Options for New Experiments and Facilities at DESY

E. Elsen (DESY) & A. Schöning (U Heidelberg)

Z-factory
Improved ep/eA collider HERA
use of intense electron (and photon) beams

with input from Ideenmarkt at DESY in June
http://beschleuniger-ideenmarkt.desy.de/
next meeting 23.-24.11.2010 at DESY

DESY committed to Energy Frontier

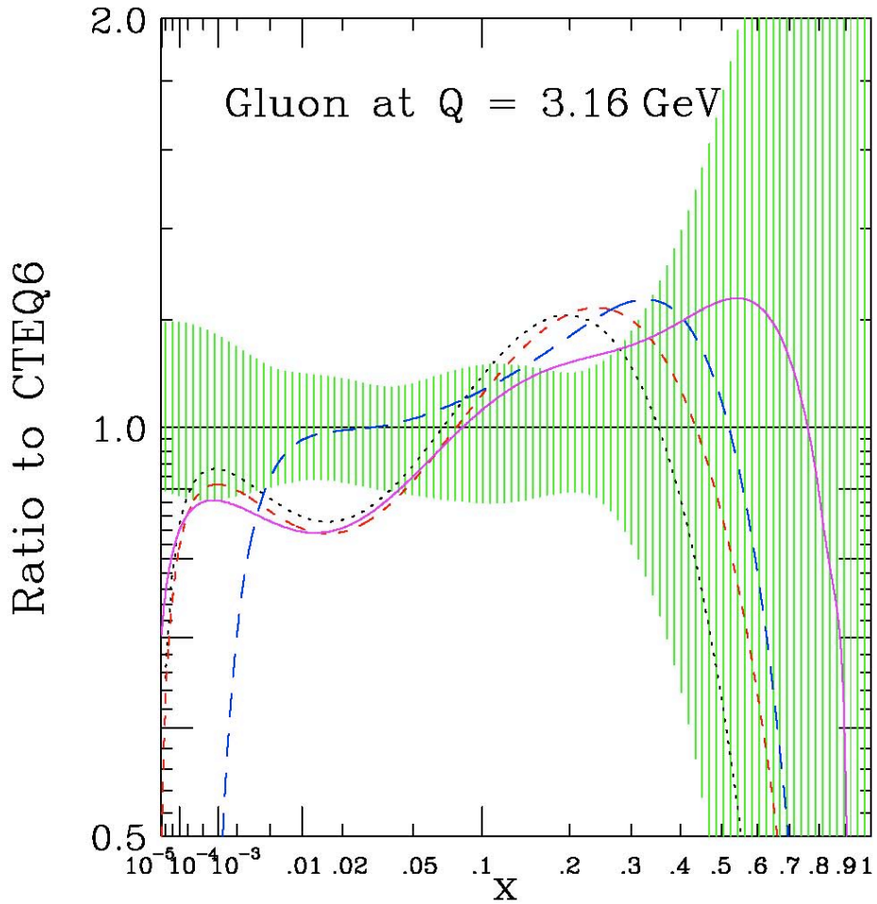
- engaging at the LHC
  - luminosity steadily improving
  - discoveries could be around the corner
  - LHC improvements/upgrades steadily extend the reach
- engaging for Linear Collider
  - ILC solidly prepared and soon ready for acceptance (0.1–1 TeV cms)
  - CLIC is under intense R&D and may eventually extend the energy window to 3 TeV
- However, if no new project **directly** targeting the energy frontier were approved one should explore facilities that do so **indirectly**. Typically these are *Factories*.

