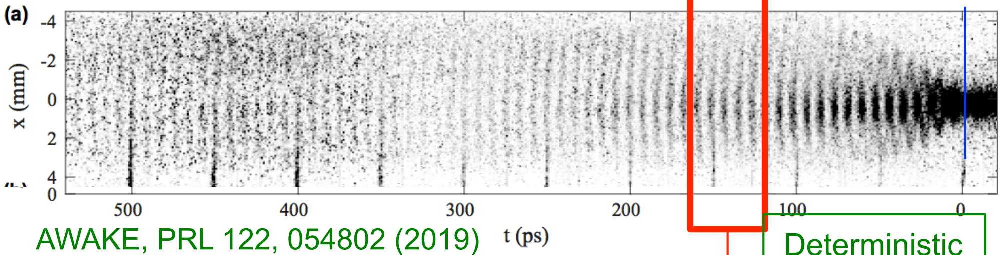


✧Long bunch: SM of the long p$^+$ bunch

10 series of >10 events



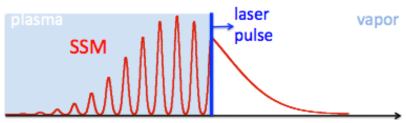
AWAKE, PRL 122, 054802 (2019)

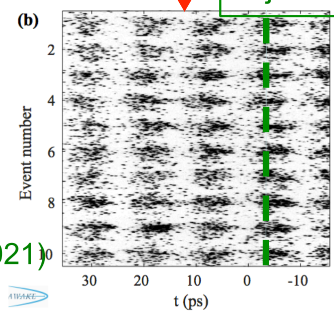
Turner, (AWAKE coll.), PRL 122, 054801 (2019)

Braunmueller, (AWAKE coll.), PRL 125, 264801 (2020)

Deterministic External Injection e$^-$

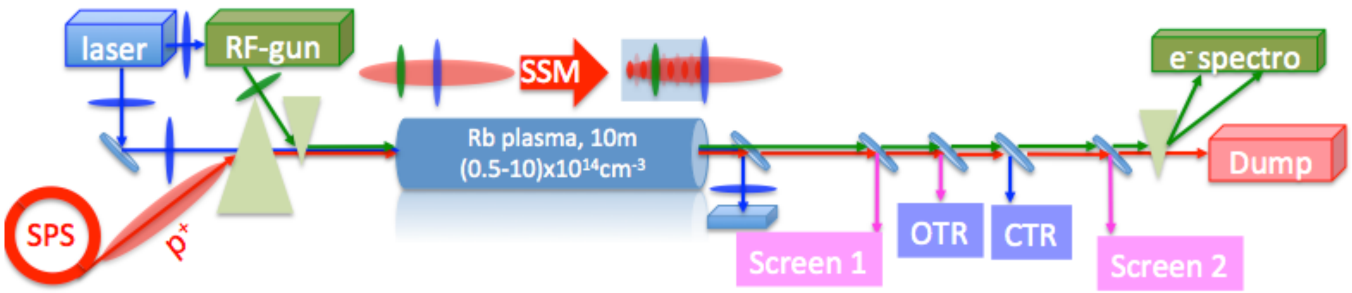
✧RIF seeding of SM





Batsch, (AWAKE coll.), PRL126, 164802 (2021)

SUCCESSFUL RUN 1

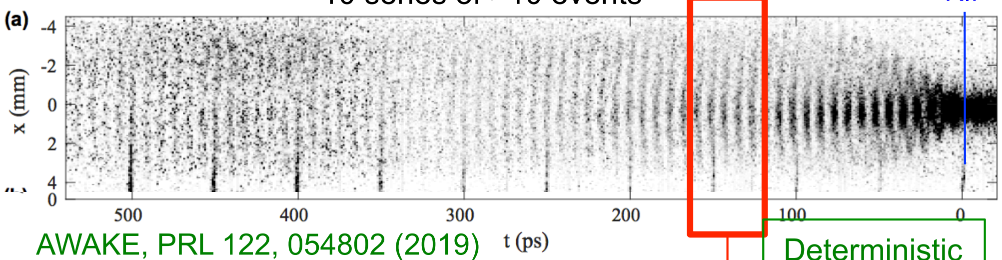


✧Single, 10m-long, rubidium plasma

✧n_{e0}=(0.5-10)x10^{14}cm^{-3}

✧Long bunch: SM of the long p^+ bunch

10 series of >10 events



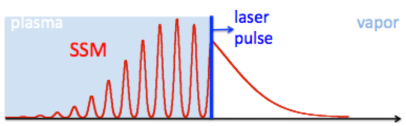
AWAKE, PRL 122, 054802 (2019)

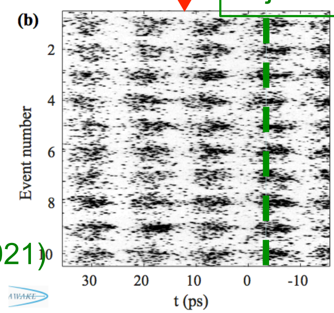
Turner, (AWAKE coll.), PRL 122, 054801 (2019)

Braunmueller, (AWAKE coll.), PRL 125, 264801 (2020)

Deterministic External Injection e-

✧RIF seeding of SM

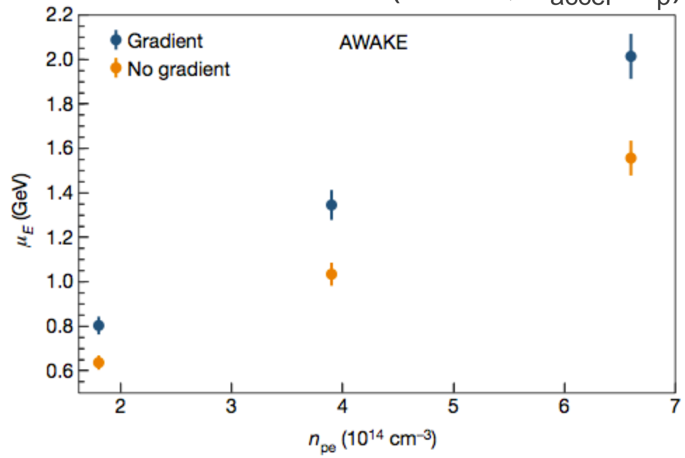




Batsch, (AWAKE coll.), PRL126, 164802 (2021)

✧Acceleration of externally-injected e-

✧19MeV -> 2GeV (test e-, L_{accel}<L_p)



AWAKE, Nature 561, 363 (2018)

SUCCESSFUL RUN 1

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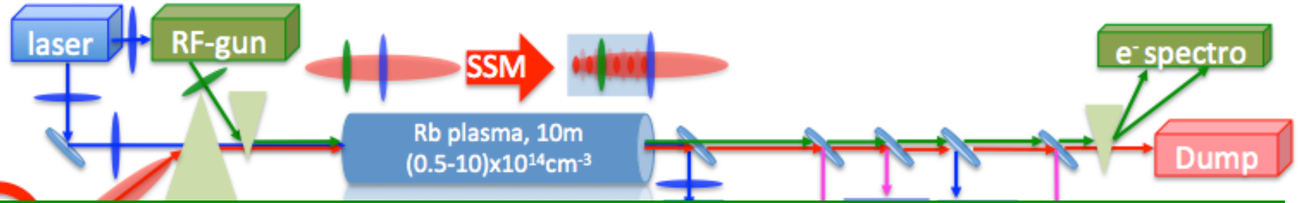
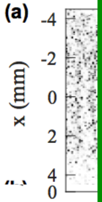


✧L



e⁻

✧Very Successful

✧Demonstration of <u>seeded</u> self-modulation

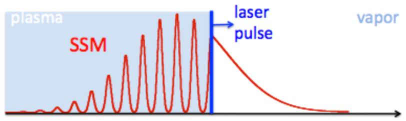
✧Acceleration of externally injected e⁻ 19MeV to 2GeV

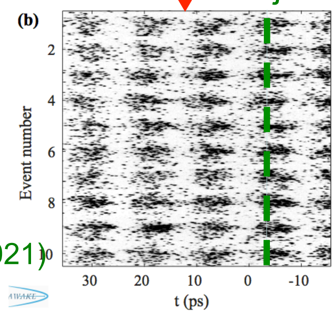
✧…

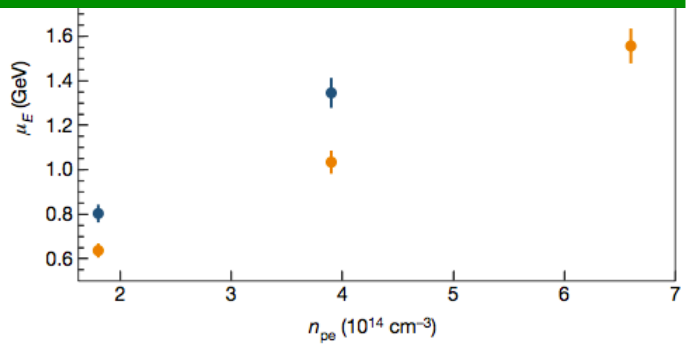
AWAKE, PRL 122, 054802 (2019)
Turner, (AWAKE coll.), PRL 122, 054801 (2019)
Braunmueller, (AWAKE coll.), PRL 125, 264801 (2020)

Deterministic
External
Injection e⁻

✧RIF seeding of SM



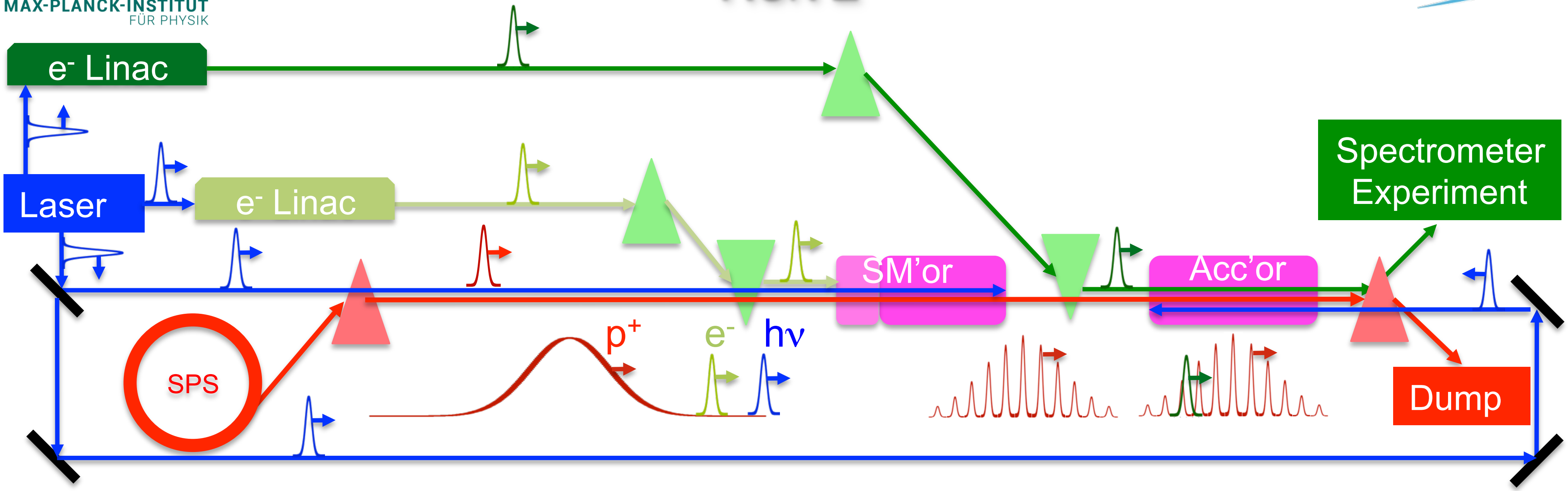




Batsch, (AWAKE coll.), PRL126, 164802 (2021)

AWAKE, Nature 561, 363 (2018)

