Particle physics plasma test facility (multi-stage, 10's of GeV)

Session — 11:20 - 12:20 — Thursday, Sep 22nd, 2022

~~**Jens Osterhoff**~~
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Carl B. Schroeder

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

EuroNNAc Special Topics Workshop
September 19th, 2022

ALEGRO Advanced LinEar collider study GROup

DESY.

A collider is the ultimate challenge, requires specific solutions

Ballpark requirements and state-of-the-art

	FEL	Collider	Current
Charge per bunch (nC)	0.01 - 0.1	0.1 - 1	0.01 - 0.1
Energy gain (GeV)	0.1 - 10	1000+	0.1 - 10
Energy spread (%)	0.1	0.1	0.1 - 1
Wall-plug efficiency (%)	< 0.1 - 10	10	< 0.1
Emittance (µm)	0.1	0.01	0.1 - 1
Rep. rate (Hz)	10^1 - 10^6	10^4 - 10^5	10^1
Avg. beam power (W)	10^1 - 10^6	10^6	10^1
Continuous run	24/1 - 24/7	24/365	24/1
Parameter stability	0.1%	0.1%	1%

**First FEL-gain demonstrated,
FEL-user facility still some way to go**

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- *highest energy:* **staging of plasma modules**
- *lowest emittance:* precision beam, laser, and plasma control
- *efficiency:* high wall-plug efficiency (energy recovery?)
- *rep. rate and avg. power:* kW/cm thermal plasma management
- ***positron acceleration*** *with exquisite quality*
- ***beam polarization*** *maintenance*
- *computing capabilities*
  for full start-to-end optimization incl. jitter studies

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Needs solutions specifically developed
for particle colliders, much more demanding — How do we get there?

Strategy in Europe (LDG) and US (Snowmass) give similar answers

How do we get to a plasma-based collider?

from LDG Accelerator R&D Roadmap

4.6.2 *Three pillars of the near-term R&D roadmap*

The panel has discussed and agreed on a roadmap that is based on three pillars that should be pursued in parallel (see also Fig. 4.1). The three pillars of our roadmap are

1. **The first international feasibility and pre-CDR study** for high-gradient plasma and laser accelerators and their particle physics reach. This paper study will lead to a comparative report on various options, a feasibility assessment, performance estimates, physics cases, intermediate HEP applications and a cost-size-benefit analysis for high energy.

from Snowmass Accelerator Frontier TG 6 Draft

- A targeted R&D program addressing high energy advanced accelerator-based colliders (e.g. to 15 TeV, with intermediate options) should develop integrated parameter sets in coordination with international efforts. This should detail components of the system and their interactions, such the injector, drivers, plasma source, beam cooling, and beam delivery system. This would set the stage for an integrated design study and a future conceptual design report, after the next Snowmass.
- A study for a collider demonstration facility and physics experiments at an intermediate energy (ca. 20–80 GeV) should establish a plan that would demonstrate essential technology and provide a facility for physics experiments at intermediate energy.

→ An intermediate step between the few GeV facilities today and a future TeV-collider is mandatory

How could an intermediate facility look like? How to solve the technology challenges?