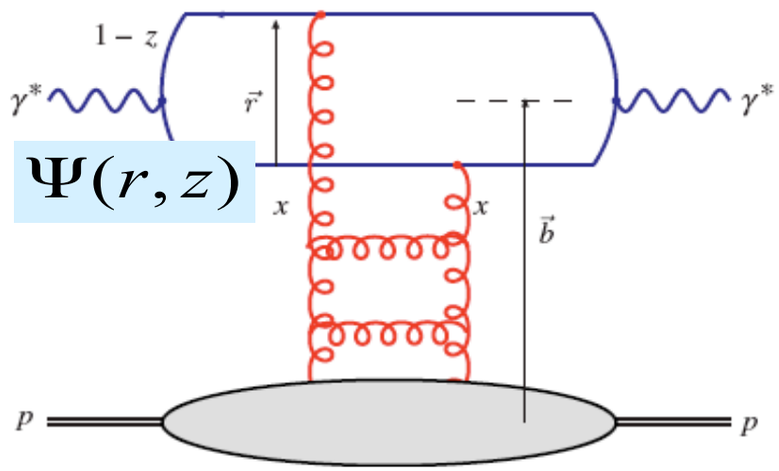
DESY Assets

- HERA tunnel & most of the machine components
- Expertise in operating large facilities
    - Focus on electron and photon facilities
    - Expertise in Applications of Superconductors
        - Magnets
        - Cavities
- Expertise in construction of large detectors

Resuming HERA physics addressing earlier weaknesses

- low x region largely unexplored
  - gluon density
    - current PDFs come with known deficiencies
    - saturation
- (hard) diffraction
  - theoretically much better understood
  - solid theory in the QCD framework
- QCD tests in eA scattering
  - g(x) ~ $A^{1/3}$

