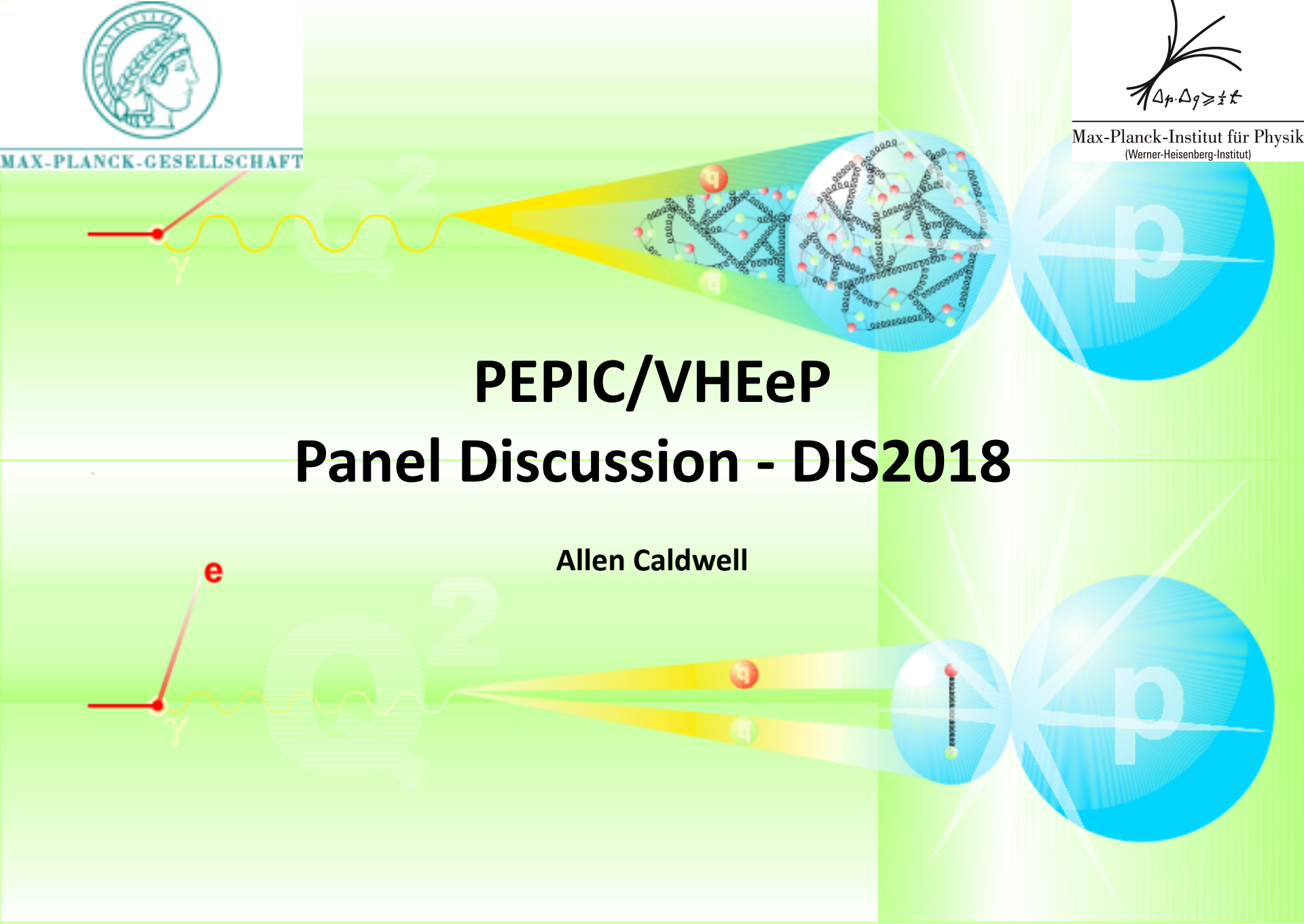


PEPIC/VHEeP
Panel Discussion - DIS2018

Allen Caldwell

Novel accelerators based on plasma wakefields, dielectric structures or direct laser acceleration will bring new scientific opportunities.

With AWAKE and proton-driven wakefield acceleration, we aim to use existing infrastructure for the wakefield driver to accelerate electrons to high energy. We want to develop the program of particle physics applications in parallel.