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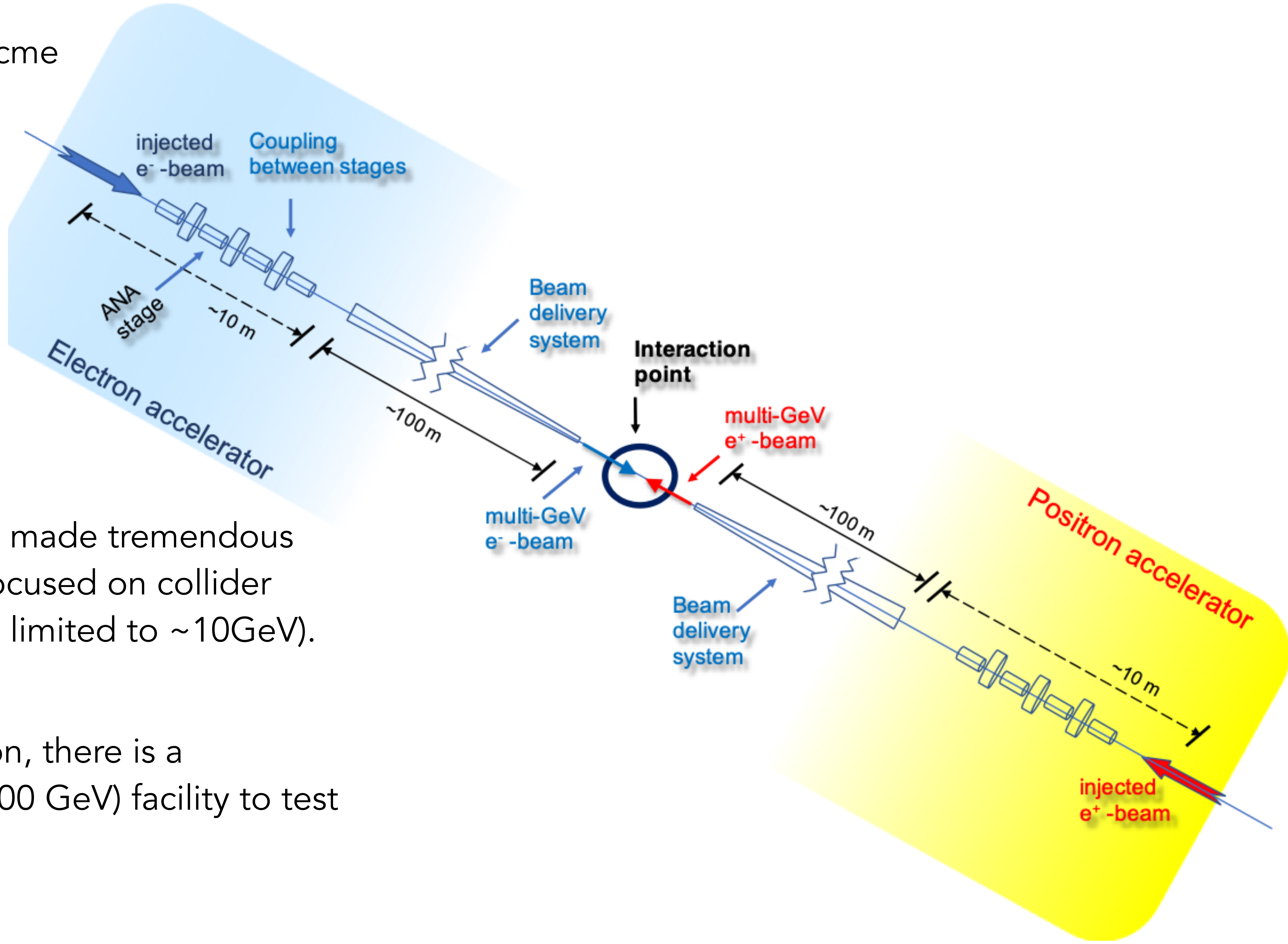
11:00

	Plasma accelerator demonstration facility at intermediate energy	*Carl Schroeder*
	Sala Maria Luisa - Hotel Hermitage	11:20 - 11:40
	Solutions and challenges for a multi-stage plasma accelerator	*Dr Carl A. Lindstrøm*
	Sala Maria Luisa - Hotel Hermitage	11:40 - 12:00
12:00	**Discussion**	*Jens Osterhoff et al.*
	Sala Maria Luisa - Hotel Hermitage	12:00 - 12:20