Run 2



Based on Run 1 results:

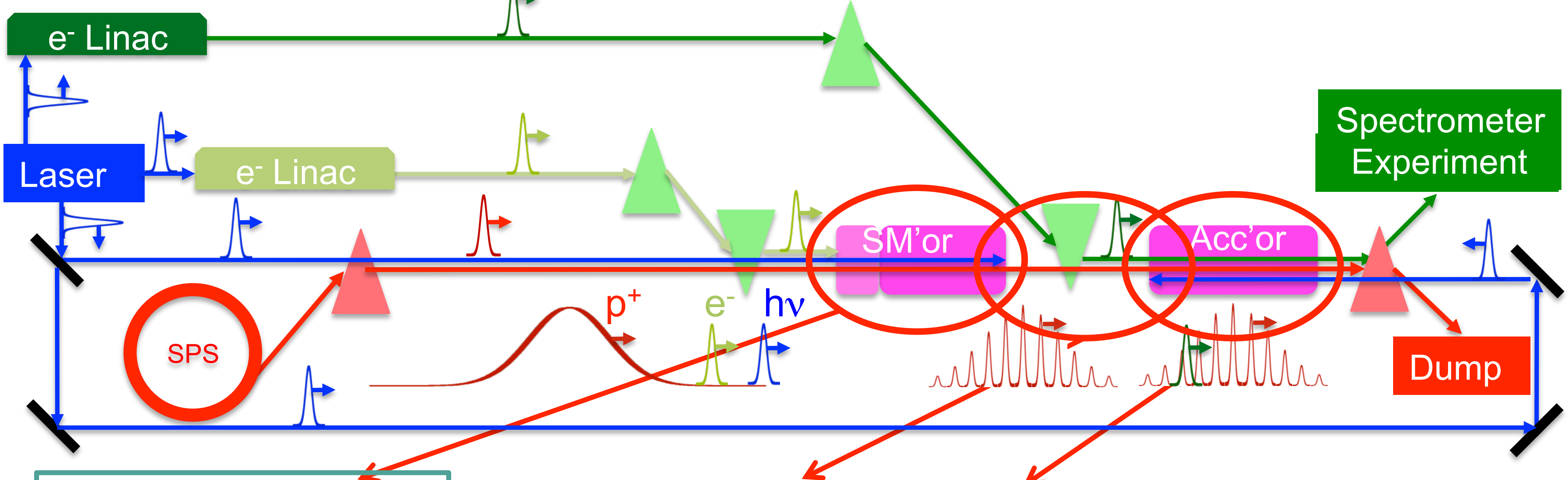
✧Separate self-modulation and acceleration

✧Two plasmas

✧Bunch quality sufficient for applications

Muggli (AWAKE Coll.), J. of Phys.: Conf. Series1596, 012008 (2020).

RUN 2: e⁻ BUNCH QUALITY, ACCELERATION



Self-Modulator, **Run 2a**,b:

✧**e⁻ bunch seeding of SM**

✧Plasma density step

e⁻ external injection, Runs 2 c,d:

✧On-axis injection

✧Bunch quality

✧Plasma source for >>GeV scale

Accelerator:

✧Blow-out, quasi-linear

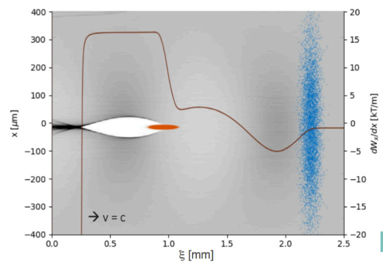
✧Beam loading

✧Beam matching

✧Bunch quality

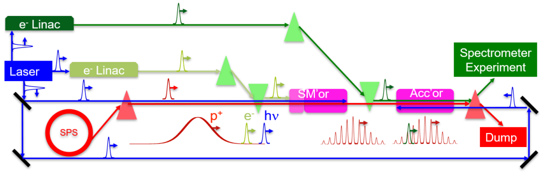
Before LS3

After LS3



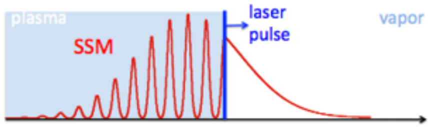
V. K. Berglyd Olsen, PR- AB 21, 011301 (2018)

Run 2a: e-Bunch Seeding of SM



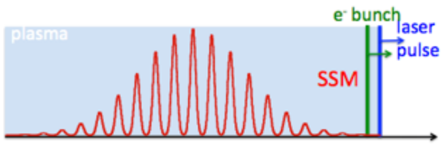
✧e-bunch seeding of SM (2021-2)

Run 1: Relativistic ionization front (RIF) seeding

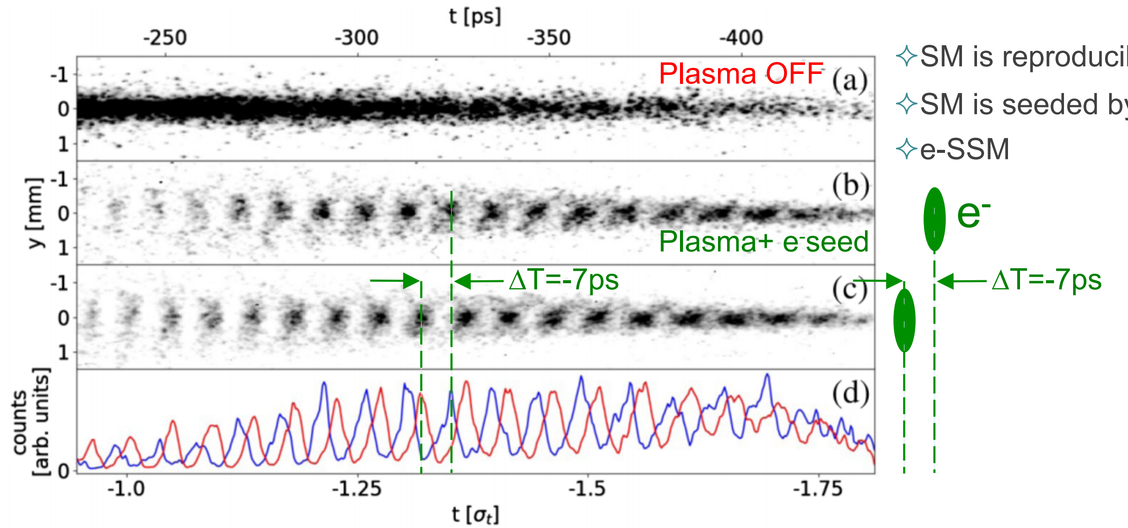


F. Batsch, PRL126, 164802 (2021)

Run 2a: e-bunch seeding



✧Whole bunch self-modulated



✧SM is reproducible

✧SM is seeded by the e⁻ bunch

✧e-SSM

L. Verra, PhD 2022

✧Demonstrated seeding of SM with e-bunch

Verra, (AWAKE Coll.), Phys. Rev. Lett. 129, 024802 (2022)

RUN 2a: e-BUNCH SEEDING OF SM

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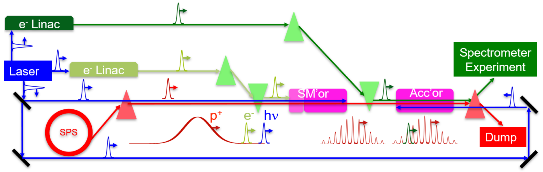
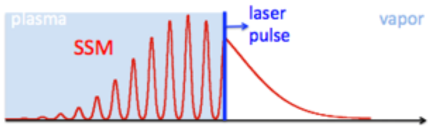
AWAKE



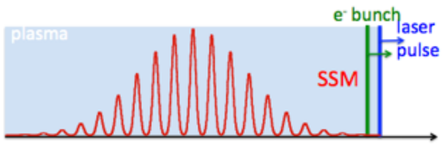
✧e-bunch seeding of SM (2021-2)

Run 1: Relativistic ionization front (RIF) seeding



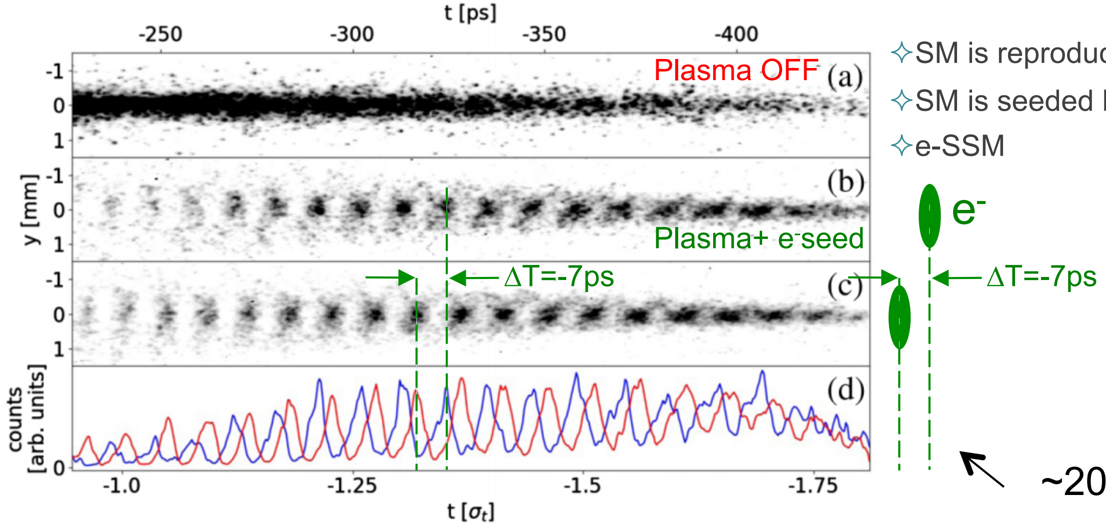
F. Batsch, PRL126, 164802 (2021)

Run 2a: e-bunch seeding



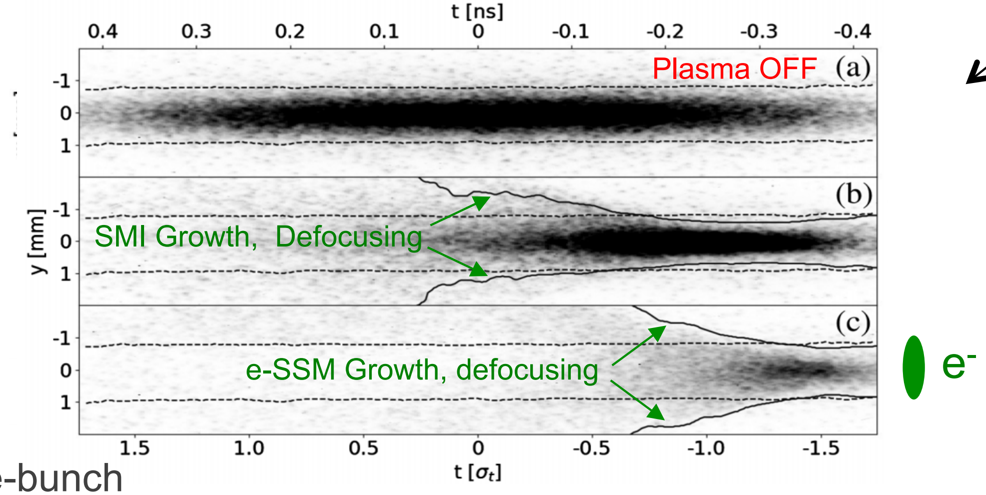
✧Whole bunch self-modulated

✧SM is reproducible
✧SM is seeded by the e- bunch
✧e-SSM



~200ps scale

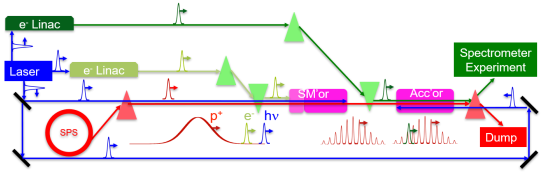
~1ns scale



✧Demonstrated seeding of SM with e-bunch

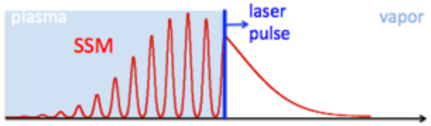
Verra, (AWAKE Coll.), Phys. Rev. Lett. 129, 024802 (2022)

