WG 8 Summary

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Los Alamos NATIONAL LABORATORY EST. 1943

Advanced and novel accelerators for High Energy Physics

Charge:

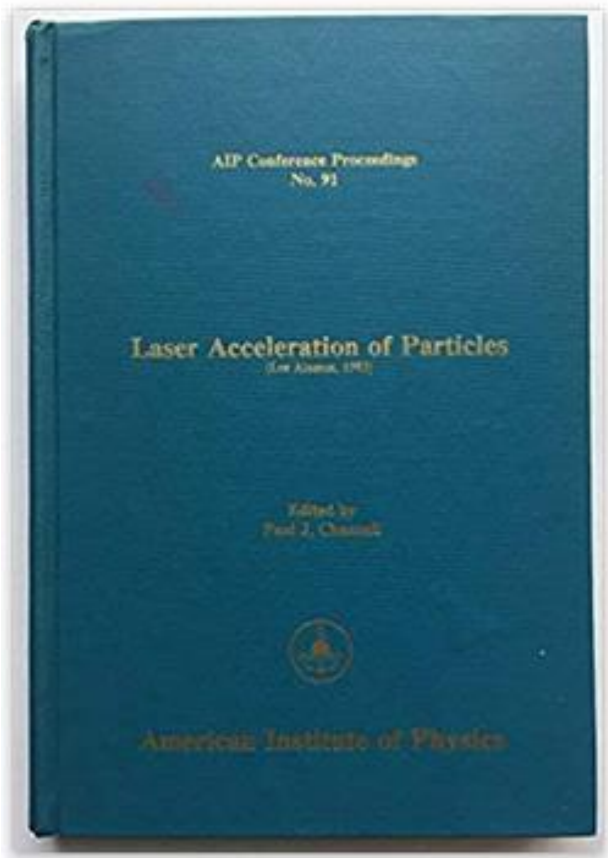
- Examine key challenges
- Discuss suitable concepts and identify topics for future R&D or innovation including electron and positron sources, acceleration of positrons, luminosity, final focus, damping ring and efficiency

From Steinar Stapnes: Need luminosities of > 10^{35} cm^{-2} sec^{-1}

Relevant metric: Luminosity/MW – 100 MW beam (10 μA at 10 TeV) with 10% efficiency needs ~GW of wall-plug power

(US HEP considers ~ 300 MW upper power limit for multi-TeV collider)

The promise of advanced accelerator for High Energy Physics has been recognized for 40 years



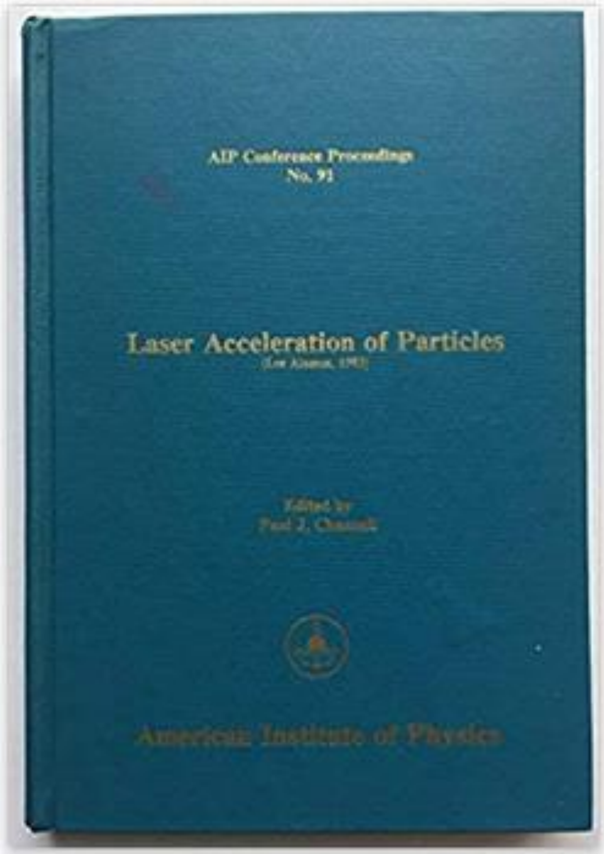
First Advanced Accelerator Concepts Workshop

January 1982

US Office of HEP started funding AAC series of workshops in recognition of the potential future impact on HEP machines

Forty years is a long time for a technology to mature

The promise of advanced accelerator for High Energy Physics has been recognized for 40 years

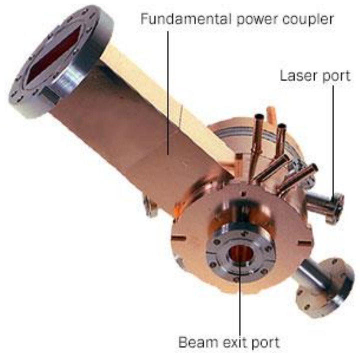


First Advanced Accelerator Concepts Workshop

January 1982

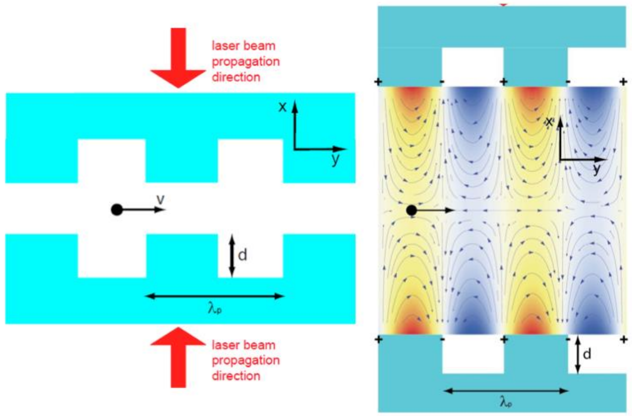
US Office of HEP started funding AAC series of workshops in recognition of the potential future impact on HEP machines

Both RF photoinjector and SRF cavity technology have been matured within this time period

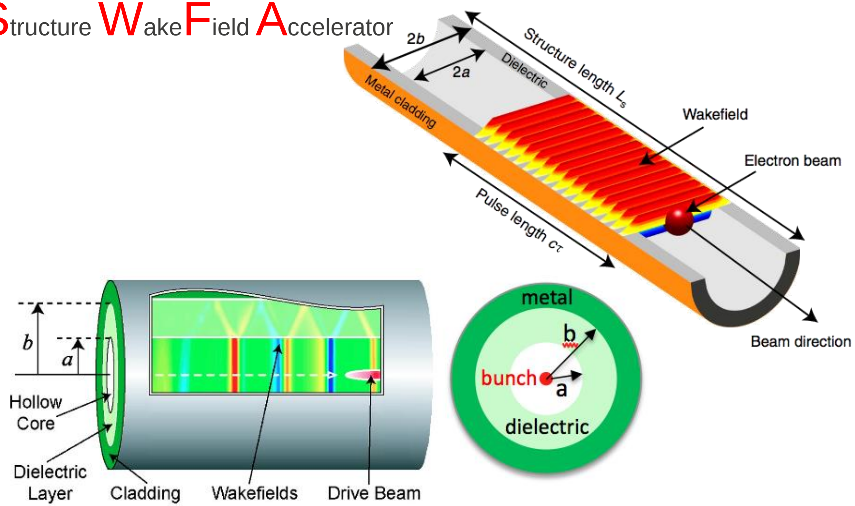


Mostly we've been thinking about these four advanced accelerator schemes for future e+/e- colliders

