An Electron and Positron External Beam Facility at DESY

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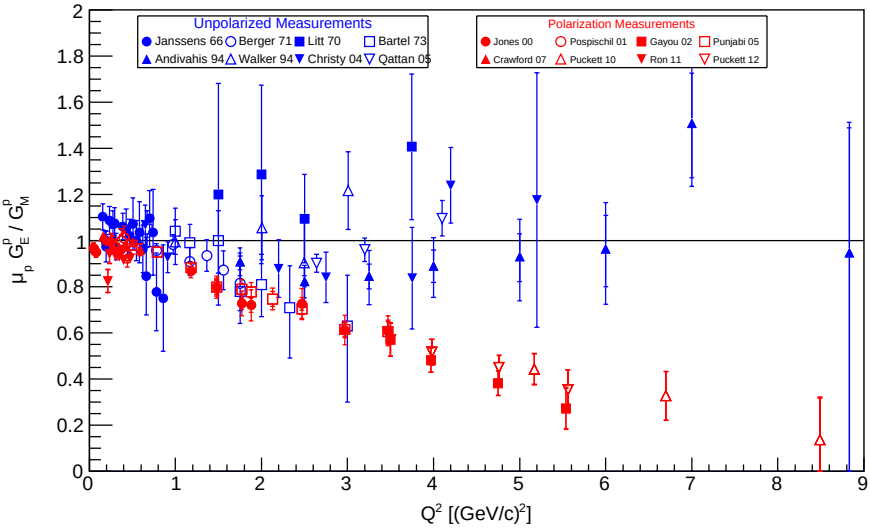
Presentation to the Positron Working Group Workshop at
the University of Virginia, Charlottesville, VA

March 8, 2023

My Motivation



Problem with Form Factor Ratio $\mu_p G_E^p / G_M^p$ Measurements

JLab found this problem !

Problem with Form Factor Ratio $\mu_p G_E^p / G_M^p$ Measurements

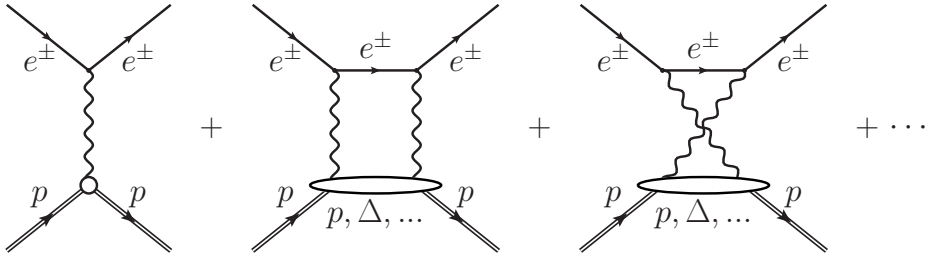
JLab found this problem !

JLab should fix it !

I fully support JLab's plans for positrons over such a large energy range

Just wish it could happen a bit sooner

Proposed Explanation - "Hard" Two Photon Exchange (TPE)

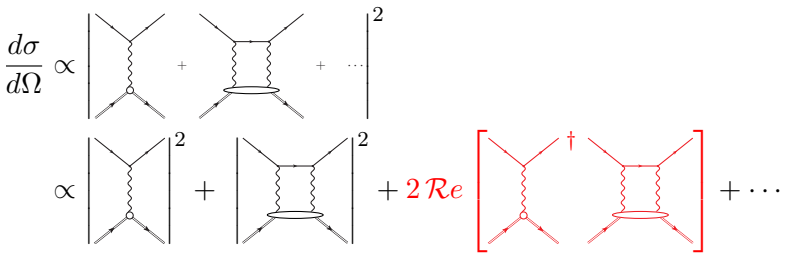


Two-photon exchange (TPE)

- "soft" TPE radiative corrections generally included in calculations
- "hard" TPE radiative corrections difficult to calculate
  - intermediate state (p, Δ, ...) model dependent