Run 2a: e-Bunch Seeding of SM



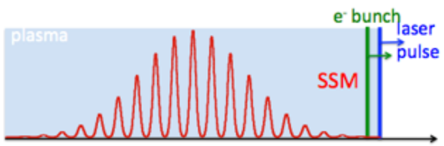
✧e-bunch seeding of SM (2021-2)

Run 1: Relativistic ionization front (RIF) seeding

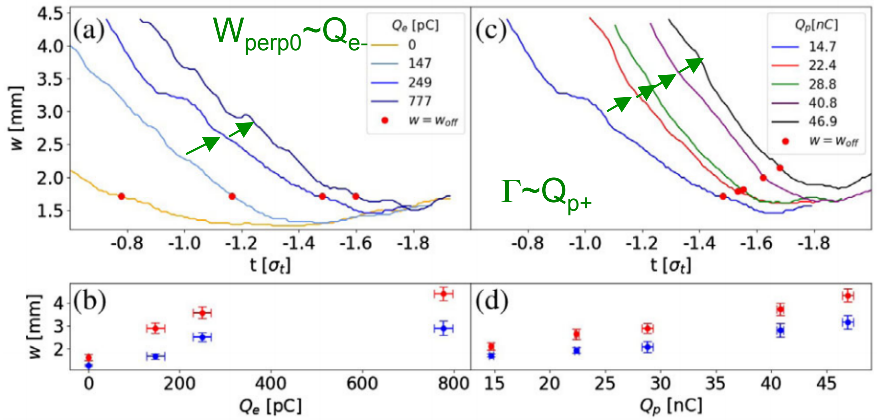


F. Batsch, PRL126, 164802 (2021)

Run 2a: e-bunch seeding



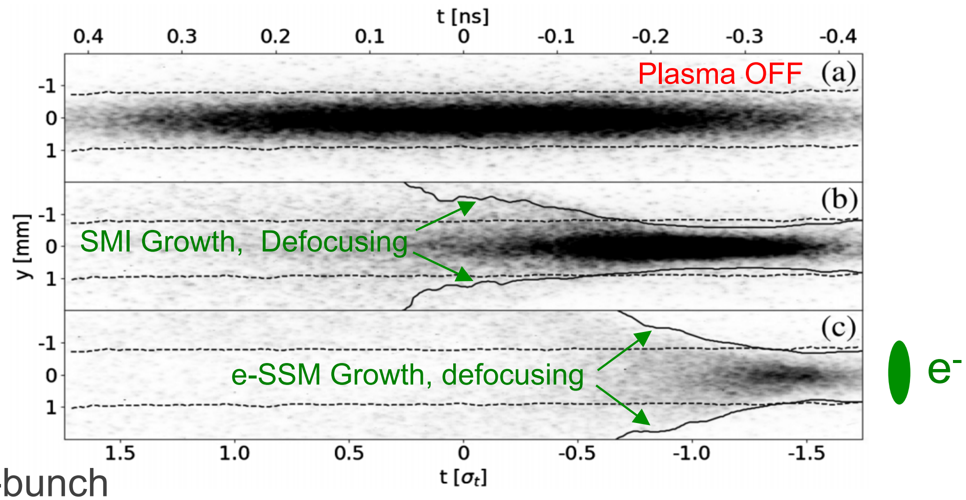
✧Whole bunch self-modulated



✧Control of growth

✧$w \sim W_{perp0}(Q_{e-}) * \exp(\Gamma(Q_{p+}))$

✧Can tune amplitude of wakefields?

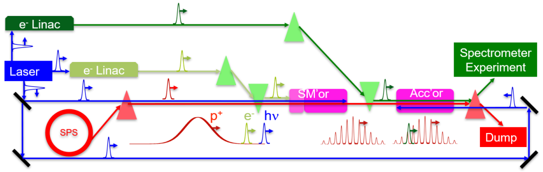


✧Demonstrated seeding of SM with e-bunch

✧Understanding/control of SM process

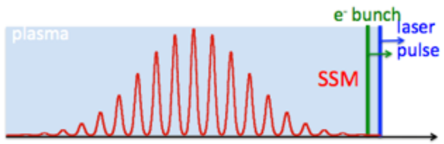
Verra, (AWAKE Coll.), Phys. Rev. Lett. 129, 024802 (2022)

RUN 2a: HOSING



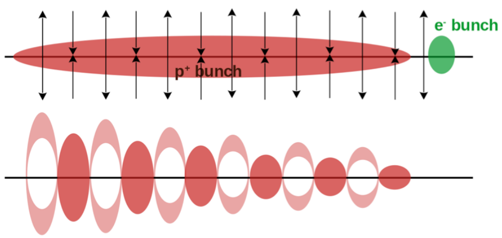
✧e-bunch seeding of SM (2021-2)

Run 2a: e-bunch seeding



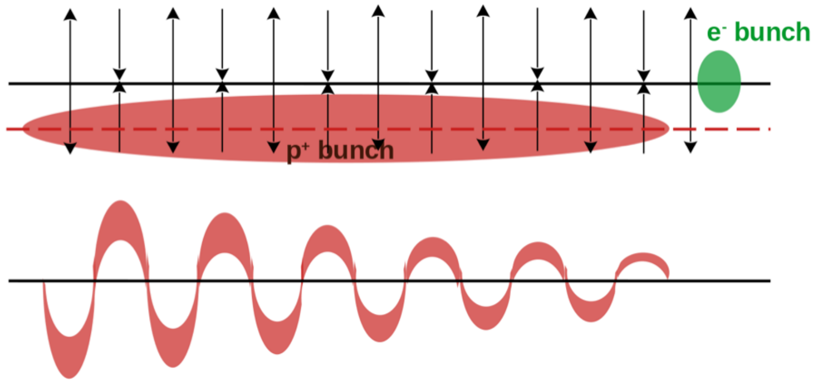
✧Whole bunch self-modulated

✧e^- and p^+ aligned …



✧… axi-symmetric SM

✧e^- and p^+ mis-aligned …

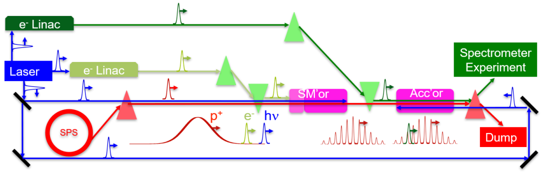


✧… non-axi-symmetric hosing (mis-alignment plane)

✧and SM in the perpendicular plane

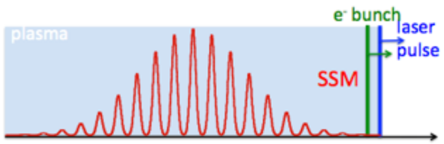
T. Nechaeva, PhD 2023?

Run 2a: Hosing



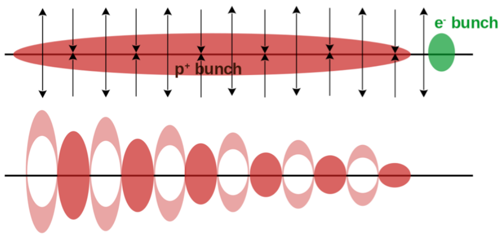
✧e-bunch seeding of SM (2021-2)

Run 2a: e-bunch seeding

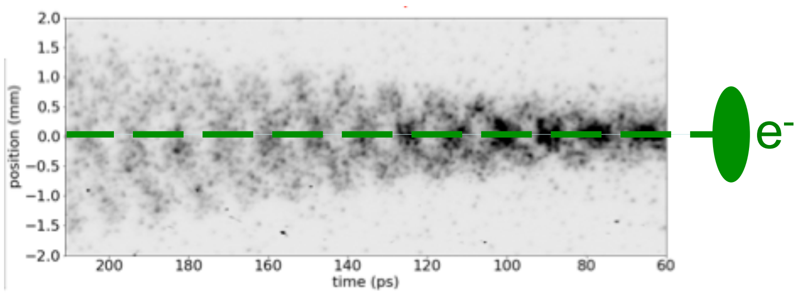


✧Whole bunch self-modulated

✧e^- and p^+ aligned …



✧… axi-symmetric SM



✧e^-/p^+ aligned

✧Self modulation

✧Symmetric

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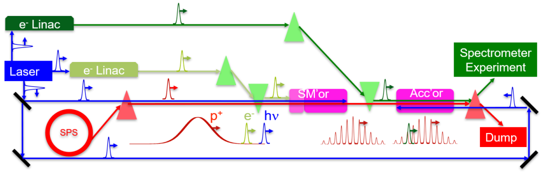
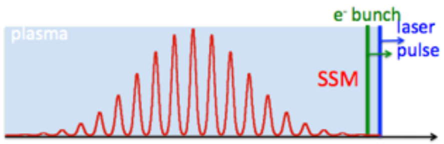
Run 2a: Hosing



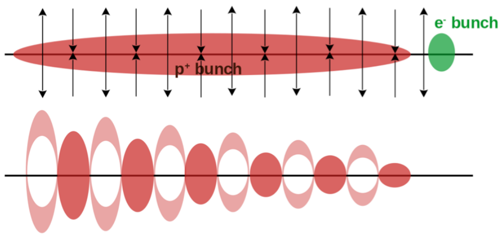
✧e-bunch seeding of SM (2021-2)

Run 2a: e-bunch seeding

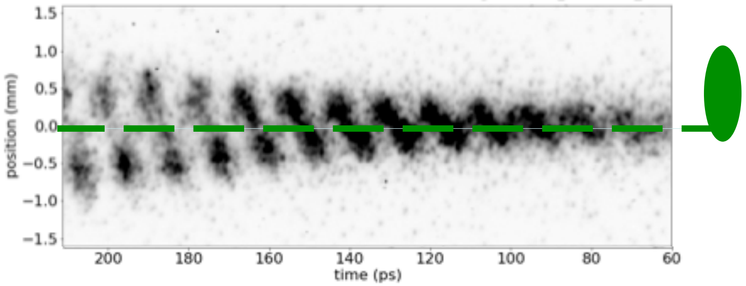


✧Whole bunch self-modulated

✧e^- and p^+ aligned …



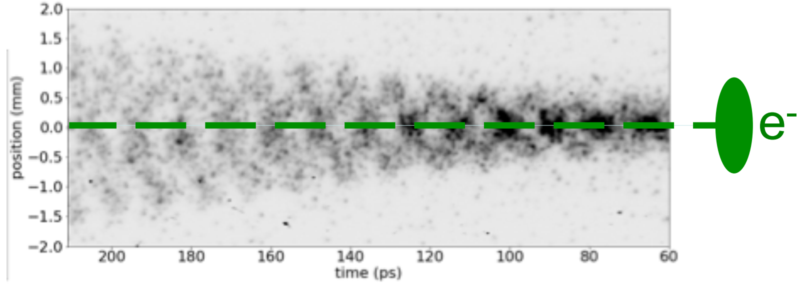
✧… axi-symmetric SM



✧e^-/p^+ mis-aligned

✧Hosing

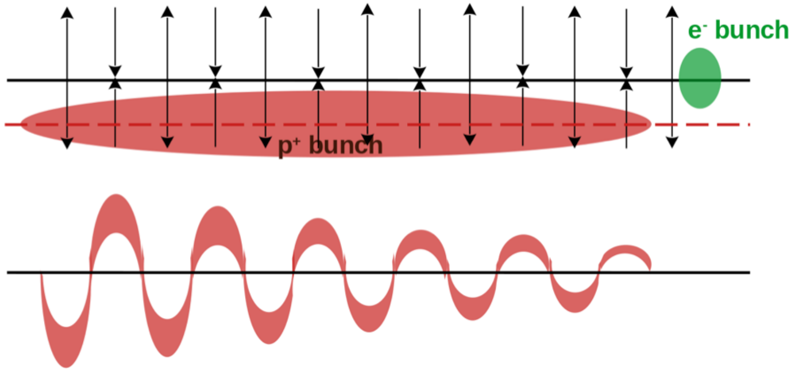
✧Centroid oscillation



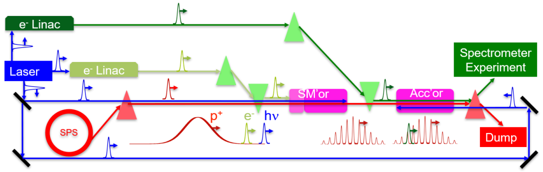
✧e^-/p^+ aligned

✧Self modulation

✧Symmetric

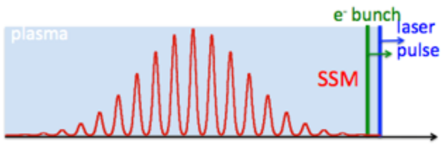


RUN 2a: HOSING



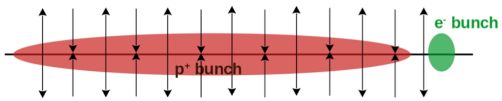
✧e-bunch seeding of SM (2021-2)