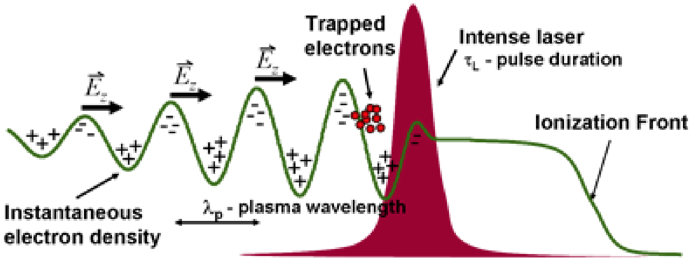
Dielectric Laser Accelerator



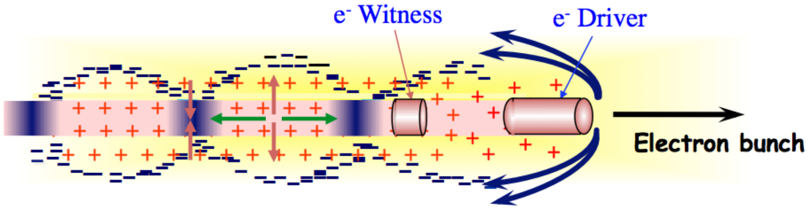
Structure WakeField Accelerator



Laser WakeField Accelerator



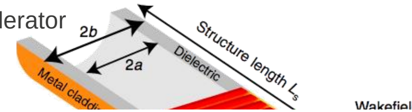
Pasma WakeField Accelerator

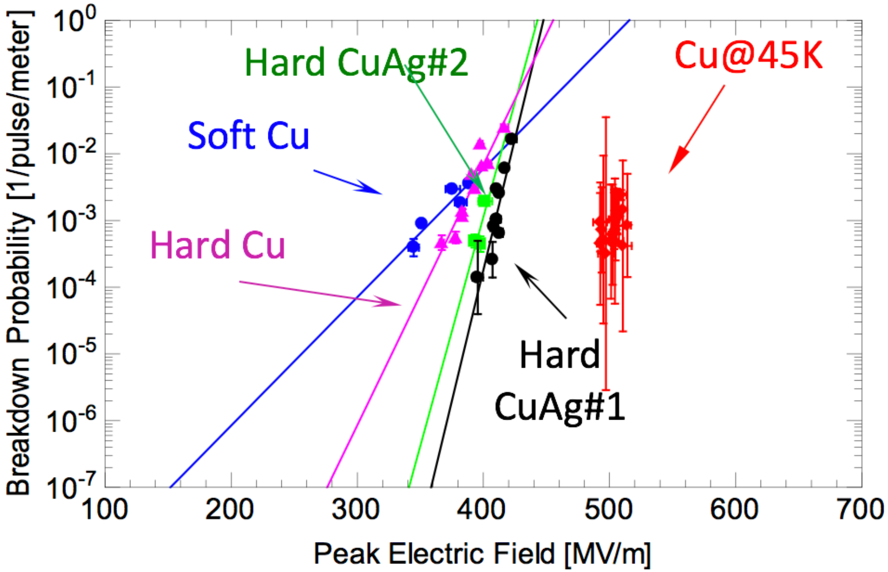


Novel normal conducting RF acceleration is now emerging as another multi-TeV collider technology option

Dielectric Laser Accelerator

Structure WakeField Accelerator





Laser W

Instantane
electron de

Cryogenic normal-conducting (NC) structures (SLAC-UCLA) give lower dissipation, higher yield strength, small coefficient of thermal expansion

James Rosenzweig (plenary)

Main technology issues for a future multi-TeV linear collider – WG8 focus areas

- Overall wall-plug efficiency
  - Increased transformer ratio (for beam-driven approaches)
- Average power (for laser-driven approaches)
- Energy spread
- Emittance of generated beam
- Emittance preservation
- Positron acceleration (not an issue for DLA, DWFA, NCRF)

Our community is steadily making progress in all these areas

Gamma-gamma and non-perturbative QED colliders won't need positrons and advanced accelerator technology can be applied now

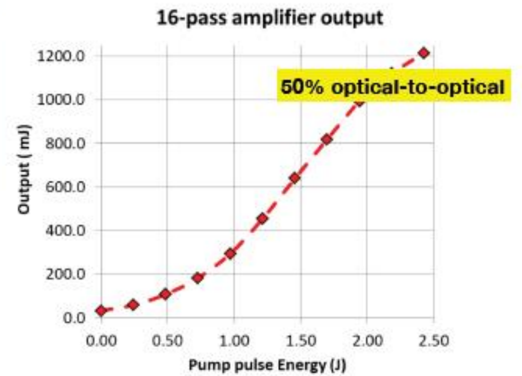
Progress on high-power lasers will lead to high average power LPAs

KALDERA: goal is 3kW average with >100 TW peak power at 1 kHz

Cryogenic Composite Thin Disk Laser Has Been Built at DESY

Pump option for KALDERA

slide: M. Pergament (DESY)



Compiled operations:

20 hrs:	0.5 J @ 100 Hz	200 W avg pump power
10 hrs:	>1 J @ 100 Hz	200 W avg pump power
4 hrs:	>1 J @ 200 Hz	400 W avg pump power
0.5 hrs:	>1 J @ 500 Hz	1 kW avg pump power

2019 EAAC| Leemans Wim Sep 17-20 2019

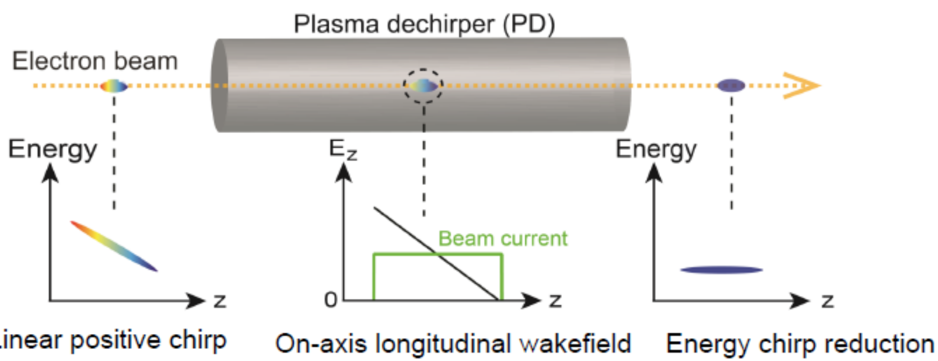
KALDERA | EAAC | Sept. 16th 2019 | page

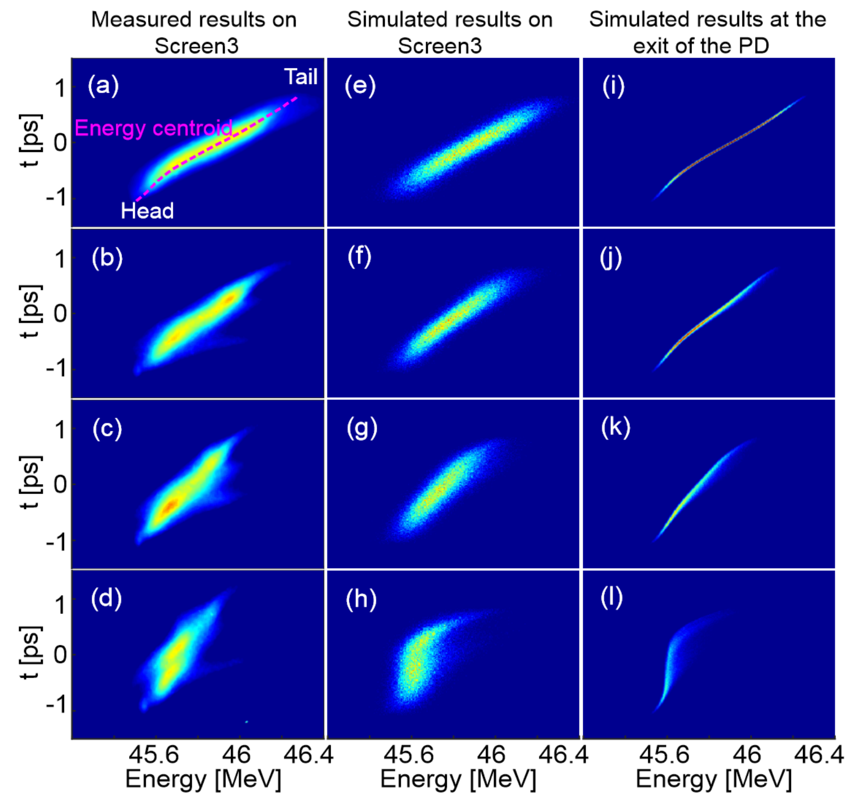
Wim Leemans (plenary)

A plasma dechirper can provide a low energy spread beams (0.13%)

Energy chirp dominated energy spread

- Energy spread ~1% > the requirement of ~0.1% for the applications of FELs and colliders
- Relatively large acceleration phase span leads to large energy chirp (positive linear).