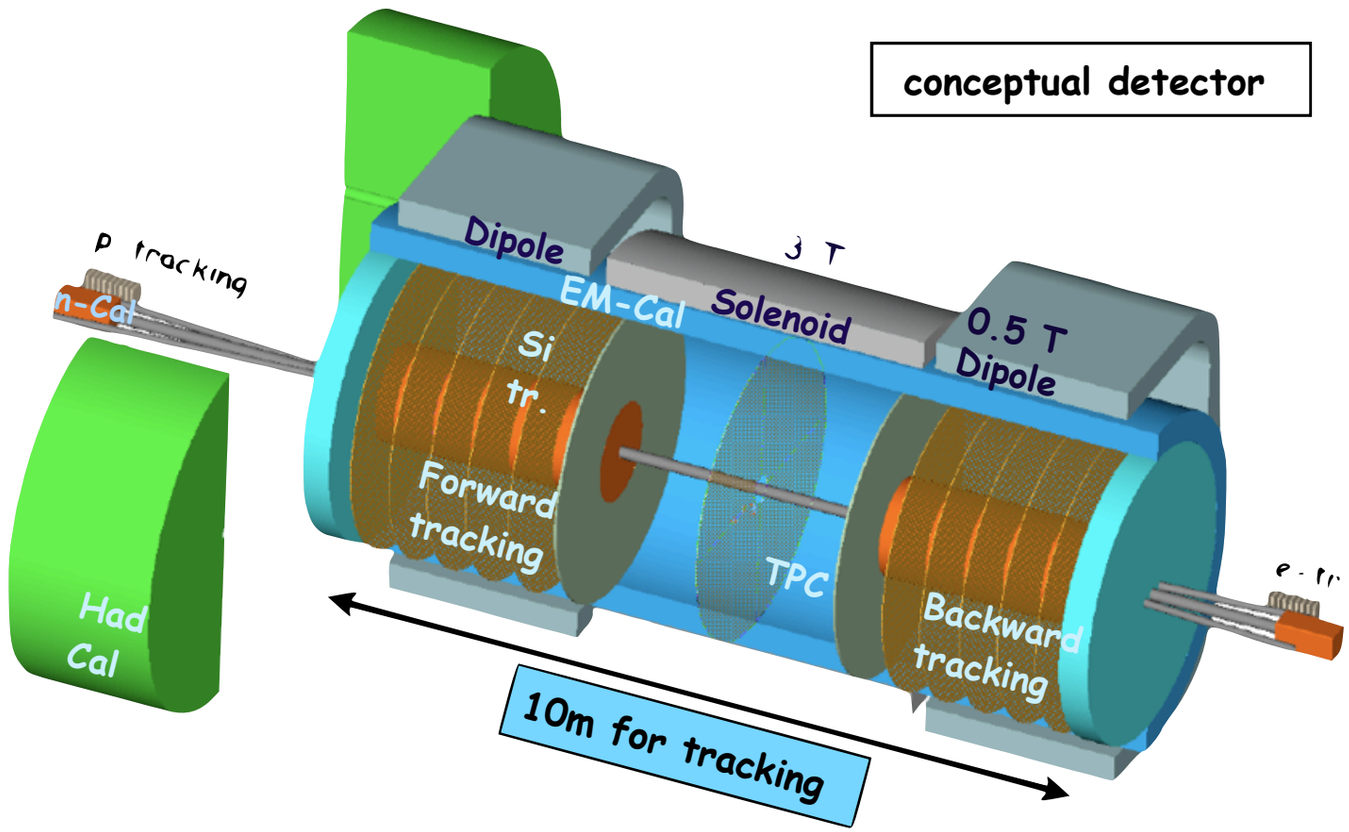




Requirements for ep/eA

- High Luminosity requires
  - shorter dipoles in electron ring
    - Cooled protons à la Fermilab
      - requires an extra ring to achieve ε=1 nm
- New detector with vastly extended forward/backward coverage

rebuilt of e-ring and injection paths



Intense Proton Beams?

- Fermilab will soon have protons in abundance
- CERN is discussing SPL
- PSI has most intense p-beam;
  ESS will eventually have intense proton beams
- DESY III has been dismantled
  - HERA proton energy ramp is slow, O(mins)
    - Nowadays competitive intense proton beams only from superconducting accelerators for which the 1.3 GHz cavities are only a compromise
  - Proton linac at DESY (still) available

Intense protons not a wise scientific extension at DESY