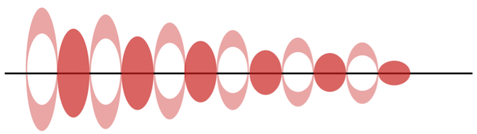
Run 2a: e-bunch seeding



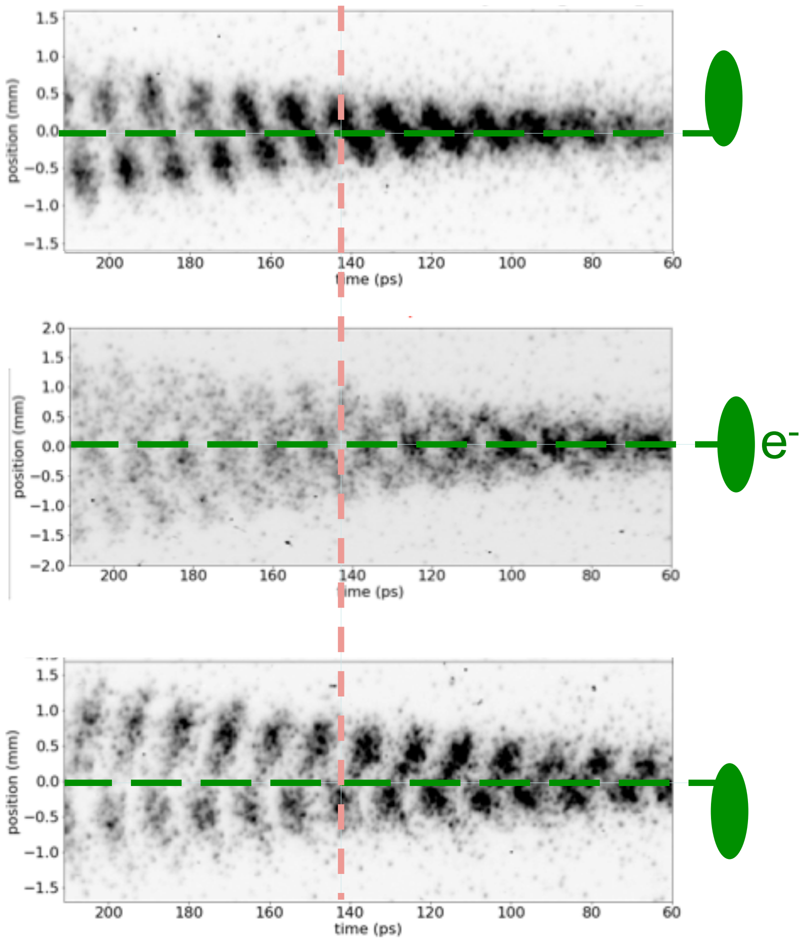
✧Whole bunch self-modulated

✧e^- and p^+ aligned …





✧… axi-symmetric SM



✧e^-/p^+ mis-aligned
✧Hosing
✧Centroid oscillation

✧e^-/p^+ aligned
✧Self modulation
✧Symmetric

✧e^-/p^+ mis-aligned
✧Hosing
✧Reversed!

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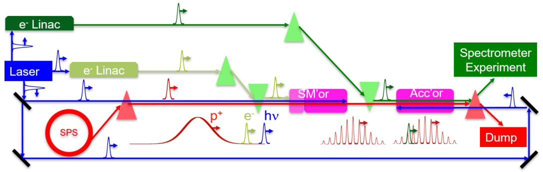
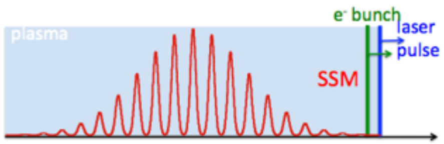
Run 2a: Hosing



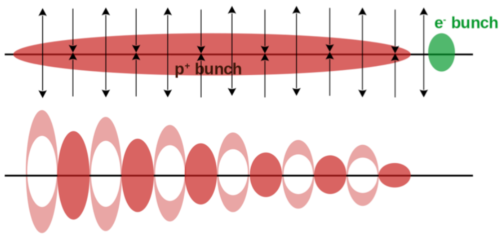
✧e-bunch seeding of SM (2021-2)

Run 2a: e-bunch seeding

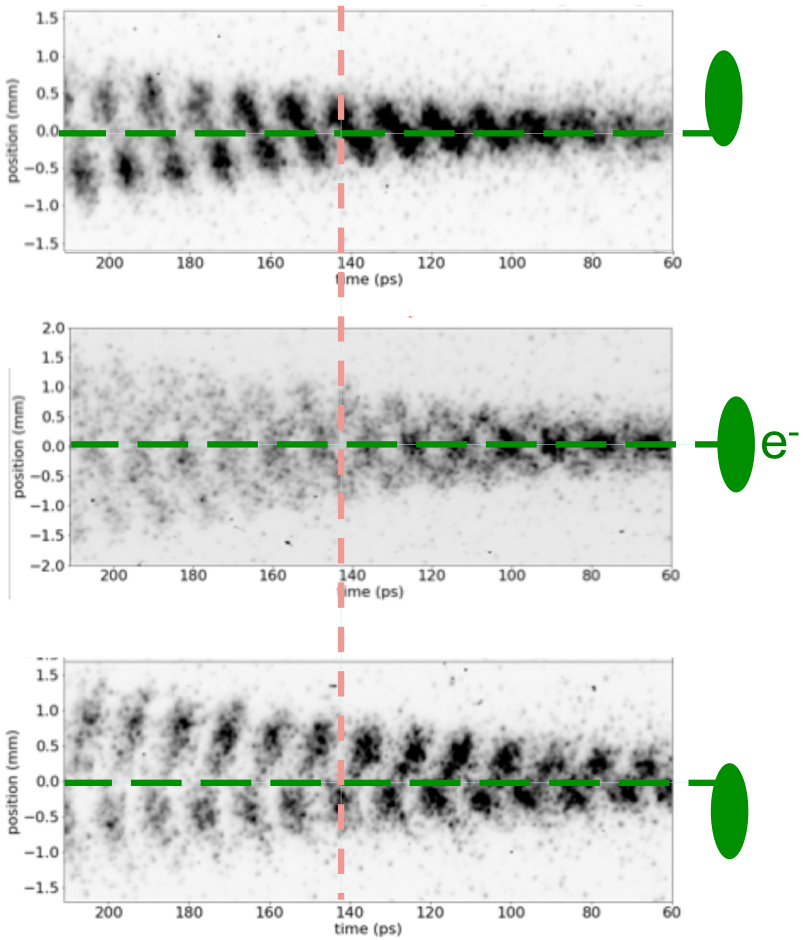


✧Whole bunch self-modulated

✧e^- and p^+ aligned …



✧… axi-symmetric SM



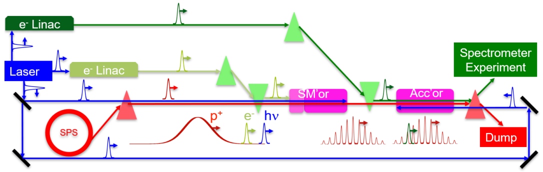
✧e^-/p^+ mis-aligned
✧Hosing
✧Centroid oscillation

✧e^-/p^+ aligned
✧Self modulation
✧Symmetric

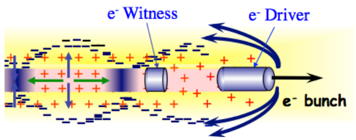
✧e^-/p^+ mis-aligned
✧Hosing
✧Reversed!

✧Hosing could deteriorate, limit the acceleration process…

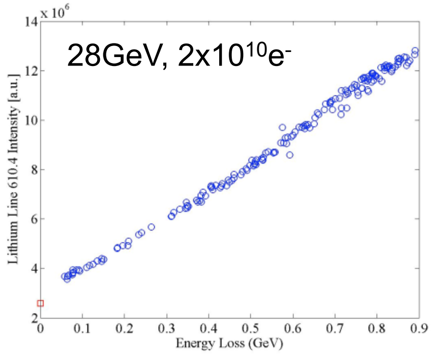
Run 2a: Plasma Light



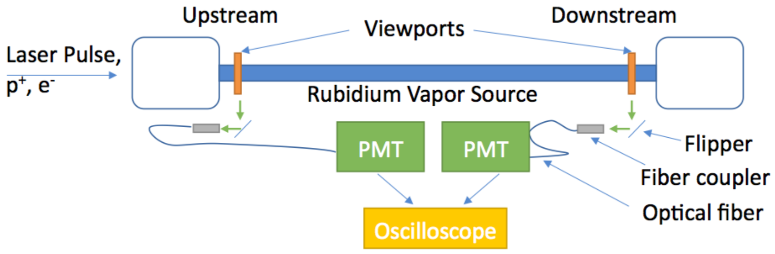
✧e-bunch seeding of SM (2021-2)



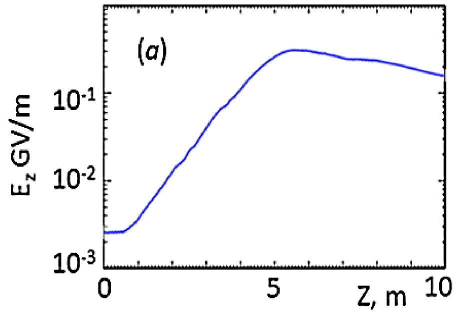
E. Oz et al, AIP Conference proceedings **737**, 708 (2004)



✧Amount of plasma light ~ energy deposited in wakefields!