First ideas:

- ➢ Fixed target experiments
- ➢ Low luminosity eP/eA using SPS driver : PEPIC
- ➢ Low luminosity eP/eA using LHC driver : VHEeP
- ➢ For-purpose built proton driver

Proton Drivers for PWFA

Proton bunches as drivers of plasma wakefields are interesting because of the very large energy content of the proton bunches.

Drivers:

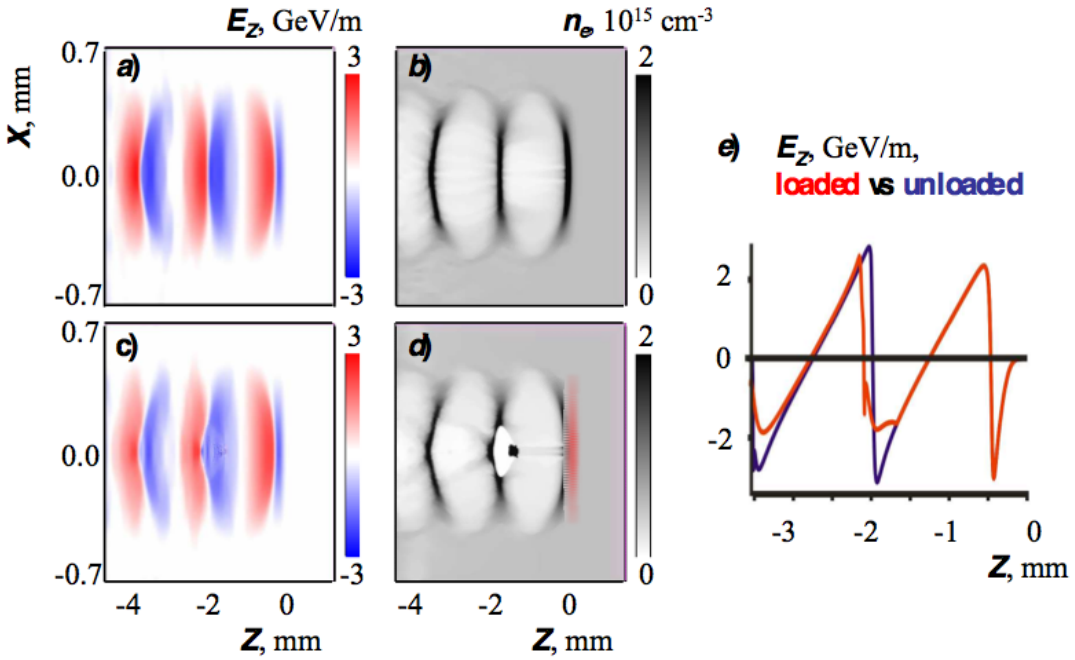
PW lasers today, ~40 J/Pulse

FACET (e beam, SLAC), 30J/bunch

SPS@CERN 20kJ/bunch
LHC@CERN 300 kJ/bunch

Witness:

10^{10} particles @ 1 TeV ≈ few kJ



$$\lambda_p \approx 1\ \mathrm{mm}\ \sqrt{\frac{1\cdot 10^{15}\mathrm{cm}^{-3}}{n_p}}$$

Energy content of driver allows to consider single stage acceleration.
Need short drivers to create strong wakefields.

Particle Physics Perspectives

Started considering:

- **Physics with a high energy electron beam**
  - E.g., search for dark photons

- **Physics with an electron-proton or electron-ion collider**
  - Low luminosity version of LHeC
  - Very high energy electron-proton, electron-ion collider

Are there fundamental particle physics topics for high energy but low luminosity colliders ?