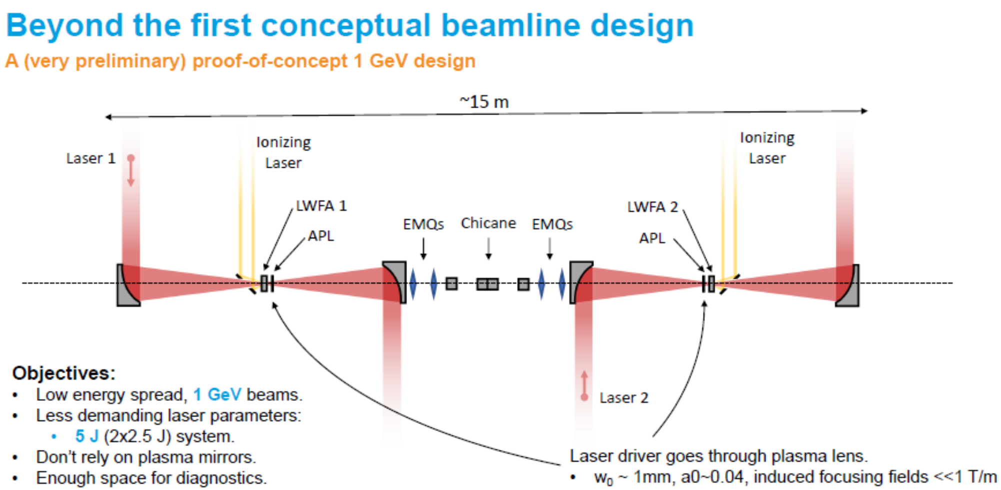




Y. P. Wu, et al., Proceedings of IPAC 2017,1258 (2017)
Y. P. Wu, et al., PRL, 122:204804, 2019

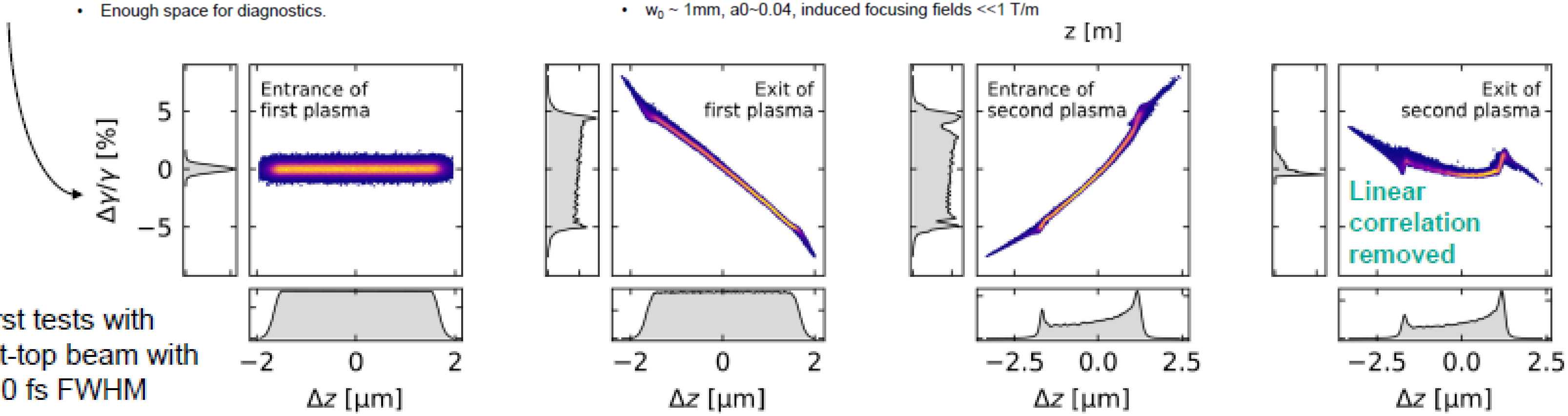
Jianfei Hua

Rotating the longitudinal phase space can also provide a low energy spread beams (0.12%)



Ángel Ferran Pousa

Final energy spread:
- 0.12%(projected)
- 0.028% (slice)

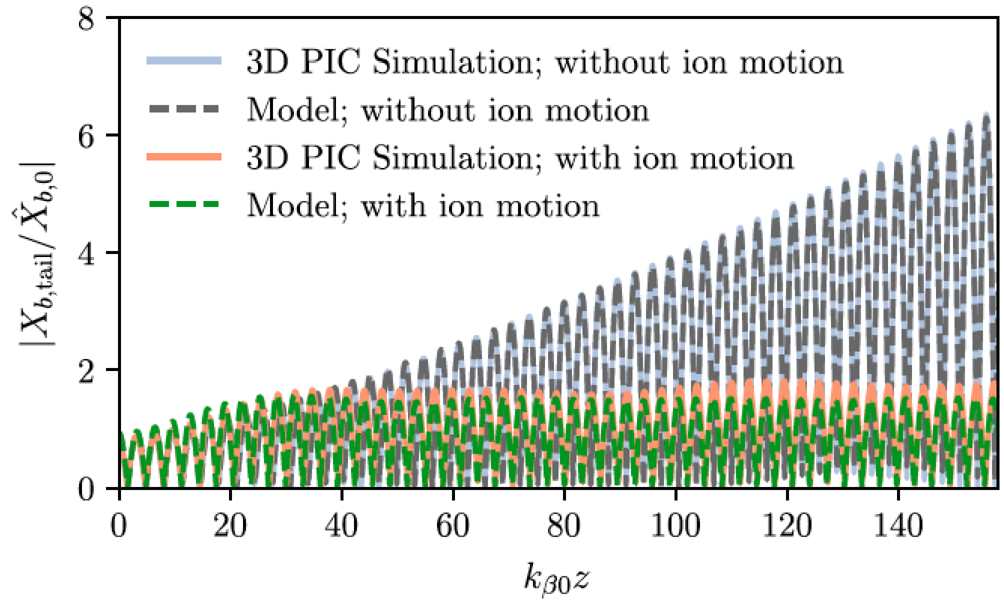


First tests with flat-top beam with ~10 fs FWHM

DESY. | Multistage Plasma Accelerator for GeV, ultra-low energy spread beams | Ángel Ferran Pousa, 18/09/19 Page 15

New approaches for improving emittance preservation appear very promising

- Active plasma lens important tool – Vladimir Shpakov (plenary)
- Hosing stabilized by bunch-induced ion motion – Weiming An and Carlo Benedetti
- Co-axial hollow plasma channels for TeV acceleration - Alexander Pukhov
- Using channeling radiation for beam control (focusing and steering, and maybe also radiation) – Sultan Dabagov