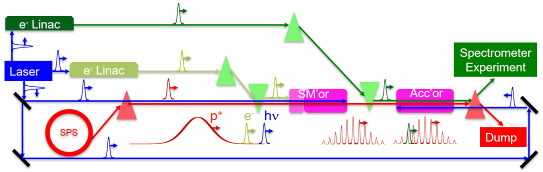
Pukhov, PRL107 145003 (2011)



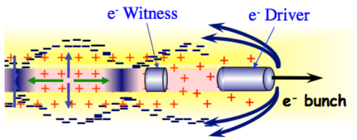
✧Fields/energy evolve along the plasma

✧Plasma light signal evolves along the plasma

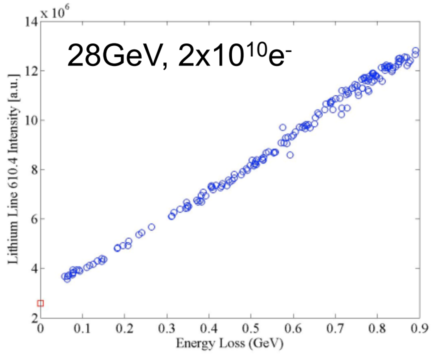
RUN 2a: PLASMA LIGHT



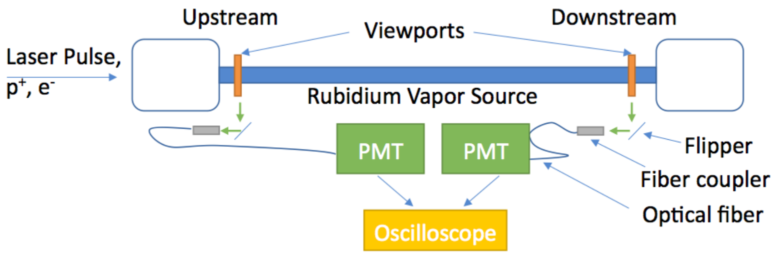
✧e-bunch seeding of SM (2021-2)

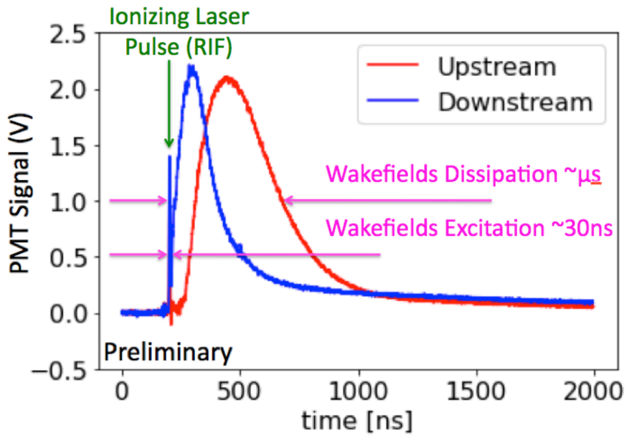


E. Oz et al, AIP Conference proceedings **737**, 708 (2004)

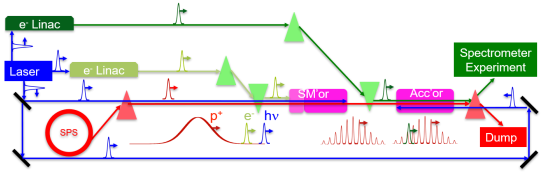


✧Amount of plasma light ~ energy deposited in wakefields!

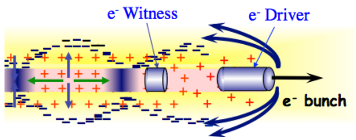




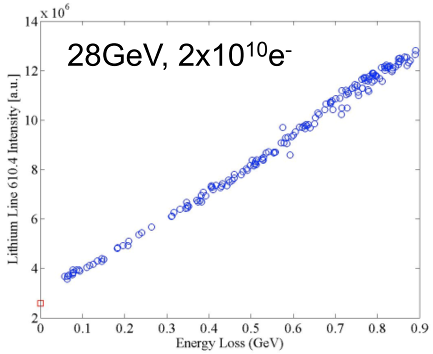
Run 2a: Plasma Light



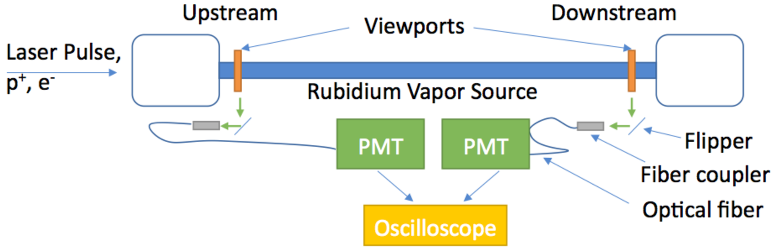
✧e-bunch seeding of SM (2021-2)

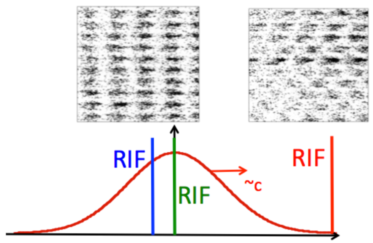


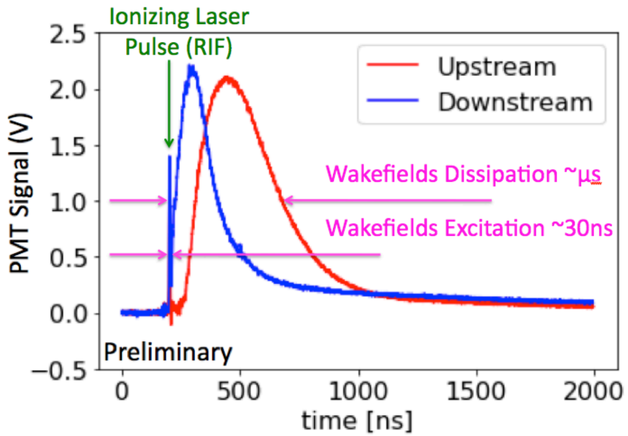
E. Oz et al, AIP Conference proceedings **737**, 708 (2004)

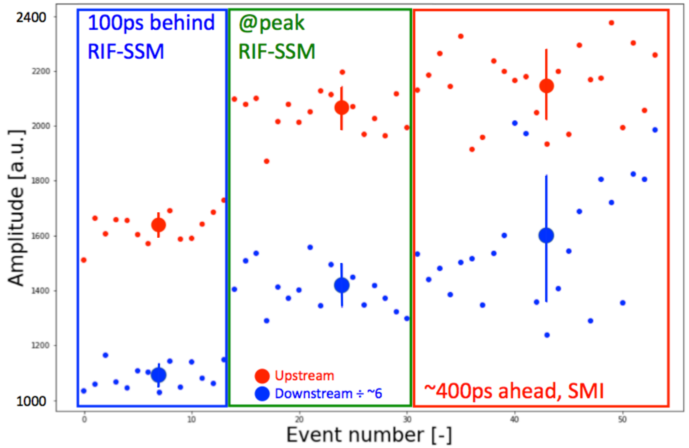


✧Amount of plasma light ~ energy deposited in wakefields!





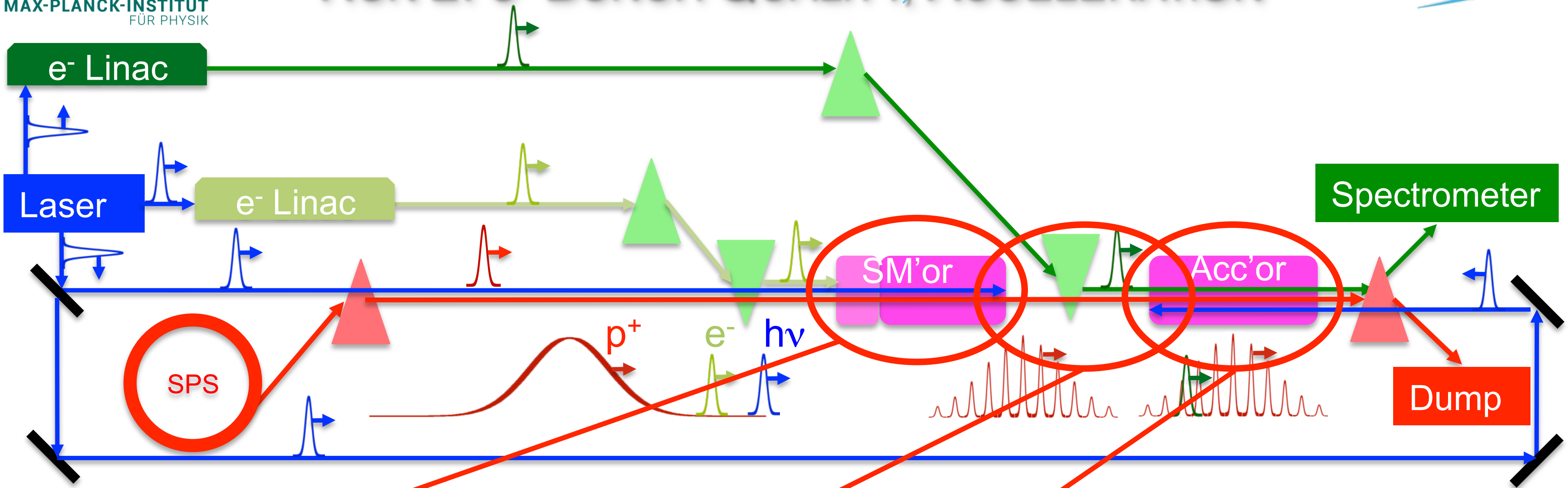




✧Plasma light can show fundamental SM/wakefield parameters:

- ✧Reproducible/irreproducible amplitude of SSM/SMI (essential)
- ✧Transition SMI/SSM along the p^+ bunch
- ✧Effect of plasma density gradient
- ✧Optimization of wakefields
- ✧…
- ✧To be used in run 2c!!

RUN 2: e⁻ BUNCH QUALITY, ACCELERATION



Self-Modulator, Run 2a,b:
- ✧e⁻ bunch seeding of SM
- ✧**Plasma density step**

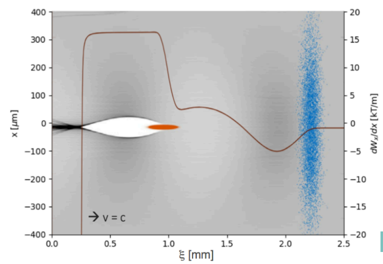
e⁻ external injection, Runs 2 c,d:
- ✧On-axis injection
- ✧Bunch quality
- ✧**Plasma source for >>GeV scale**