e^+e^- Factories

- Super-τ/charm factory
  - Extreme luminosity
  - little reuse of existing infrastructure

technically
extremely difficult

- B-Factory
  - BELLE II will get high luminosity
  - Super-B discussed in Italy
  - could use HERA tunnel

feasible but not considered
because of other ongoing efforts

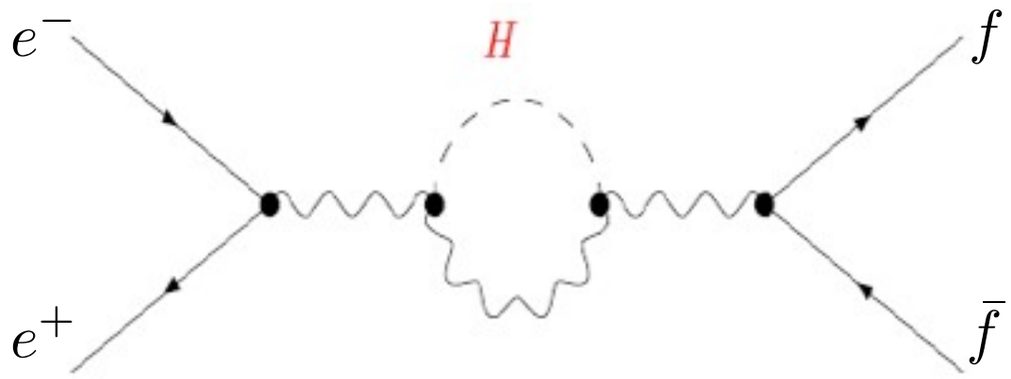
- Z-Factory
  - HERA ~1/5 size of LEP

interesting

Case for Z-Factory

- New physics may be hidden in virtual corrections; requires
  - Precision
  - Polarisation
- At the current level of LEP/SLC the two most sensitive measurements show tension:
  - $\sin^2\theta_{eff}(A_{LR}) = 0.23098 \pm 0.00026$
  - $\sin^2\theta_{eff}(A_{FB}^b) = 0.23221 \pm 0.00029$
- Theoretical uncertainty ±0.00005 can be improved