Carlo Benedetti - Bunch-induced ion motion as a way to generate betatron frequency chirp that suppresses hosing

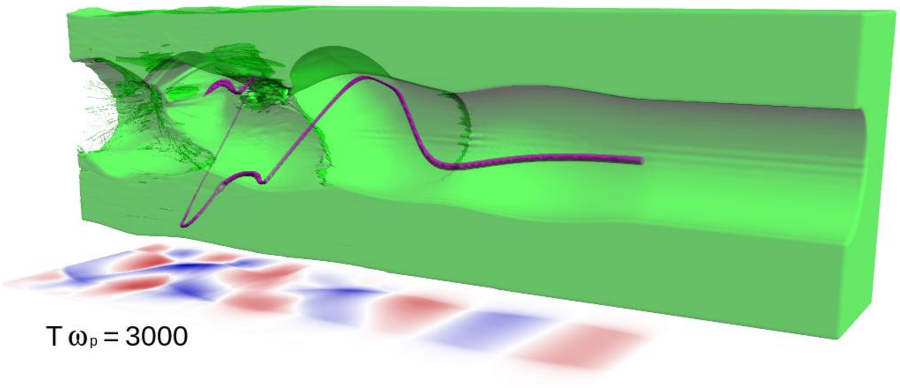
Co-axial hollow plasma channel can stabilize the ion hose instability

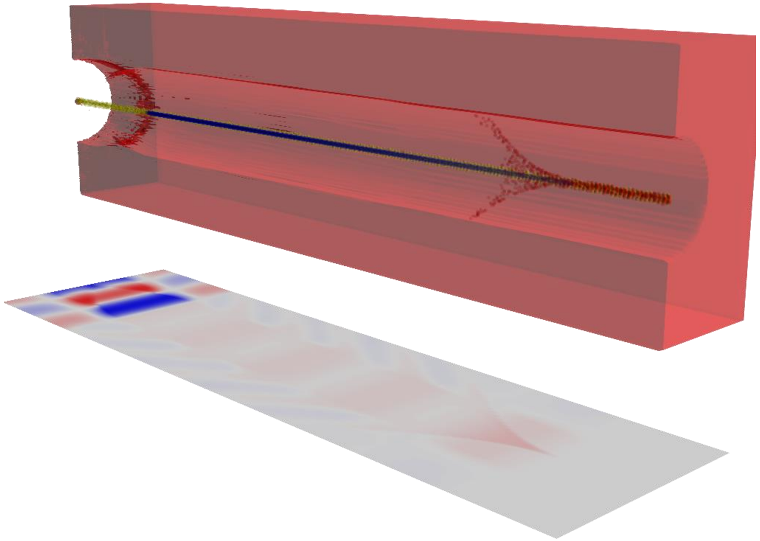
Final energy spread 0.2%
Final emittance 1.5 μm

Accelerating gradient 2 GV/m

Loaded transformer ratio is *R*=10.5

44% driver-to-witness energy efficiency





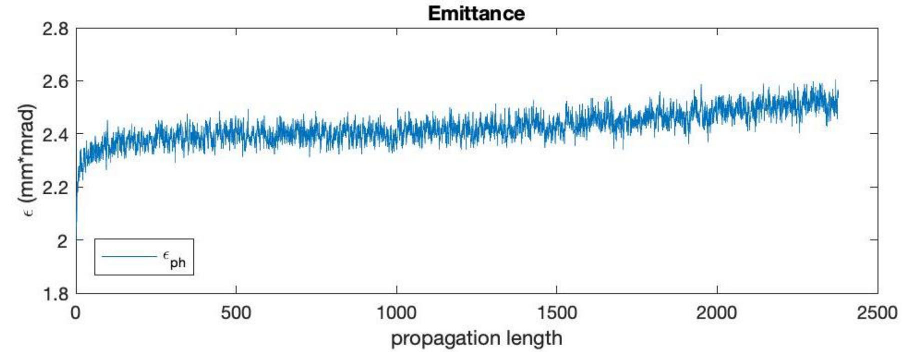
Alexander Pukhov

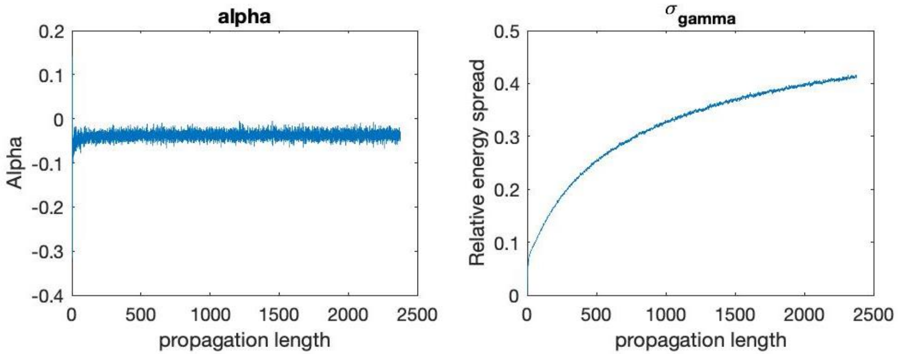
While positron acceleration still seems to be difficult, promising approaches are being identified

Carl Lindstrom (plenary) pointed out plasmas are asymmetric – the blowout regime is *defocusing for positrons*.

A new concept for accelerating positrons is needed, will likely be one of these approaches:

Linear Wakes	*Nonlinear Wakes*
Wake Inversion	*Hollow Channels*



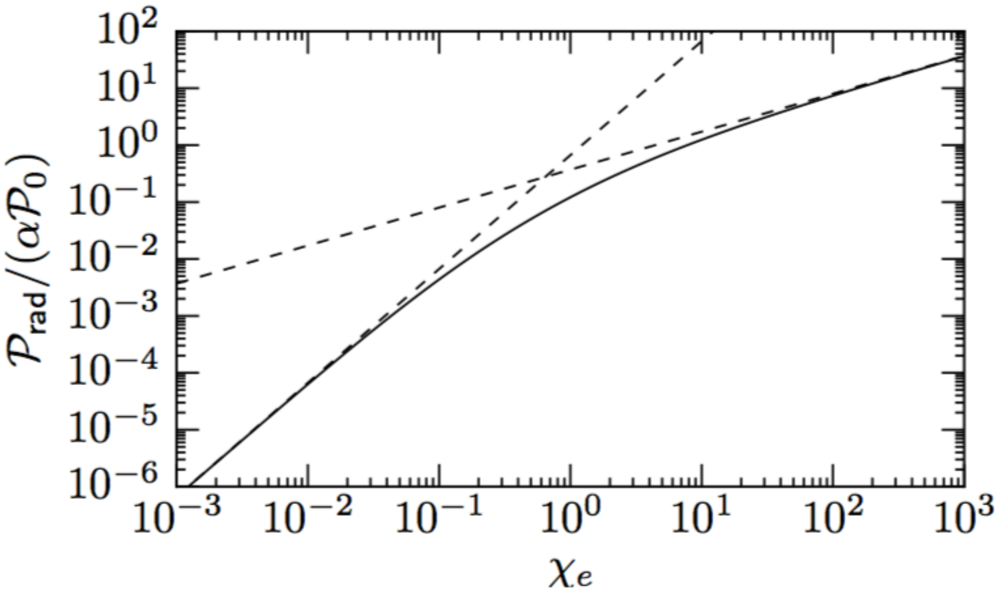


Denys Bondar – conditions for uniform focusing for a train of positron bunches

Severin Diederichs – positron transport and acceleration in beam-driven, pre-ionized, finite plasma column

Siyi Yu - Improved transport and efficiency for positron acceleration in a quasilinear PWFA