Accelerator:
- ✧Blow-out, quasi-linear
- ✧Beam loading
- ✧Beam matching

} ✧Bunch quality

Before LS3

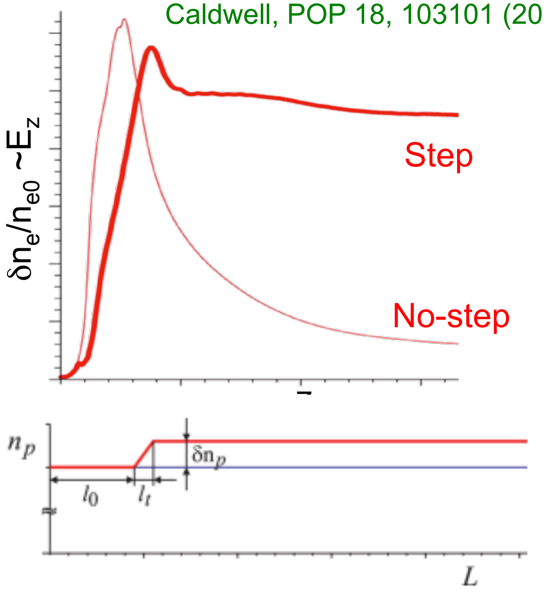
After LS3

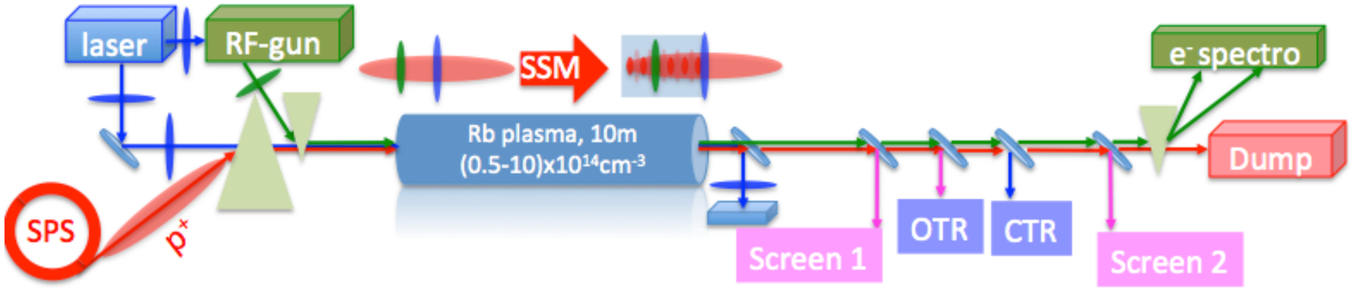


V. K. Berglyd Olsen, PR- AB 21, 011301 (2018)

RUN 2b: DENSITY STEP

✧Constant plasma density: wakefields decrease after saturation

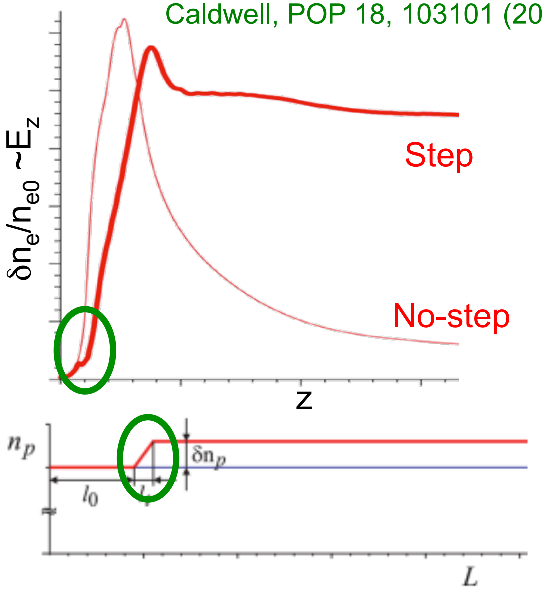




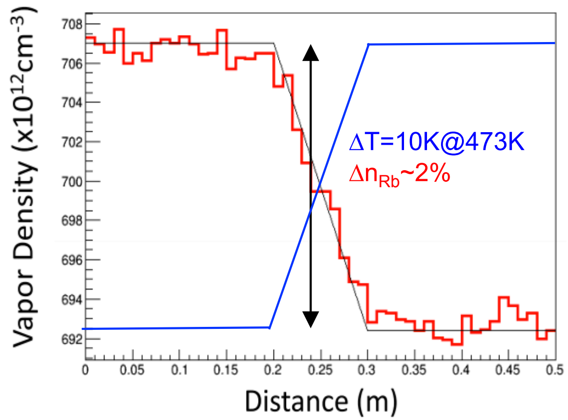
RUN 2b: DENSITY STEP

✧Constant plasma density: wakefields decrease after saturation

Caldwell, POP 18, 103101 (2011)



G. Plyuschev , J. Phys. D: 51(2), 025203 (2017)

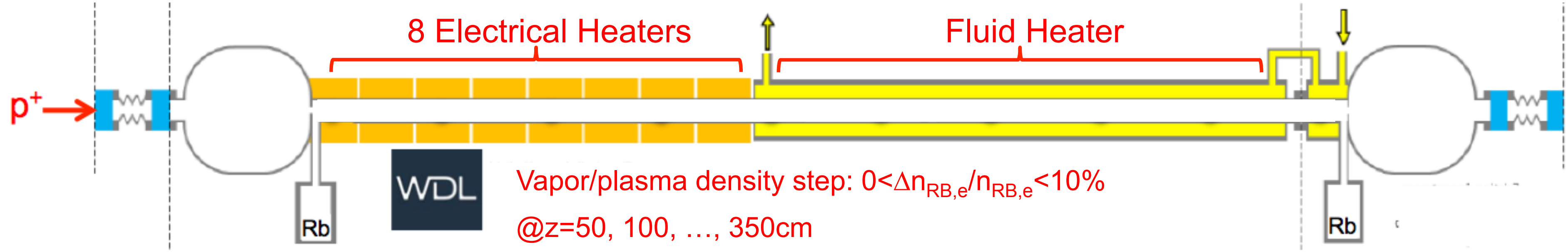


DSMC simulations:

Temperature step

Vapor density step

Plasma density step

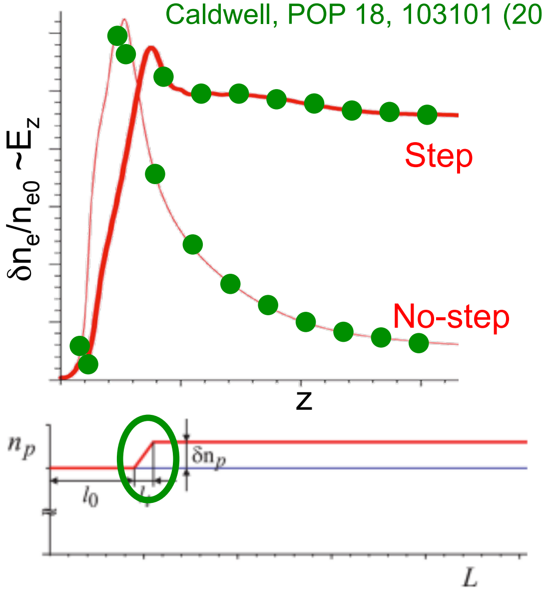


✧Vapor source allows for temperature / rubidium density / plasma density (ionization) step

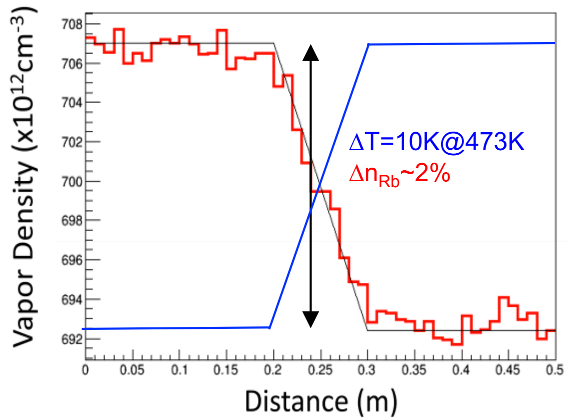
RUN 2b: DENSITY STEP

✧Constant plasma density: wakefields decrease after saturation

Caldwell, POP 18, 103101 (2011)



G. Plyuschev , J. Phys. D: 51(2), 025203 (2017)

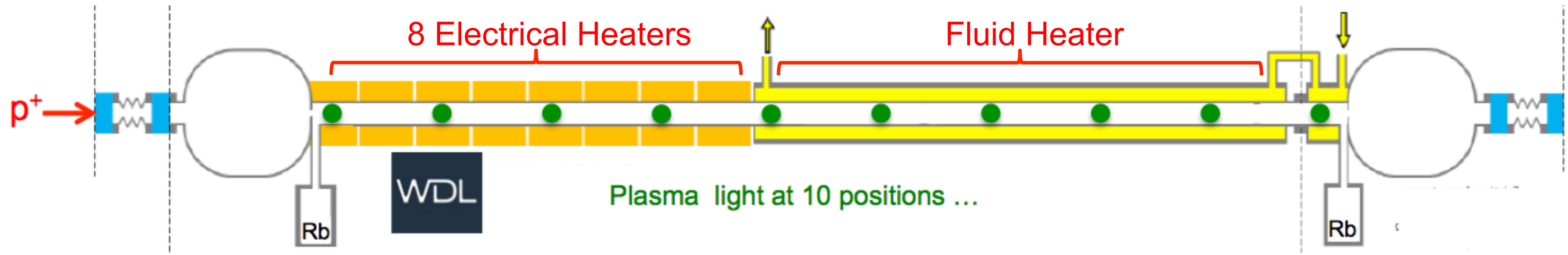


DSMC simulations:

Temperature step

Vapor density step

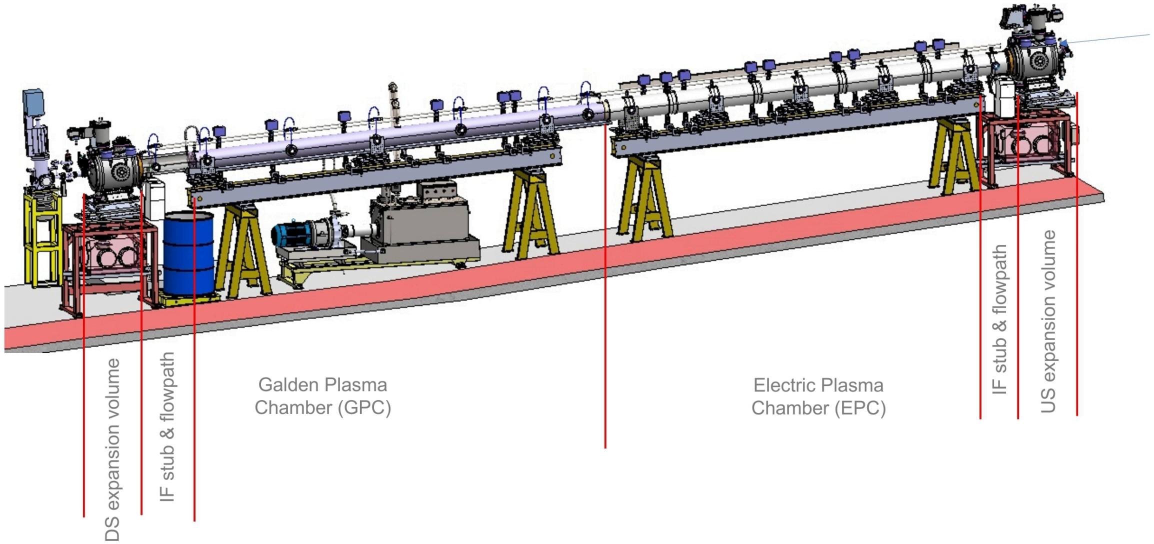
Plasma density step

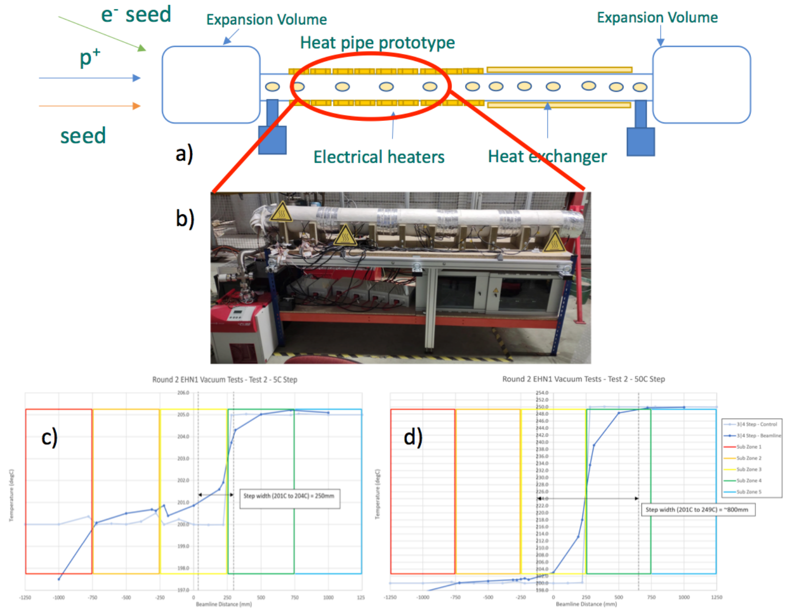


✧Vapor source allows for temperature / rubidium density / plasma density (ionization) step

✧Plasma light allows for mapping of the amplitude of wakefields

RUN 2b: NEW VAPOR SOURCE



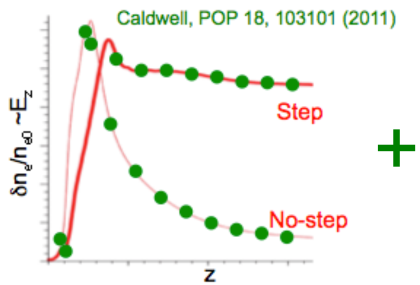


$\Delta T=5°@\sim500K\ (\sim1\%)$
$\Delta L\sim25cm$

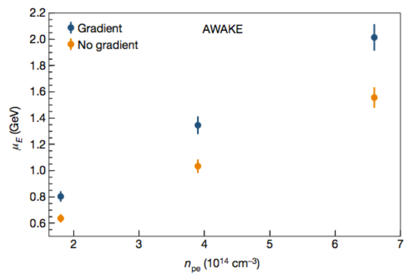
$\Delta T=50°@\sim500K\ (\sim10\%)$
$\Delta L\sim80cm$