Polarisation mandatory



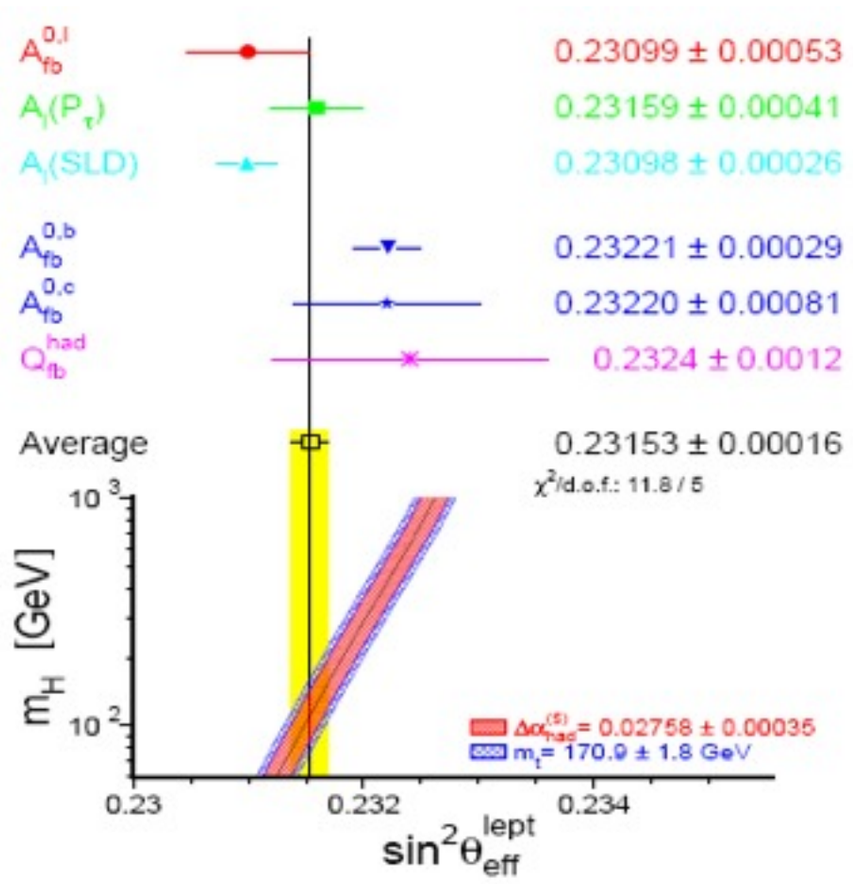
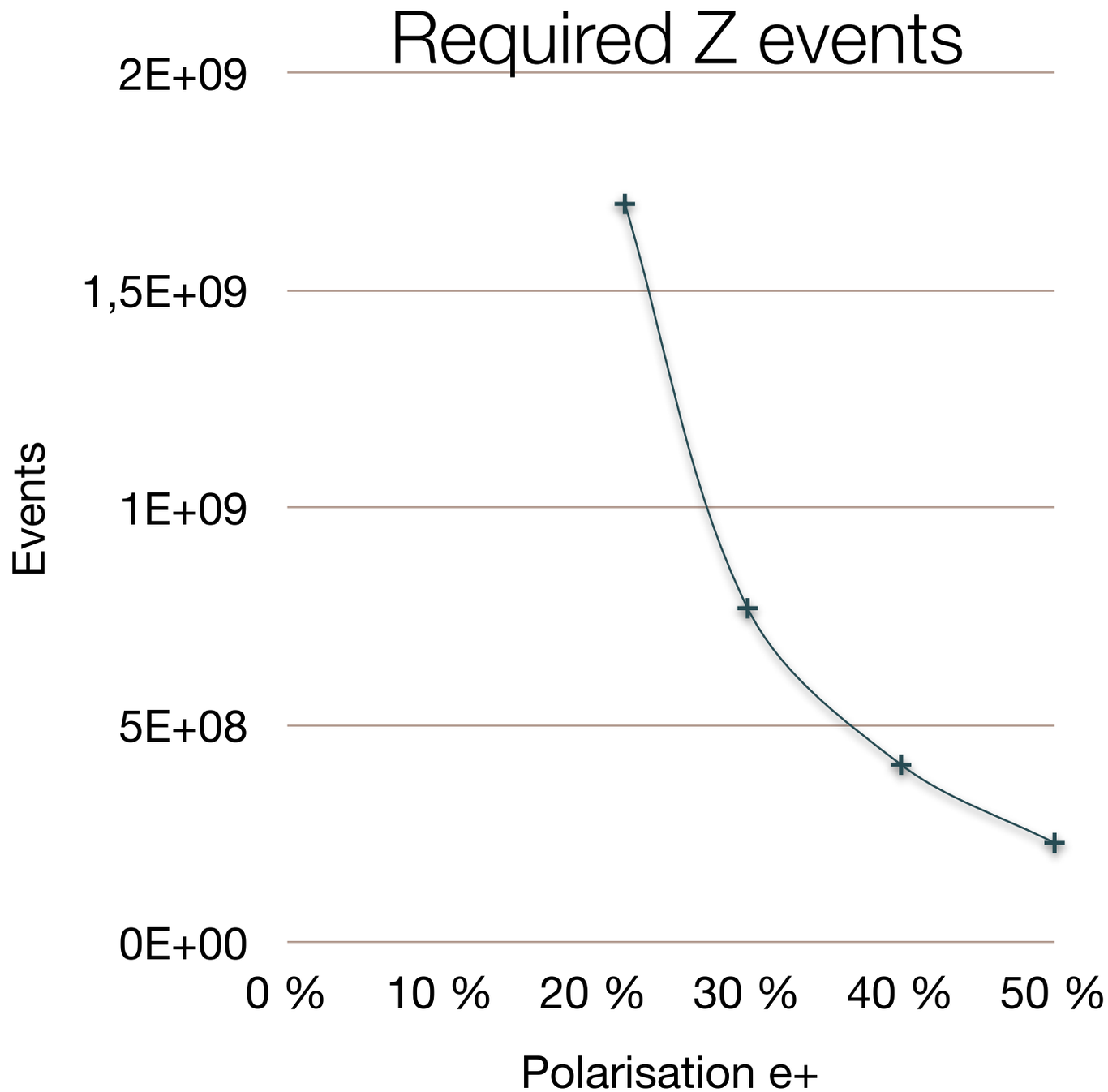