Plasma accelerator demonstration facility at intermediate energy

- Energy frontier desires lepton collider at 10+ TeV cme

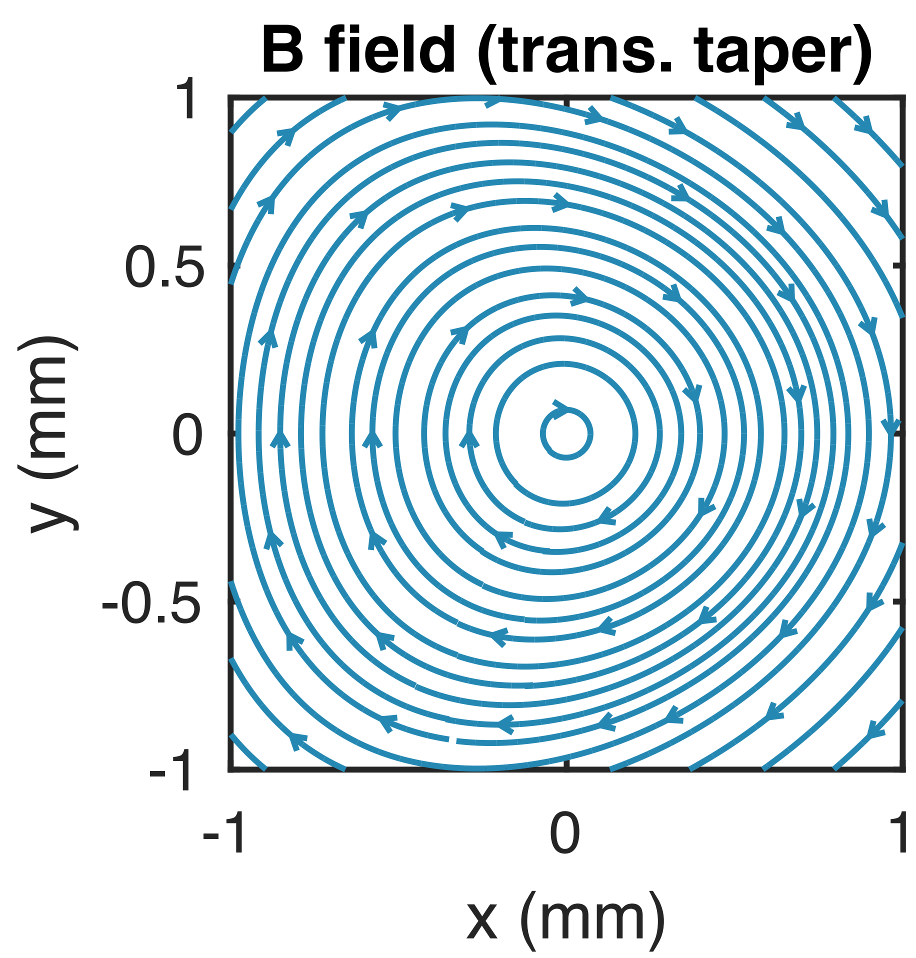


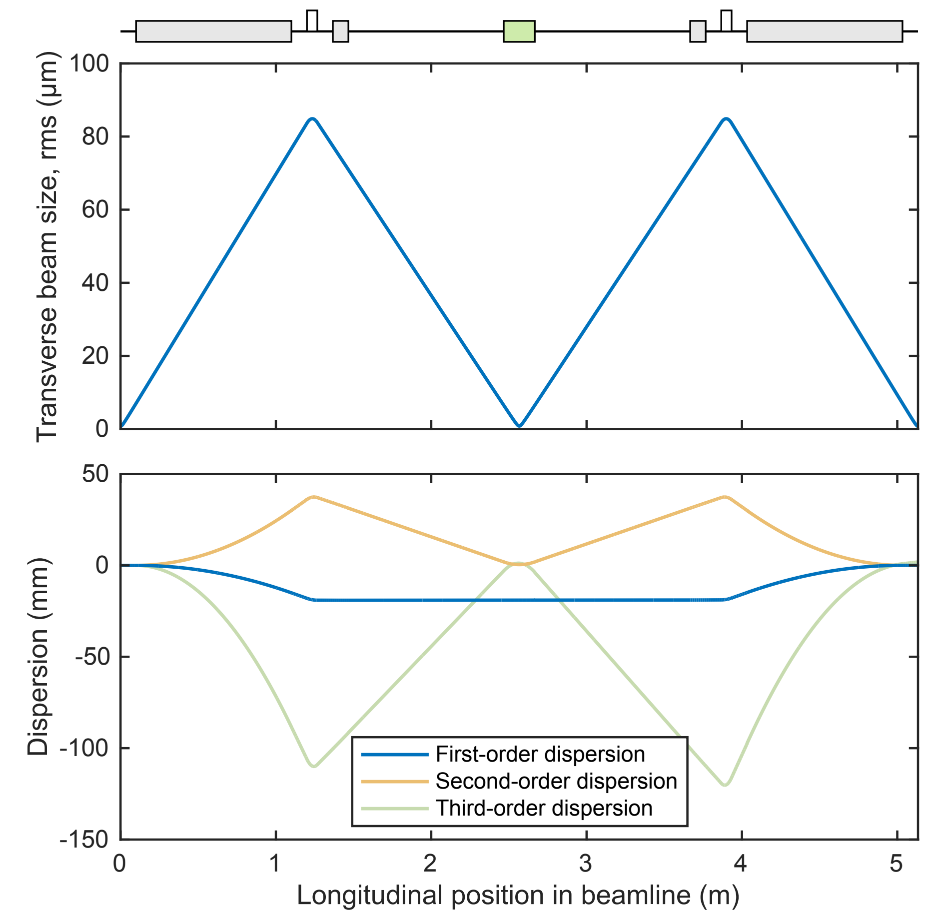
- Wakefield accelerators (LWFA, PWFA, SWFA) have made tremendous progress, but current beam test facilities are not focused on collider systems R&D (and acceleration at present facilities limited to ~10GeV).