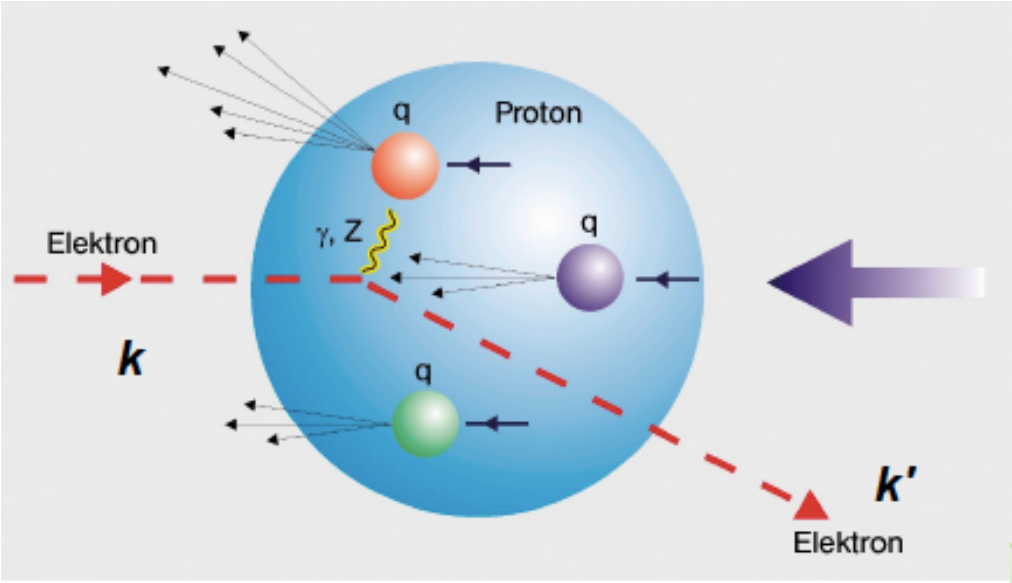
I believe – yes ! Particle physicists will be interested in going to much higher energies, even if the luminosity is low.

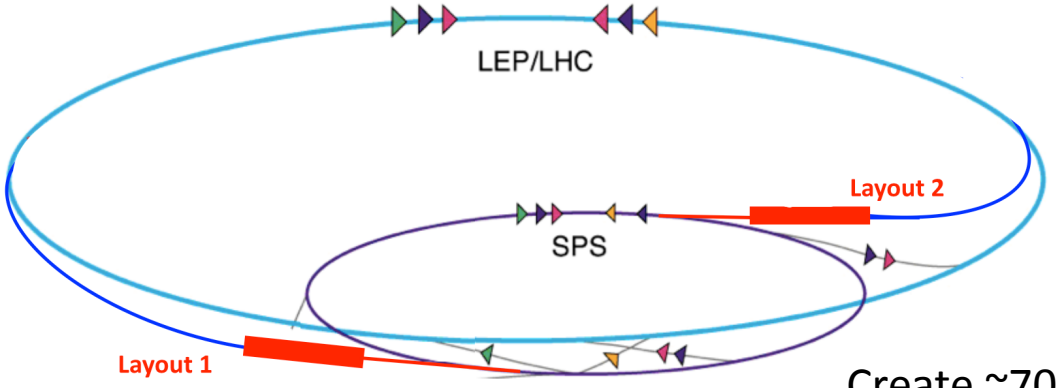
In general – start investigating the particle physics potential of an AWAKE-like acceleration scheme.

PEPIC: SPS Driver

Focus on QCD:

- Large cross sections – low luminosity (HERA level) enough
- Many open physics questions !
- Consider high energy ep collider with Ee up to O(100 GeV), colliding with LHC proton; e.g. Ee = 10 GeV, Ep = 7 TeV, √s = 530 GeV already exceeds HERA cm energy.





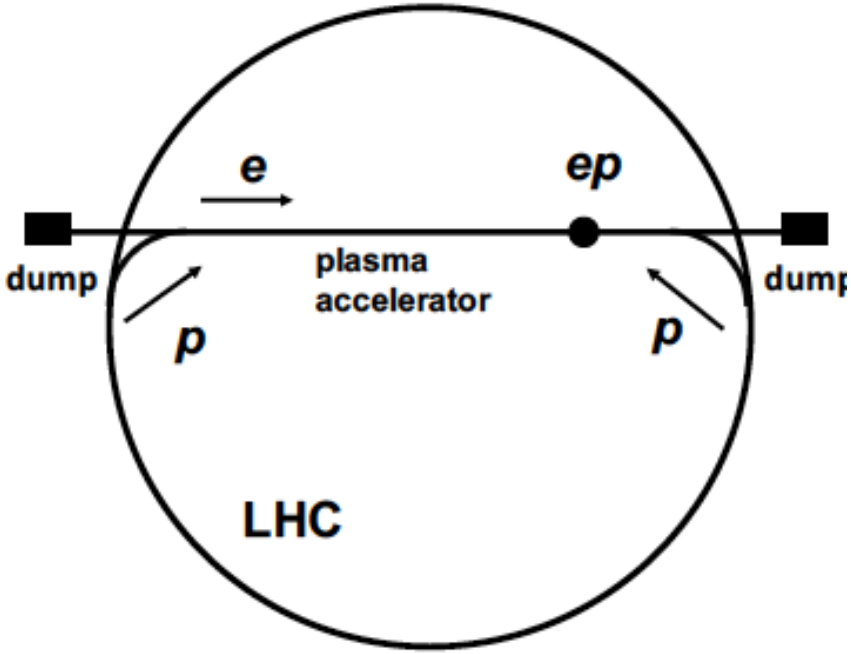
G. Xia et al., Nucl. Instrum. Meth. A 740 (2014) 173.