Illustration of Role of e^+ Polarisation

- For fixed e^- Polarisation of 90% in both helicities
  - and a required precision of $\Delta\sin^2\theta_{eff}=3\times10^{-5}$
  - with no e+ polarisation 9×10^8 events yield $\Delta\sin^2\theta_{eff}=1\times10^{-4}$



e+ Polarisation helps quickly

Many Physics Options at a Z-Factory

- QCD
  Measurements of $\alpha_s = 0.1176(20) \pm 0.0017$ (PDG 2009)
  - Event shape variables
  - Progress in higher order calculations
    - SCET reduce hadronisation uncertainties
- Γ_l measurement requires luminosity and scan over Z-resonance
- Z-Factory is also a B- and a τ-Factory
  - Clean environment, τ-polarisation measurement
  - Progress in detector technology enables precise measurements

High precision detectors

Full programme needs further elaboration

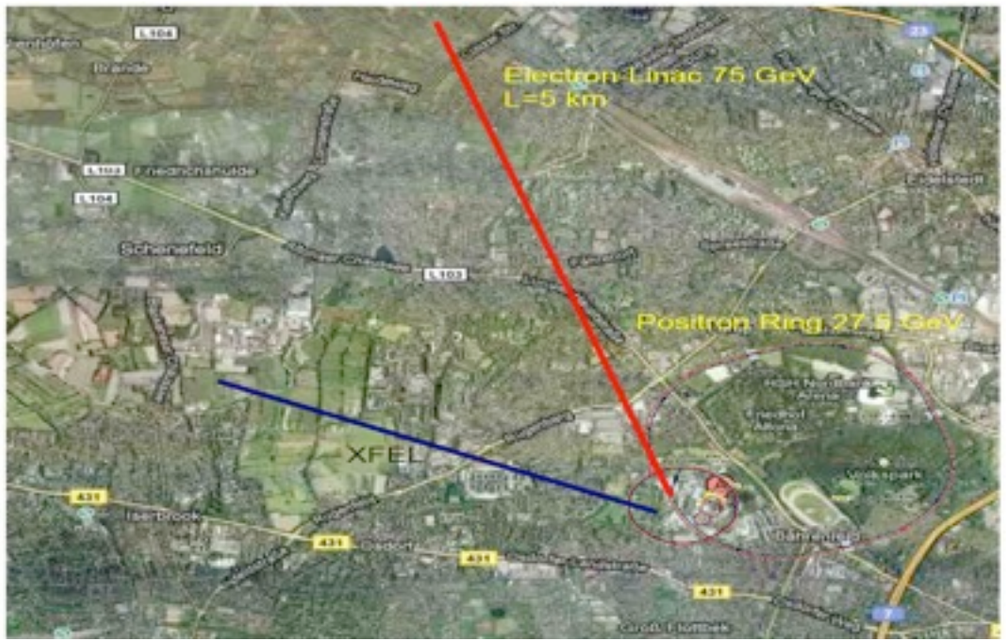
Z-factory in HERA tunnel – Ring-Ring Option

- HERA magnets are suitable for 50 GeV beams
  - Synchrotron radiation excessive
    - ΔE/turn > 0.5 GeV lost into pipe and magnets
      - Imposes a current limitation
    - Luminosity limited to LEP I values of 2×10^{31} $cm^{-2}s^{-1}$
- Polarisation very small if at all: radiation induced energy spread too close to depolarising resonances

not sufficient

Z-Factory in HERA – Linac-Ring Option

- Positrons are difficult to obtain in large numbers
  - Store polarised positrons at 27.5 GeV in HERA
- Electrons can be readily obtained from a polarised source
  - Accelerate polarised electrons in a superconducting linac to 75 GeV
- Collide asymmetric particle beams
  - abandon electrons (disruption too large)
  - preserve positrons after collision
- $L > 2\times10^{32}\ cm^{-2}s^{-1}$
- $P(e^-) = 90\%;\ \ P(e^+) > 50\%$



will exceed LEP luminosity by an order of magnitude and meet polarisation and energy resolution requirements

Linac-Ring Luminosity

Linac energy	**75.5**	**GeV**
Linac beam power	**20**	**MW**
Linac current	0.26	mA
bunch charge	**2.7**	**nC**
Linac bunches	99963	/s
Linac duty cycle	**0.05**	
bunch rate	2.0	MHz
Ring energy	27.54	GeV
Ring current	**50**	**mA**
e^+ eps x	**3.4**	nm rad
e^+ eps y	**0.17**	nm rad
beta* x	**3.0**	cm
beta* y	**0.45**	cm
Lumi	2.33E+32	/cm^2/s
Z	45	M/year

D.Pitzl, B.Paschen et al.

cross section	30	nb
Ring	42	bunches
Polarization	50	%
Ring	1.56E+11	e/bunch
coupling	0.05	
beam width	10.1	um
beam height	0.87	um
tune shift	0.070	
year*eff	75	days