- ✧Design complete
- ✧In fabrication
- ✧Plasma density step program: 2023-24
- ✧Installation completion: end July 2023
- ✧Plasma light
- ✧e-acceleration
- ✧Optimize density step effect

✧Effect of the "step" very weakly dependent on ΔL



+



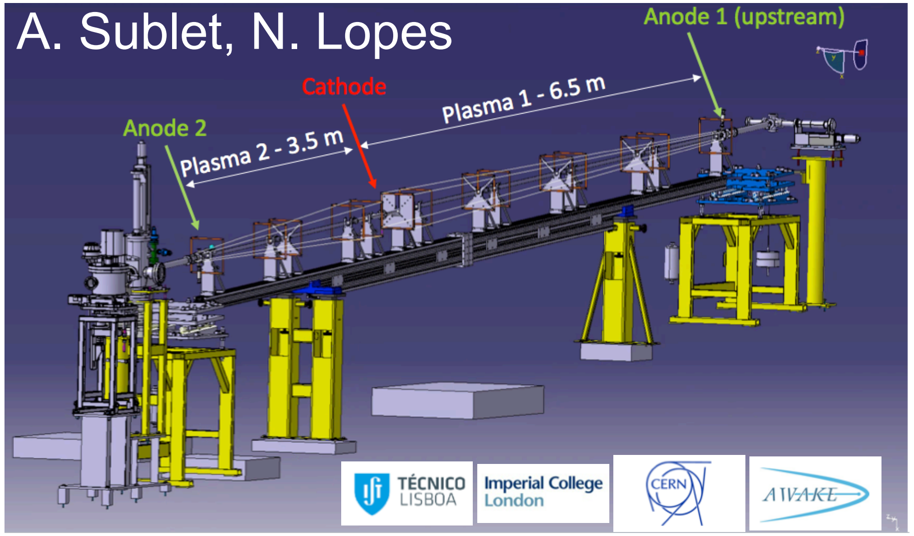
Run 2b: Discharge Plasma Source (DPS)

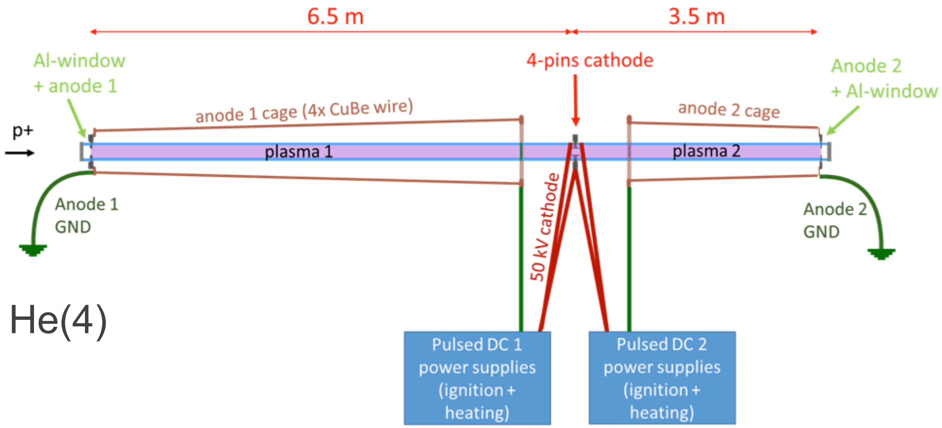
Why?

- ✧Much simpler
- ✧Stack to reach very long plasma length
- ✧Candidate accelerator source for Run 2 c,d?

Plan:

- ✧Replace vapor source by DPS
- ✧Installed for April 2023 p^+ run





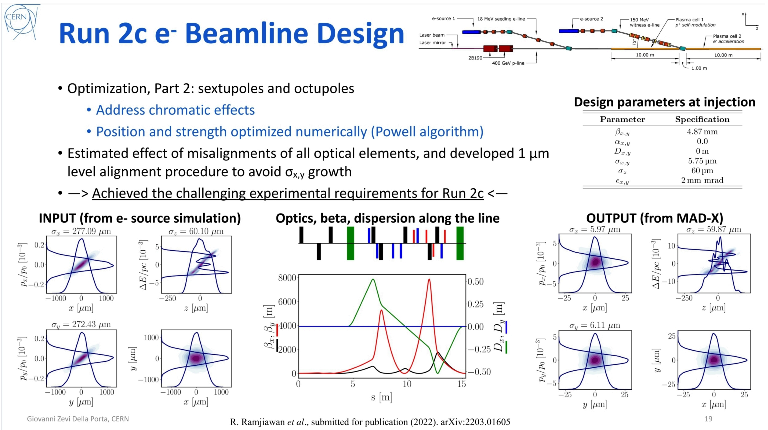
Double discharge system

Physics plan for 2-3 weeks run:

- ✧SMI versus plasma lengths: 3.5, 6.5, 10m
- ✧Detectable effect of plasma ion motion? Xe(131), Ar(40), He(4)
- ✧Focusing at low/high plasma densities
- ✧Hosing at very low plasma densities? ($<0.5\times10^{14}cm^{-3}$)
- ✧Vary plasma density over a very wide range ($<1\times10^{13}cm^{-3}$ to $2\times10^{15}cm^{-3}$)

GENERAL RUN 2 PREPARATiON

✧Machine learning for new e-beamline design



R. Ramjiawan et al., arXiv:2203.01605

GENERAL RUN 2 PREPARATION

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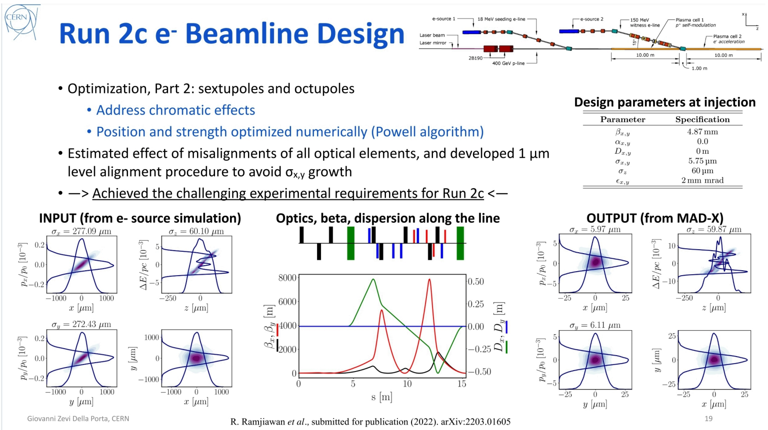

R. Ramjiawan et al., arXiv:2203.01605

✧Parameters and tolerance studies for external injection

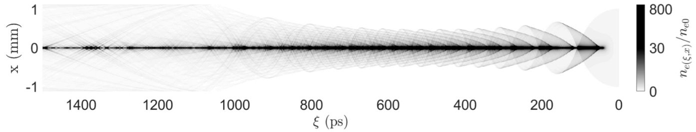

Fig. 11: In regimes where the proton charge density is much greater than that of the plasma, plasma electrons are pulled towards the beam axis, forming a filament.

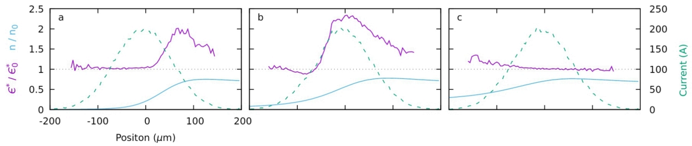

Fig. 12: Plots showing the current and slice emittance of witness bunch, as well as the on-axis plasma density, after 10 m acceleration. a) A bunch with a 2 μm initial emittance rapidly expels the plasma electrons (blue line), allowing emittance preservation (purple line) for most of the beam. b) For an initial emittance of 8 μm, the plasma electrons are expelled more slowly, resulting in an increase in emittance. c) This effect can be avoided by increasing the initial bunch radius.

J. P. Farmer et al., arXiv:2203.11622

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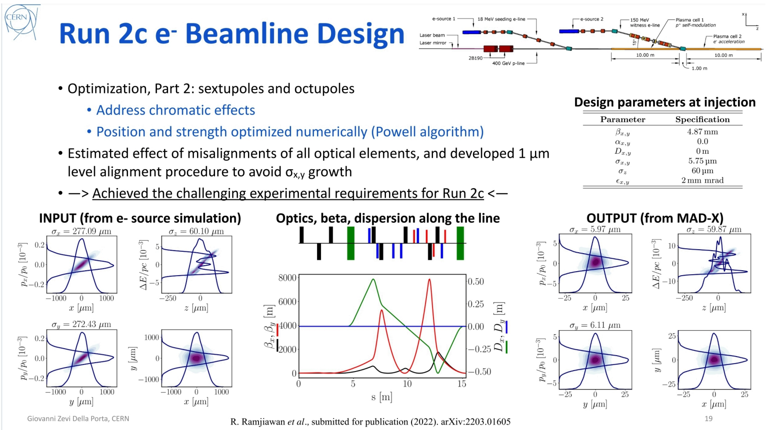


R. Ramjiawan et al., arXiv:2203.01605

✧e-gun for new 150MeV linac injector

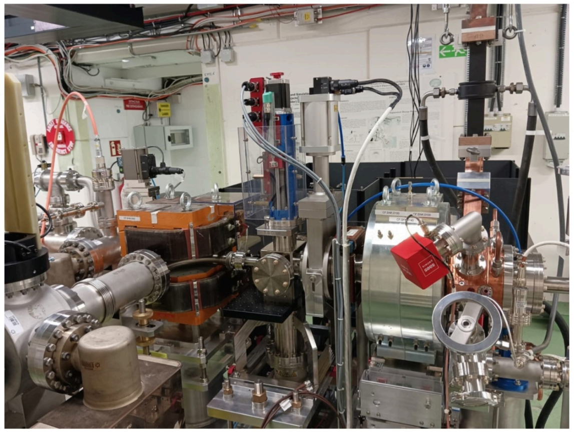
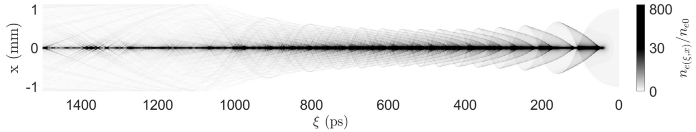


Fig. 8: Picture of the Photo Injector test stand for AWAKE in the CTF2 tunnel.