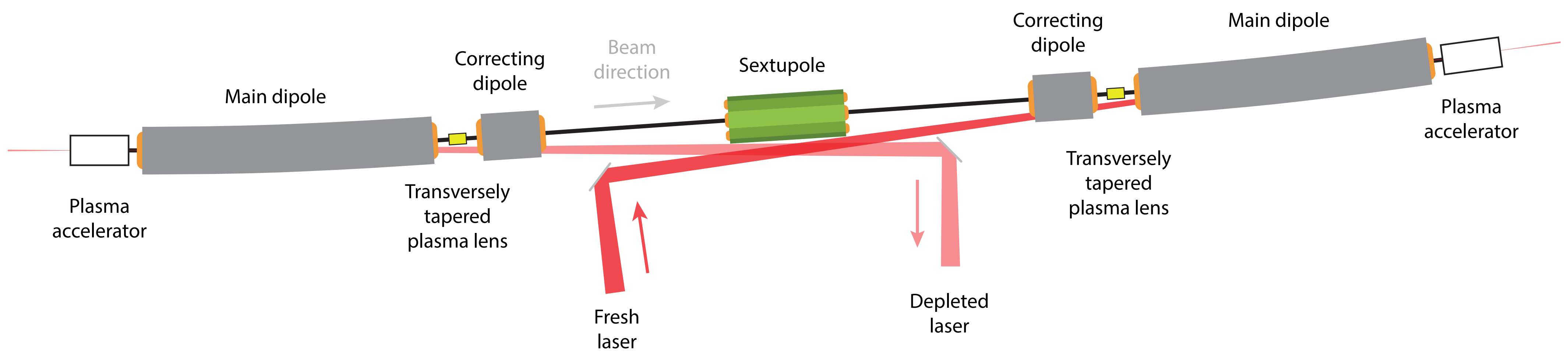
- To develop ANA technology for collider application, there is a recognized need for an intermediate energy (20-100 GeV) facility to test key collider systems.
  - Main motivation is advanced accelerator R&D
  - Opportunities for QCD and BSM physics studies

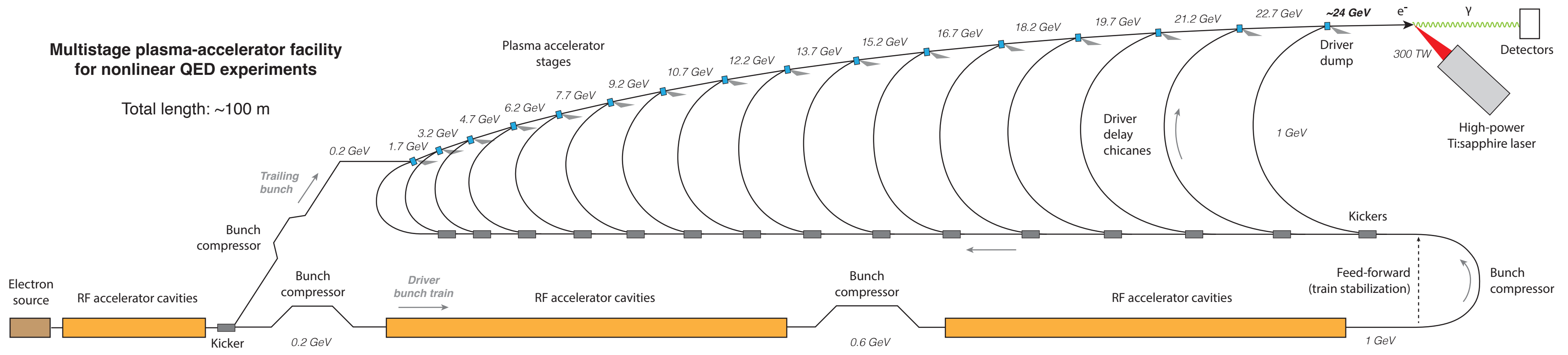
Solutions and challenges for a multi-stage plasma accelerator

- **Staging** is likely **required to reach high energies**, efficiently.
- Four staging problems:
  - *Compactness*
  - *In- and out-coupling of drivers*
  - *Emittance growth from chromatic mismatching*
  - *Tight synchronization tolerances*
- **Nonlinear plasma lenses can potentially solve all the above problems.**
  - Lattice of two nonlinear plasma lenses, two dipoles, one sextupole ⇒ **achromatic transport (emittance preserved)**
    - How do we make an appropriately nonlinear plasma lens?
  - R_{56} between stages ⇒ **self-correction (passive stability)**
- Can be used to **design compact high-energy facilities** ⇒ **nonlinear QED** (medium scale) or a **photon collider** (large scale)









Summary / Discussion

Science case at 10's of GeV needs to be sharpened

- γ - γ collider for Higgs production may be game changer if affordable (< 1 $B) [Brian Foster]
- QCD / BSM / nonlinear QED
- Keep e+ e- at forefront. Don't abandon the positron! [Ralph Assmann]

Technical design of facility

- need research into facility layout
- tailored sextupole-like plasma lenses for achromatic staging
- transverse stability is unsolved
- longitudinal stability solution proposed


ALEGRO 2023
Organisation: Brigitte Cros, Richard D'Arcy, Patric Muggli, Jens Osterhoff
Administration: Daniela Koch
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