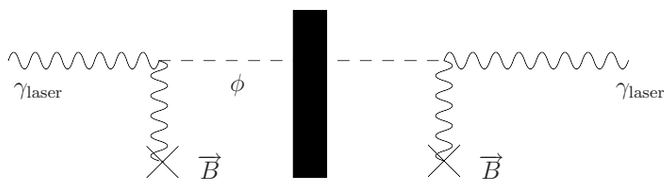
Z-Factory using Linac-Linac Option

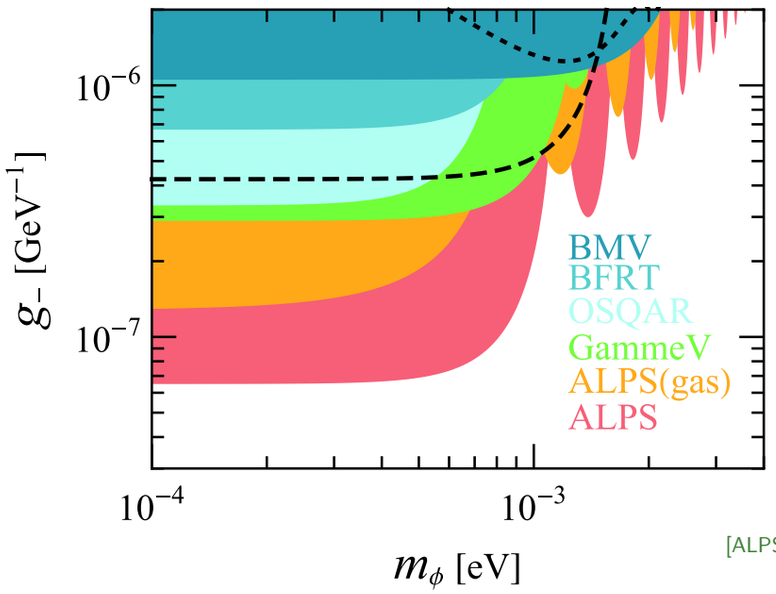
- This is essentially 1/5 of the ILC energy including
  - Intense positron source
  - Damping rings for both beams
  - Sophisticated beam delivery section

This machine is effectively the precursor of the ILC

Use of DESY infrastructure: e-, γ and more

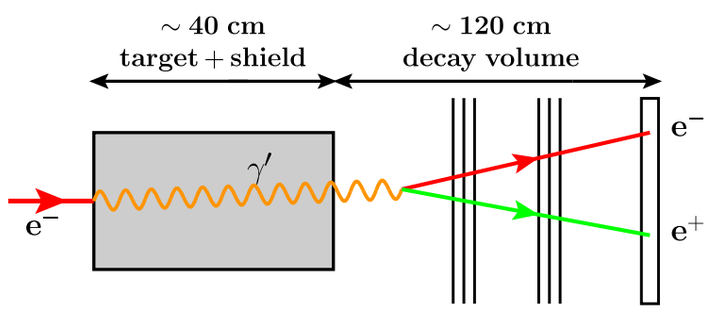
- Axion search





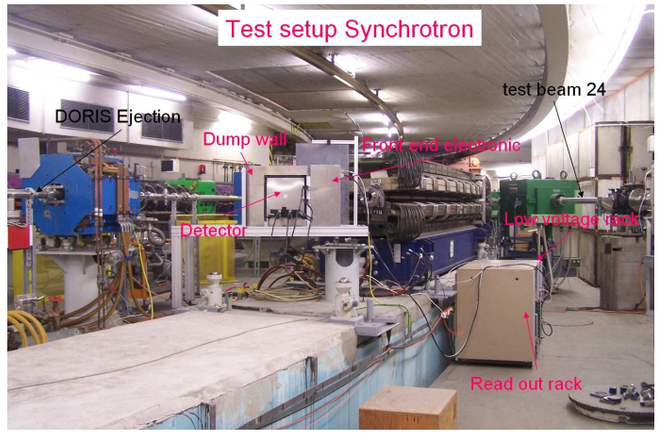
[ALPS Collaboration '10]