✧Parameters and tolerance studies for external injection



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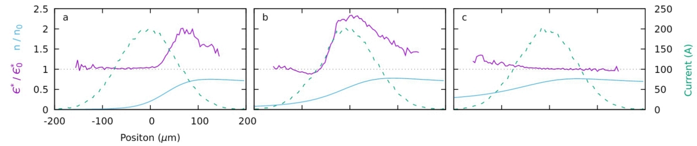

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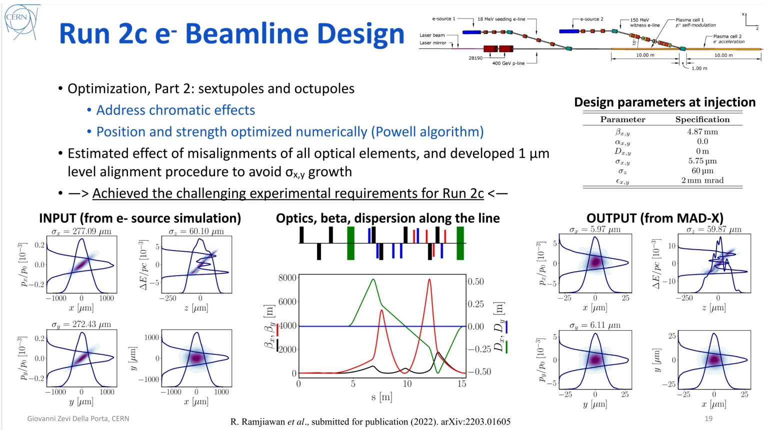

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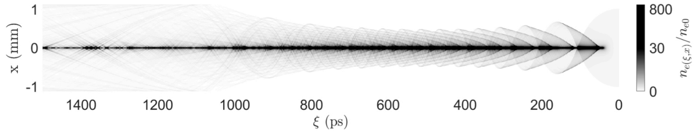

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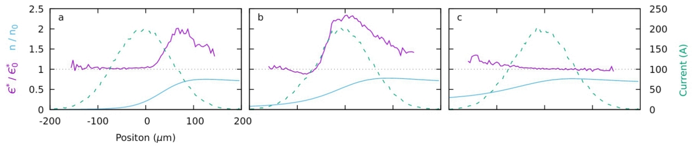

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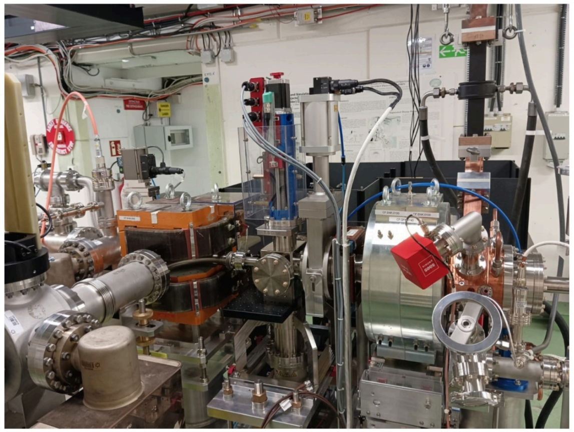

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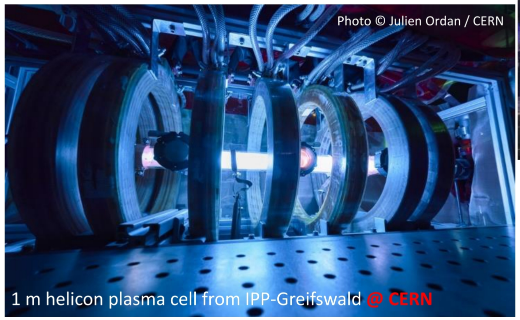
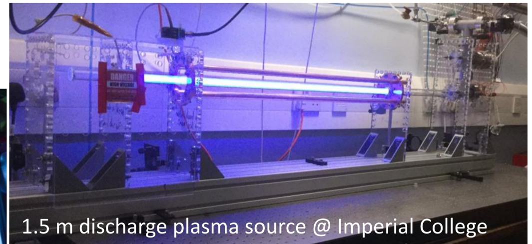
✧Scalable plasma source for Run 2c, d

Helicon Source





Discharge Source

SCIENTIFIC OUTPUT

Publications/Submission 2022:

- E. Gschwendtner et al. (AWAKE Collaboration), The AWAKE Run 2 programme and beyond, Symmetry 2022, 14(8), 1680
- L. Verra et al. (AWAKE Collaboration), Controlled Growth of the Self-Modulation of a Relativistic Proton Bunch in Plasma, Phys. Rev. Lett. 129, 024802 (2022)
- L. Liang et al., Acceleration of an electron bunch with a non-Gaussian transverse profile in a quasilinear plasma wakefield, arXiv:2208.04585
- M. Moreira et al., Mitigation of the onset of hosing in the linear regime through plasma frequency detuning, arXiv:2207.14763
- L. Liang et al., Simulation study of betatron radiation in AWAKE Run 2 experiment, arXiv:2204.13199
- J. P. Farmer et al., Injection tolerances and self-matching in a quasilinear wakefield accelerator, arXiv:2203.11622
- R. Ramjiawan et al., Design of the AWAKE Run 2c transfer lines using numerical optimizers, arXiv:2203.01605
- V. Khudiakov and A. Pukhov, Optimized laser-assisted electron injection into a quasi-inear plasma wakefield, Phys. Rev. E 105, 035201 (2022)
- M.A. Baistrukov and K.V. Lotov, Evolution of equilibrium particle beams under external wake-fields, Plasma Phys. Control. Fusion 64 075003 (2022)
- A.A. Gorn and K.V. Lotov, Generation of plasma electron halo by a charged particle beam in a low density plasma, Phys. Plasmas 29, 023104 (2022)

Past Experimental PhDs:

- Marlene Turner (2018)
- Fearghus Keeble (2019)
- Barney Williamson (2020)
- James Chappell (2021)
- Anna-Maria Bachman (2021)
- Mathias Huetther (2021)
- Fabian Batsch (2022)

} Run 1

- Vasyl Hafych (2022)
- Livio Verra (2022)

} Run 2a

PhDs Experimental to come:

- Pablo Guzman (2023)
- Jan Pucek (2023)
- Tatiana Nechaeva (2023)

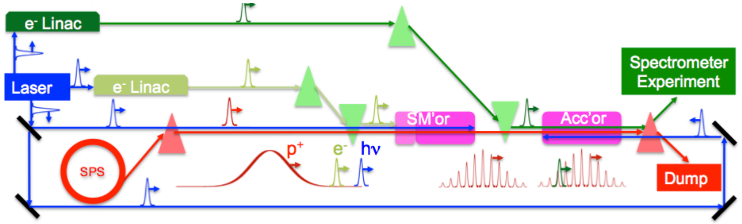
} Run 2a

- Karl Rieger (2023)

- + many theoretical, simulation, bachelor and master theses …

AWAKE ORGANIZATIONAL UPDATE

- CERN MTP:
  - The timeline of AWAKE has been extended to 2030, following the recommendations from the ESPP.
  - CERN staff position for a plasma-based acceleration scientist was approved. New staff will start Jan. 1, 2023.
  - The CNGS dismantling to prepare the required space for AWAKE Run 2c has been added in the MTP in the AWAKE budget (+11MCHF!)
    - CNGS dismantling will be its own project inside the AWAKE project.
    - Ans Pardons is nominated as project leader.
    - Details of the project now to be organized.



- Additional budget required for AWAKE Run 2c not yet fully available
  - Efforts to receive additional budget from AWAKE collaborating institutes
    - E.g. Good news! STFC approved UK funding!!
  - Discussions on how to save additional money without descoping the experiment. (e.g. retreat beginning of 2023).
  - CERN budget secured to prepare Run 2c in next 2 years → have another Cost and Schedule review in 2023/24.

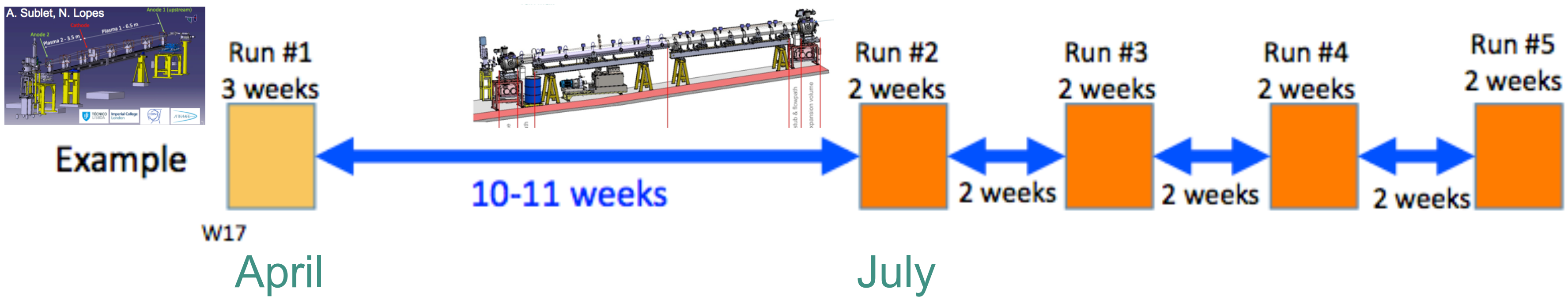
Beam Time Request For 2023

- 2023 measurement program:
  - First run with the discharge plasma source
  - Following runs with the density step Rb vapor source

- Tight constraints due to de-installation/installation/commissioning procedures

- Adapting to the reduced beam-time in 2023, AWAKE requests 11 weeks of proton run:
  - 3-week run starting in week 17 (discharge plasma source not ready earlier)
  - No beam for 10 – 11 weeks between the end of the 1st run and the start of the 2nd run for the discharge plasma source de-installation and the installation/commissioning of the density step Rb vapor source
  - 2-3 week blocks of proton run, separated by at least 2 weeks

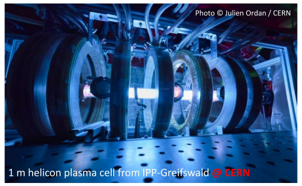
- For the physics program we need ~8 hours stable conditions per day, i.e. continuous AWAKE cycle in the super-cycle, with no interruptions

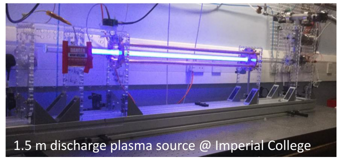


SUMMARY

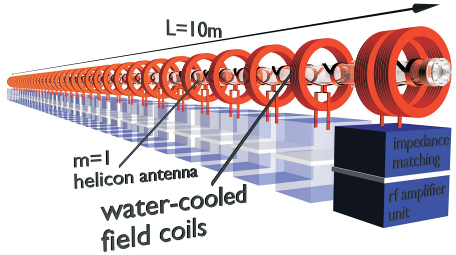
- ✧Successful Run 2a (2021-22)
  - ✧Demonstration of e-bunch seeding of self-modulation
  - ✧Number of significant scientific results: hosing, plasma ramp, bunch focusing, plasma light, etc.
  - ✧5 PhDs and a number of publications

- ✧Preparation for Run 2b (2023-24), experiments with
  - ✧Discharge plasma source for p^+ in April
  - ✧Vapor source with density step for p^+ in July →2024

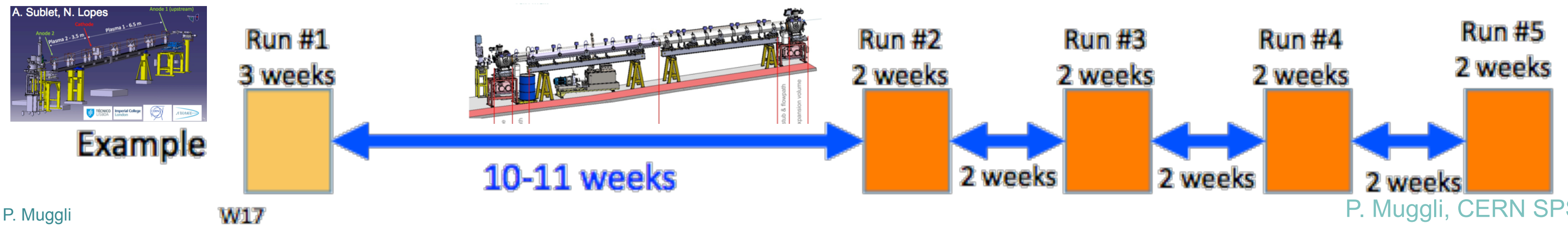




- ✧Continue clear plan for applications to particle physics in 2030's
  - ✧CERN long term commitment, new PWFA staff position
  - ✧Clear scientific program
    - ✧Run 2 b: plasma density step
    - ✧Run 2c: external injection of e-bunch in second plasma, quality
    - ✧Run 2d: scalable plasma source
  - ✧Continue development of scalable plasma sources at CERN



- ✧Beam request for 2023 driven by fabrication/installation of new plasma sources



Thank you to my collaborators

Thank you!

http://www.mpp.mpg.de/~muggli
muggli@mpp.mpg.de