Non-perturbative QED collider may reveal new physics



Can be built without positrons

Vitaly Yakimenko

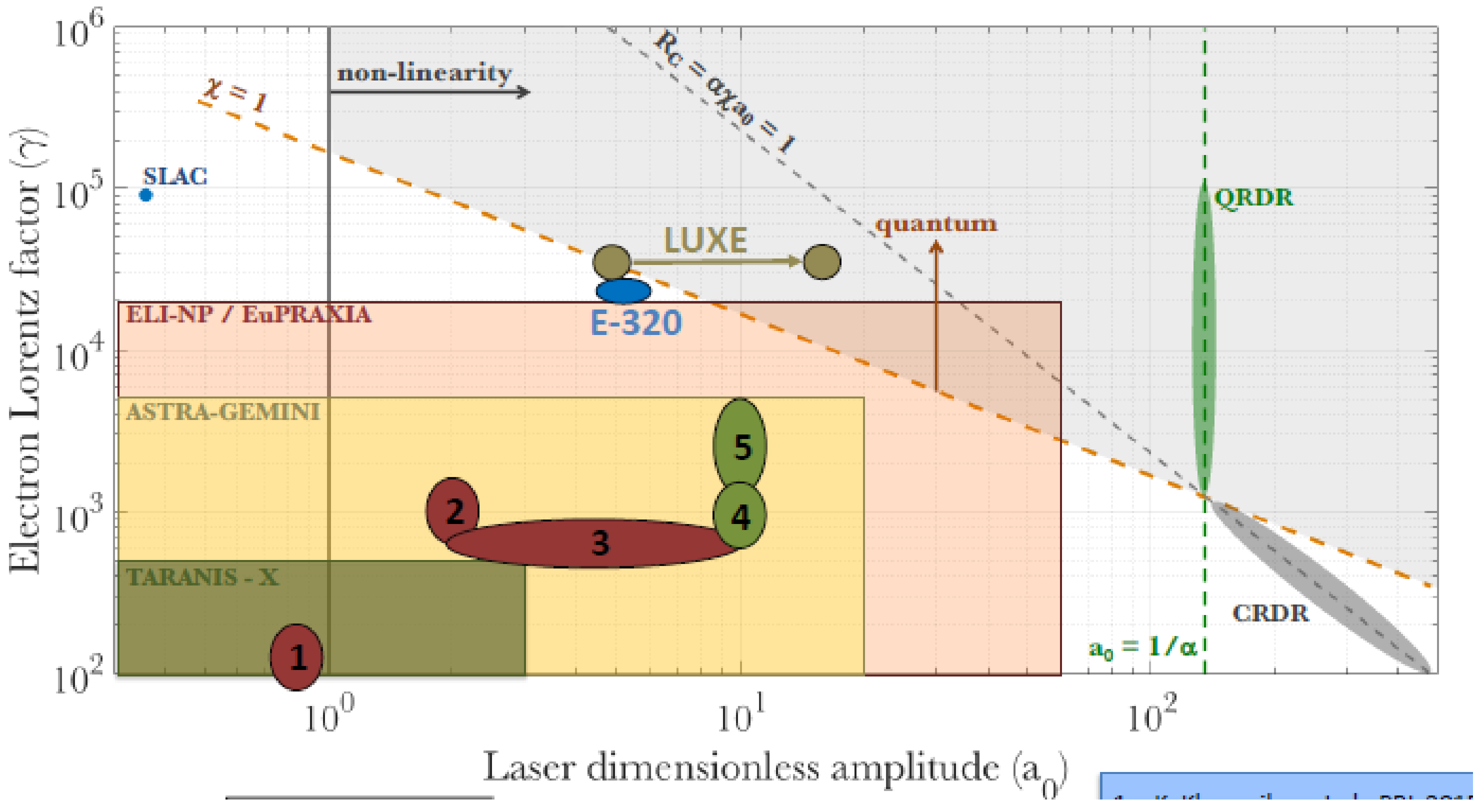
χ ***<< 1:* classical regime:** Quantum effects are small, pair production is exponentially suppressed

***$\chi \gtrsim$ 0.1, χ <~10: transition to* quantum regime:** Recoil and pair production are important

***$\chi \gtrsim$ 10:* quantum regime:** Importance of pair production cascades, the radiation field is a perturbation

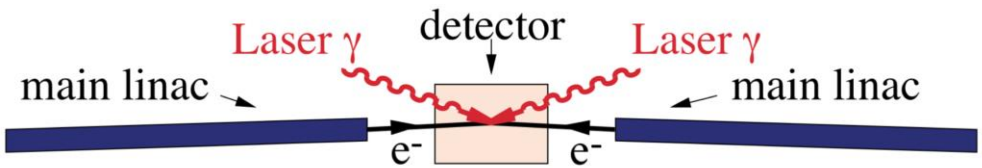
***$\chi \gtrsim$1700:* fully non-perturbative regime:** Perturbative treatment of the radiation field breaks down

Non-perturbative QED physics can be looked at with FACET-II



Gianluca Sarri (plenary)

Gamma-gamma collider may be an intermediate HEP step



Gamma-gamma collider can do much of the physics of an e+/e- collider while not requiring positrons