- **Hi**dden **P**article **S**earch (HIPS)
  - DESY
  - FLASH / FLASH II
  - XFEL



[Andreas,AR '10]

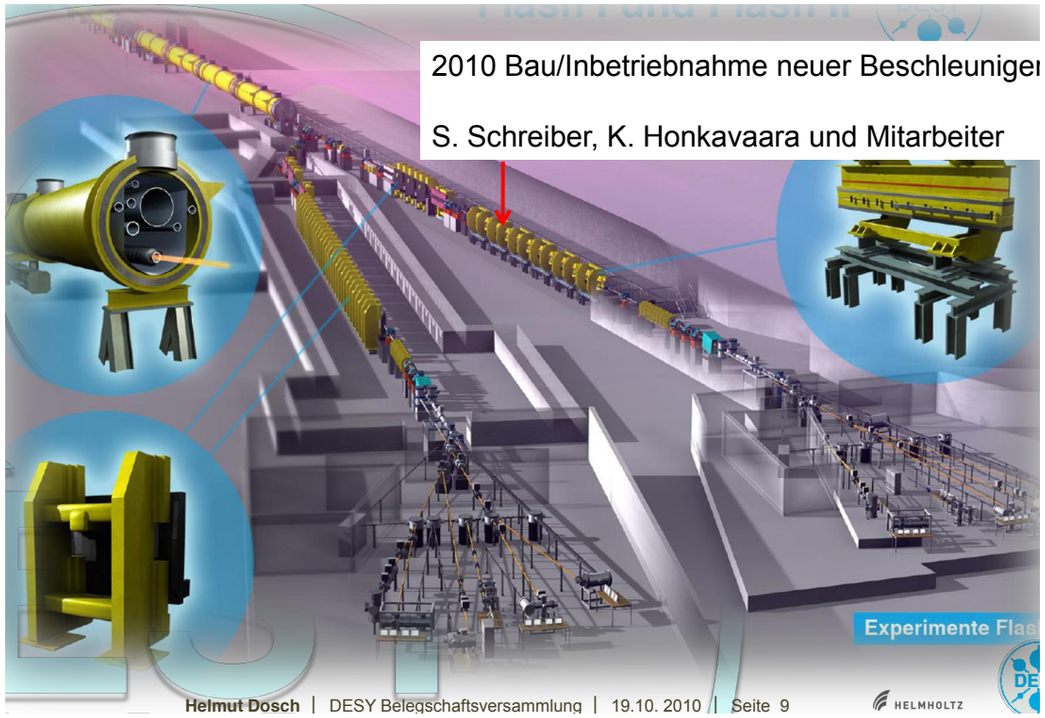
- Photons from FELs or dedicated lasers



Such endeavours will always be adequately supported

Electron Experiments

- Beam Dump experiment
  à la HIPS
- Experiments for high density QED
- Plasma experiments for novel accelerators techniques
  - Short pulses for beam injection experiments



Vital interest of HEP;
discussion on realisation in progress

Summary

- DESY dedicated to High Energy Frontier
    - LHC
    - ILC
- **Z-Factory** in ring-linac mode would enable **indirect searches** in the TeV region using high precision experiments
- an **upgraded HERA** machine with dedicated large η detectors would pin down low-x QCD and diffraction. Theoretical understanding has much advanced
- There are opportunities for (intense) **electron beam** experiments at DESY. The requirements have to be agreed upon with the respective main users.
    - HIPS etc.
    - Plasma experiments for accelerator development

Comment on lifetime of HERA tunnel

- Maintenance and preservation of infrastructure of the HERA tunnel is expensive
  - not really attractive as a light source
    - emittance not superior to that of PETRA
    - restrictions in underground experimental halls
    - HEP use cases have not really been put forward recently
      - Z-Factory
      - ep / eA collider

      } presented today
- Eventually the tunnel will have to be sand-filled again (safety hazard)
-

The opportunity of using a >6 km ring "for free" will not exist forever