Create ~70 GeV beam within 100 m of plasma driven by SPS protons.

Luminosity currently expected to be < 10^{30} cm^{-2} s^{-1}.

VHEeP

(Very High Energy electron-Proton collider)



One proton beam used for electron acceleration to then collide with one bunch from other proton beam

Luminosity ~ 10^{28} – 10^{29} cm^{-2} s^{-1} gives ~ 1 pb^{-1} per year.

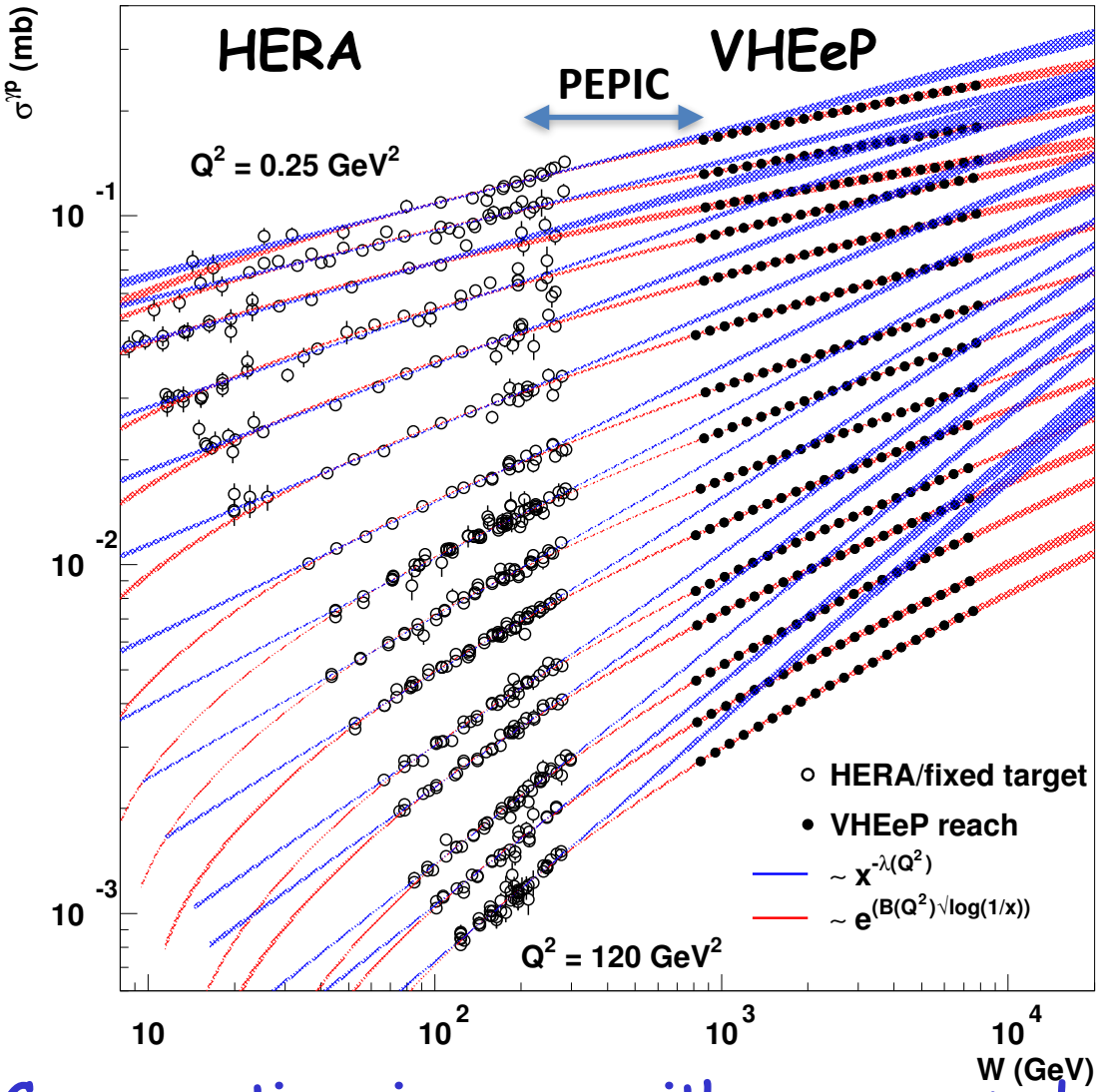
E_e = 3 TeV as a baseline ; with E_P = 7 TeV yields √s = 9 TeV. Can vary.