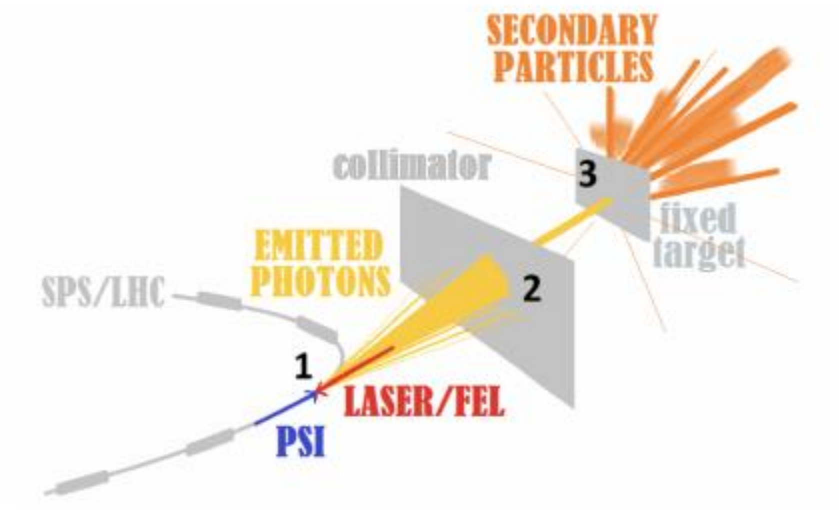
Suited to PWFA accelerator technology

Erik Adli

Particle pair	Mass [GeV]	$\sigma(e^+e^- \to XX)$ [fb] Circe2 + ISR, unpol.	$\sigma(\gamma\gamma \to XX)$ [fb] Circe2, unpol.
$\tilde{d}_L\tilde{d}_L$	1009	0.61	0.07
$\tilde{u}_L\tilde{u}_L$	1006	0.89	1.2
$\tilde{s}_L\tilde{s}_L$	1009	0.61	0.07
$\tilde{c}_L\tilde{c}_L$	1006	0.89	1.2
$\tilde{b}_1\tilde{b}_1$	1997	0.19	0.01
$\tilde{t}_1\tilde{t}_1$	1866	0.28	0.22
$\tilde{e}_L\tilde{e}_L$	1869	0.95	0.37
$\tilde{\nu}_{eL}\tilde{\nu}_{eL}$	1867	4.6	/
$\tilde{\mu}_L\tilde{\mu}_L$	1869	0.25	0.37
$\tilde{\nu}_{\mu L}\tilde{\nu}_{\mu L}$	1867	0.11	/
$\tilde{\tau}_1\tilde{\tau}_1$	1328	0.30	0.93
$\tilde{\nu}_\tau\tilde{\nu}_\tau$	1364	0.15	/
$\tilde{d}_R\tilde{d}_R$	988	0.13	0.08
$\tilde{u}_R\tilde{u}_R$	989	0.53	1.2
$\tilde{s}_R\tilde{s}_R$	988	0.13	0.08
$\tilde{c}_R\tilde{c}_R$	989	0.53	1.2
$\tilde{b}_2\tilde{b}_2$	2032	0.07	0.01
$\tilde{t}_2\tilde{t}_2$	2108	0.26	0.16
$\tilde{e}_R\tilde{e}_R$	1856	1.4	0.38
$\tilde{\nu}_{\mu R}\tilde{\nu}_{\mu R}$	1856	0.21	0.38
$\tilde{\tau}_2\tilde{\tau}_2$	1365	0.31	0.86
$\tilde{\chi}_1^0\tilde{\chi}_1^0$	954	≈ 0	/
$\tilde{\chi}_2^0\tilde{\chi}_2^0$	954	≈ 0	/
$\tilde{\chi}_1^+\tilde{\chi}_1^-$	955	2.7	1.4
$\tilde{\chi}_3^0\tilde{\chi}_3^0$	1294	1.1	/
$\tilde{\chi}_4^0\tilde{\chi}_4^0$	2262	0.53	/
$\tilde{\chi}_2^+\tilde{\chi}_2^-$	2262	1.3	1.3
H^0A^0	3046	0.04	/
H^+H^-	3046	0.10	0.08

Gamma Factory

GammaFactory



Camilla Curatolo
W. Placzek *et al.* - Gamma Factory at CERN – novel research tools made of light,
doi 10.5506/APhysPolB.50.1191

Kevin Cassou

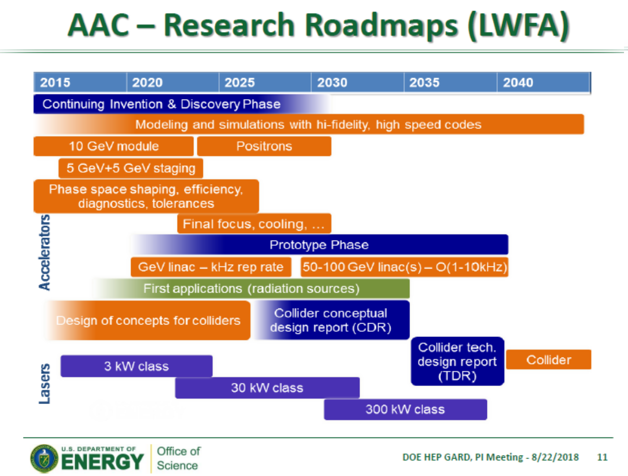
9-orders of magnitude larger cross section than electrons

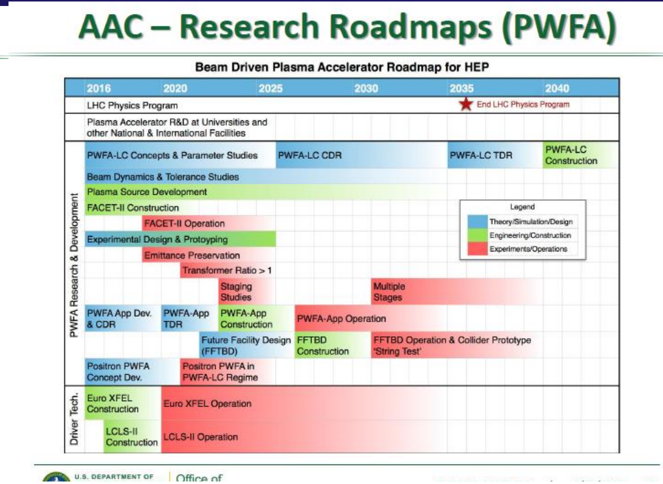
Partially stripped ions are not lost like electrons would be at high energy

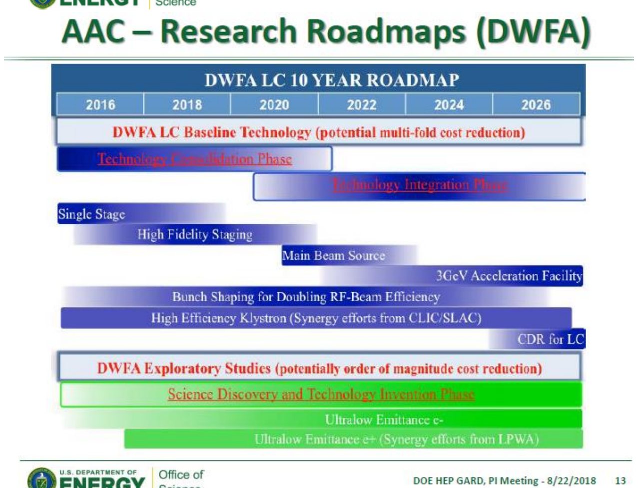
First PSI in the LHC in summer 2018

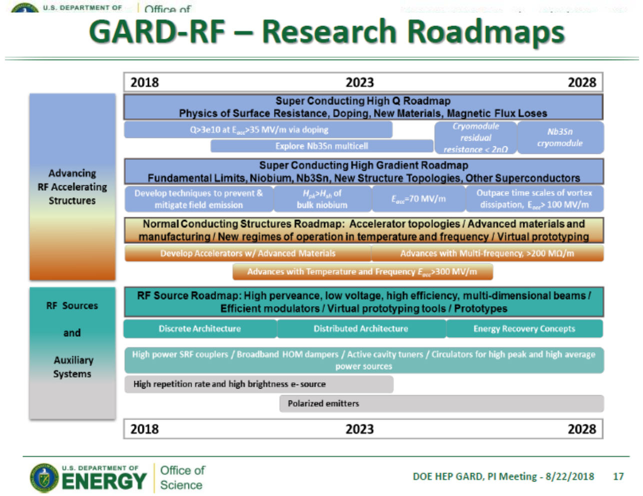
GF-POP in SPS being proposed, completed by 2024

Technology roadmaps include a step with multi-GeV, multi-stage prototypes





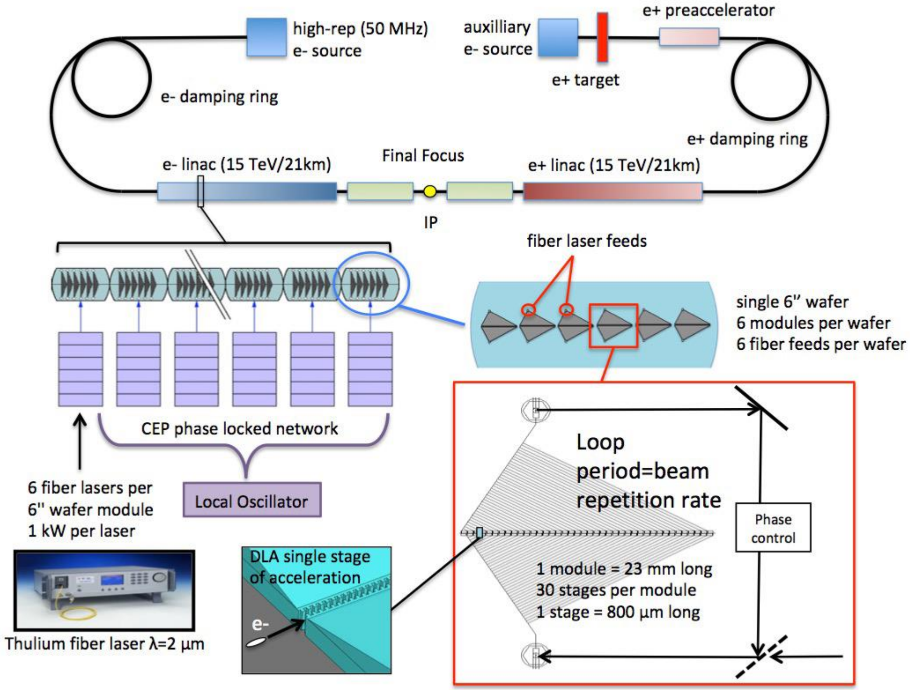


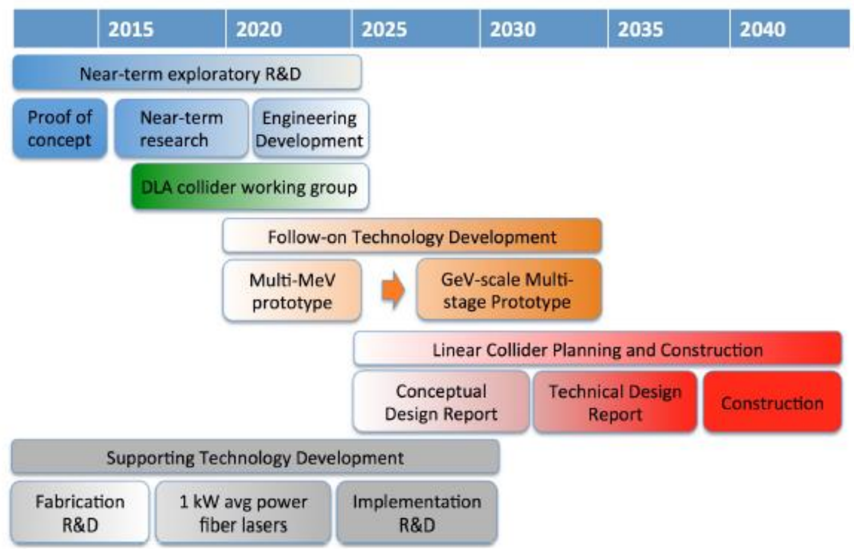


In the US, the multi-stage prototypes will be used to inform a down-select to a higher energy demonstration machine.

Continued research requires experimental progress on achieving beam stability and control, narrow energy spread of the beam, emittance preservation, and stageability

There is an additional community roadmap for DLA technology development

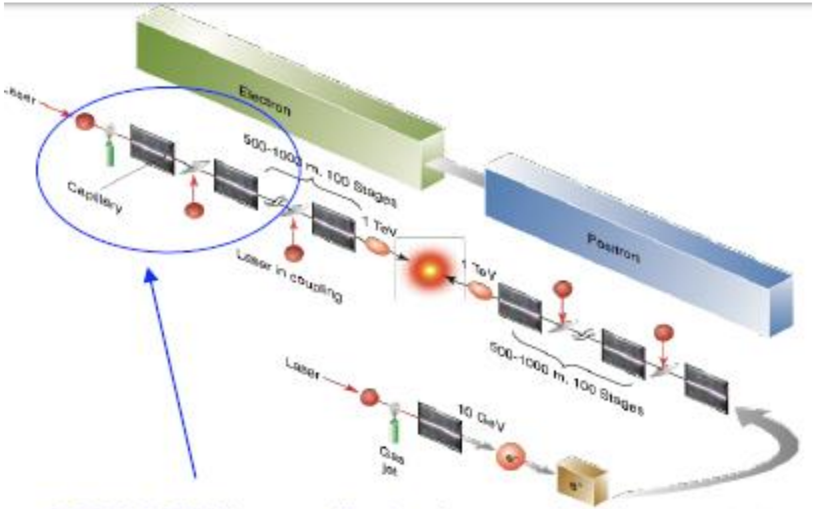




: Thirty-year roadmap for a DLA collider, reproduced from the ANAR 2017 Working Group 4 Report

Conceptual schematic of a 30 TeV DLA e+ e- collider

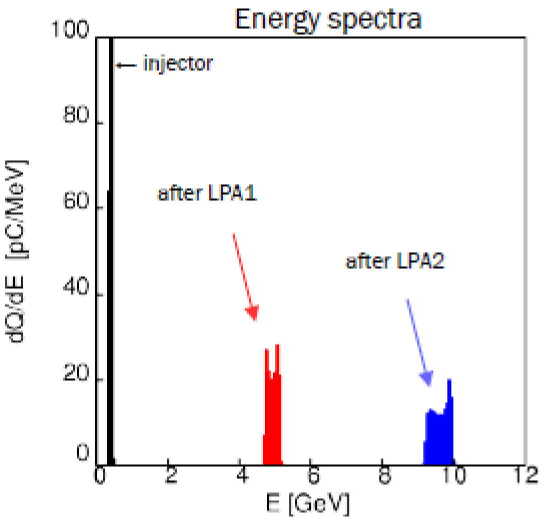
LPA technology development is moving towards a multi-stage prototype



BELLA PW laser will also be used to demonstrate multi-GeV staging

A. J. Gonsalves (plenary)

BELLA PW staging design shows 100% bunch capture and acceleration



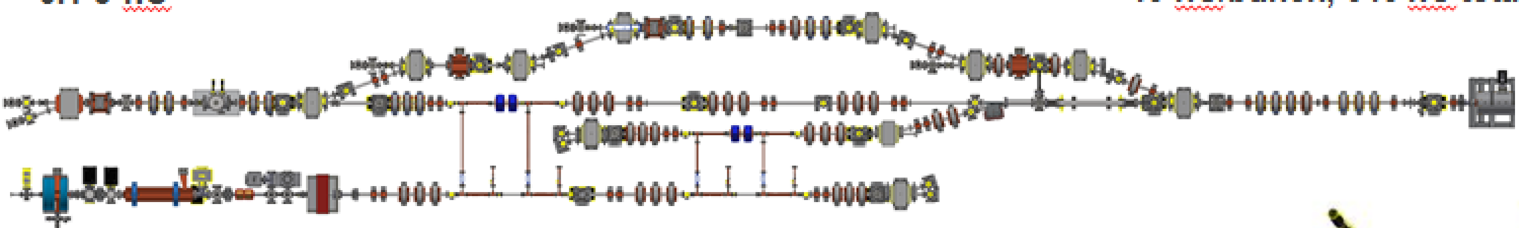
DWFA technology development is moving towards a multi-stage prototype