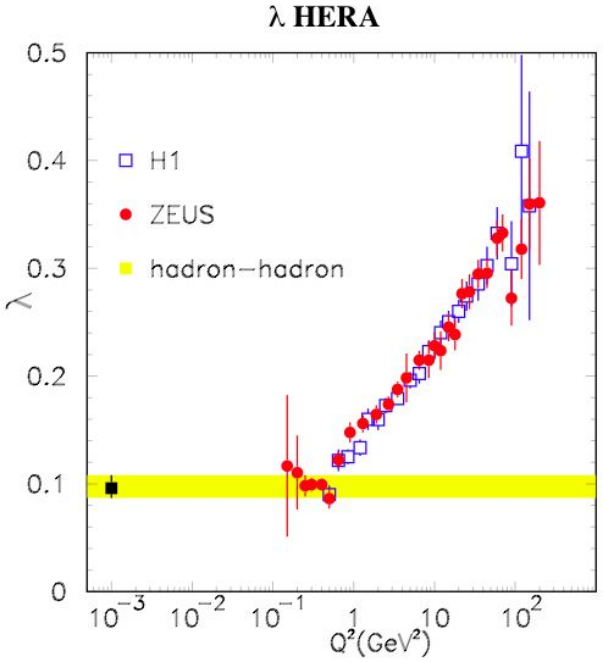
- Center-of-mass energy ~30 higher than HERA.
- Reach in (high) Q^2 and (low) Bjorken x extended by ~1000 compared to HERA.
- Opens new physics perspectives

First ideas on physics reach discussed in

VHEeP: A. Caldwell and M. Wing, Eur. Phys. J. C 76 (2016) 463

Virtual Photon-Proton Cross Section





Cross sections increase with energy -> do not require large luminosity to probe this physics. PEPIC & VHEeP will distinguish the important physics.

Path Forward (PEPIC&VHEeP)

Technology

- demonstrate electron acceleration
- demonstrate required emittance
- plasma cell scheme

Physics

- total cross sections (real & virtual photon)
- vector meson production
- other aspects of low-x physics (classicalization, AdS/CFT, ???)
- specific eA physics topics
- BSM opportunities (VHEeP)
- anything interesting in the beam dump. E.g.:
  - search for dark photons, like NA64.
  - strong-field QED by colliding electron bunches with laser beam.

Realization

- determine luminosity
- determine range of possible electron energies
- understand how to get rid of defocused protons
- understand how to separate protons from electrons
- beam dump
- IP design
- how fit into CERN infrastructure
- detector studies

Need to push on all aspects in parallel !

Summary:PEPIC

particle species: electrons (no positrons foreseen for now), A=full range of LHC

beam energies: electrons few GeV -> ~100 GeV, p, A from LHC

particle polarization: depends on source, PDPWA should preserve beam polarization

integrated luminosity: initial estimate 100 pb^{-1} in 10 years

targeted physics:
- small-x processes& total cross sections
- generally QCD studies (instantons ? …)

technological status: at the start of technology demonstration; goal is demonstration by 2024

possible sites: CERN, BNL (? for eA) have existing p,A accelerators

project status & plans: electron acceleration 2018, demonstration of stable&high gradient acceleration + good emittance by 2024

specific aspect: run concurrently with LHC, requires SPS

project cost: <= 200 MChF for accelerator (target, not estimate)

Summary:VHEeP

particle species: electrons & positrons, A=full range of LHC

beam energies: electrons few GeV -> several TeV, p, A from LHC

particle polarization: depends on source, PDPWA should preserve beam polarization

integrated luminosity: aim for 100 pb^{-1} in 10 years

targeted physics:
- small-x & saturation
- resonant processes in eP, eA
- fundamental understanding of high energy behavior of cross sections

technological status: at the start of technology demonstration; should follow PEPIC or other demo

possible sites: CERN

project status & plans: electron acceleration 2018, demonstration of stable&high gradient acceleration + good emittance by 2024; PEPIC <2030

specific aspect: run after LHC program, requires LHC for acceleration

project cost: <= few G for accelerator