Conceptual design of the 500-MeV demonstrator at AWA

Proposed layout

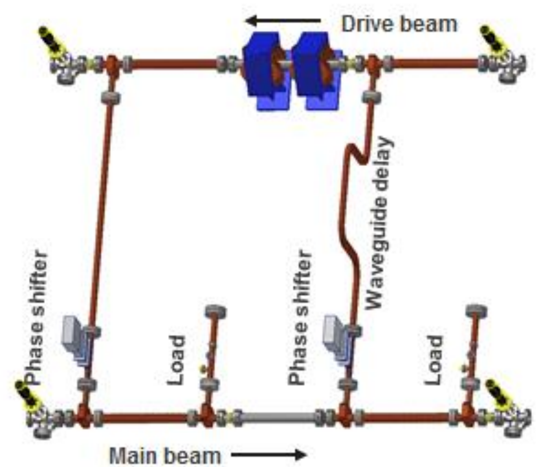
15 MeV main beam
Single bunch
0.1-3 nC

70 MeV drive beam
2 x 8-bunch trains
40 nC/bunch, 640 nC total



- 2 stages
- 2 pairs of structures per stage

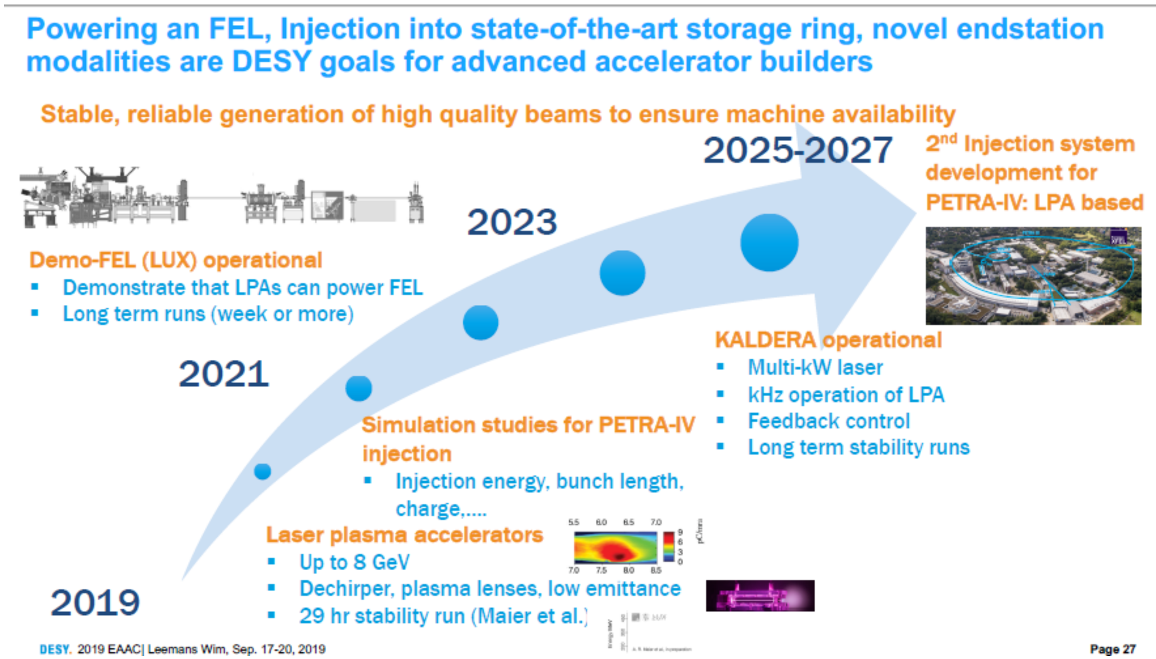
- Drive beam: 70 to ~20 MeV
- Main beam: 15 to ~500 MeV



John Power

Using advanced accelerator technologies for non-HEP applications is important to drive the technology forward

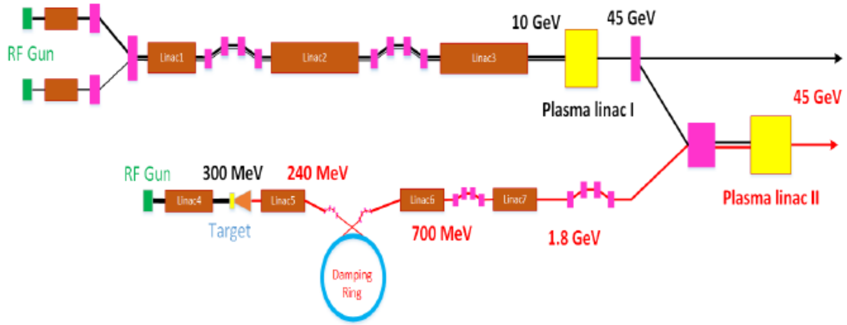
- Injector for PETRA-IV
- EuPRAXIA
- Compact XFEL (cyro-NCRF)
- MaRIE XFEL (cyro-NCRF)
- Dark matter/sector searches
- Non-perturbative QED studies
- Gamma factory



Wim Leemans (plenary)

First applications of advanced acceleration schemes to HEP (1 of 2) – CEPC plasma injector

A preliminary design of CEPC plasma based high energy injector



- Driver/trailer beam generation through Photo-injector
- HTR PWFA with good stability (single stage TR=3-4, Cascaded stages 6-12, high efficiency)
- Positron generation and acceleration in an electron beam driven PWFA using hollow plasma channel (TR=1)

Ref: CEPC CDR

Jianfei Hua

Driver and Acceleration Media

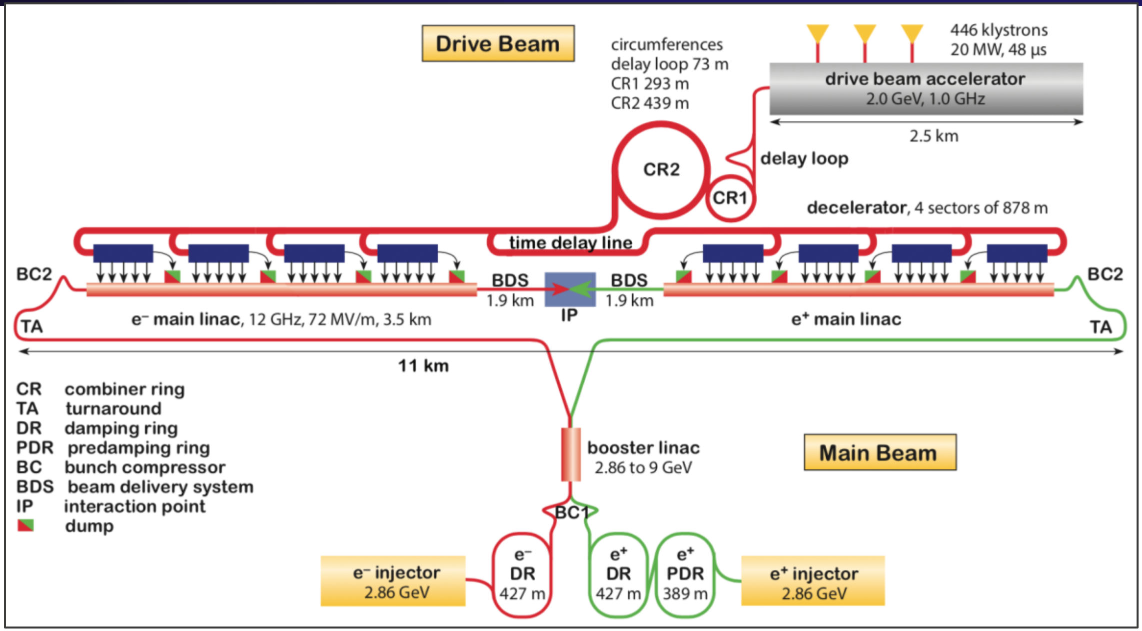
- Shaped Bunch Generation
- Plasma source (1-10m)
- Hollow plasma channel generation

Accelerator and Beam Manipulation

- HTR PWFA
- Positron acceleration
- External injection
- Plasma dechirper

This approach is motivated by the fact that all the required technology elements have already been demonstrated

First applications of advanced acceleration schemes to HEP (2 of 2) – ILC/CLIC plasma upgrade/booster, possible γ–γ



Erik Adli

The following features of the CLIC machine may upgraded with future technology :

– **The Main Linacs tunnels of 2x3.5km**. Assuming 1 GV/m for plasma technology, beams of up to **3.5 TeV** could be produced

– **The crossing angle of 20 mrad** optimal for 3 TeV CM energy collisions, also likely to be a good choice for higher c.m. energy collisions. **Compatible with high-energy γγ collisions**

– Could be possible to modify parts of the **CLIC Drive-Beam Complex** to produce appropriately spaced drive beams for a PWFA-LC

– **The injectors** providing 9 GeV low emittance electron and positron beams, could also inject into a main linac based on future technology