Need to measure "hard" TPE

How to Measure "Hard" Two-Photon Contribution



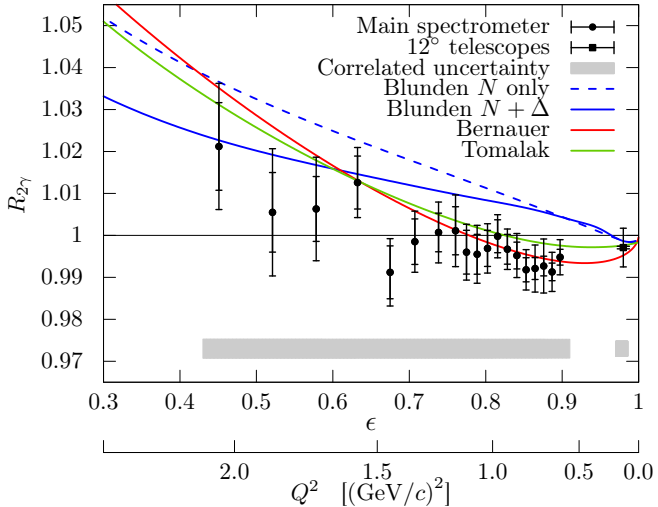
Interference term has a factor z^3, where z is the lepton charge

$\Rightarrow$ Interference term changes sign between e^+p and e^-p scattering

$\Rightarrow$ Measure ratio $R_{2\gamma} = \frac{\sigma_{e^+p}}{\sigma_{e^-p}}$

VEPP-3 (Novosibirsk), CLAS (JLab), and OLYMPUS (DESY)

OLYMPUS Results



B. Henderson *et al.* Phys. Rev. Lett. **118** 092501 (2017).

JLab is addressing the problem

but positrons in 2035 - 2037 and nothing beyond !

It's not enough to exploit the wealth of physics topics proposed

I propose an additional approach

DESY - has a long, established history with electrons and positrons

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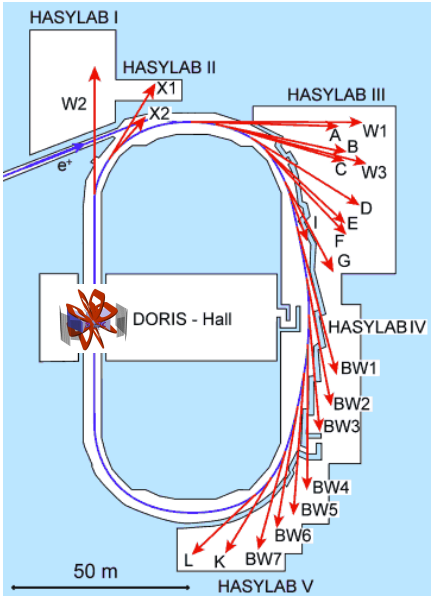
DESY - 1964 - original synchrotron for e^- scattering experiments
- experimental areas - Hall 1 and 2

Discovery of heavy quarks c and b drove interest in new measurements

e^+ capability with positron accumulator PIA added

DORIS - 1974 - 289 m storage ring for e^-e^+ collisions, 5 GeV per beam
- studies of J/ψ and Υ, $B_0\bar{B}_0$ mixing
- Crystal Ball (SLAC, DESY, BNL, Mainz), ARGUS
- 1980 - converted into HASYLAB, 36 beamlines
- 2011-2012 OLYMPUS - Two-Photon Exchange measurement


HASYLAB I
HASYLAB II
HASYLAB III
HASYLAB IV
HASYLAB V
DORIS - Hall
W2
X1
X2
W1
W3
A
B
C
D
E
F
G
I
e+
BW1
BW2
BW3
BW4
BW5
BW6
BW7
L
K
50 m

DESY - has a long, established history with electrons and positrons

In mid-1970s wondering: Are there more quarks ????

PETRA -
- search for new, heavy quarks
- 1978 - 2.3 km e^-e^+ collider, 19 GeV per beam
- TASSO, CLEO, PLUTO, MARK-J, and JADE
- lots of elementary particle studies, no new quarks, discovery of the gluon
- 1987-2007 - pre-accelerator for HERA

HERA -
- 1990-2007 - 6.3 km $e^{\pm}p$ collider, 27.5 GeV on 920 GeV
- H1, ZEUS, HERMES, HERA-B
- proton structure, PDFs, proton spin, data still being analysed


HERA
PETRA

Unfortunately after 2007 photon scientists gained the upper hand

- most DESY particle physicists jumped to LHC, counting rooms at DESY
- small nuclear experiments, axion searches, etc. still at DESY

FLASH - FEL 2002 109 nm, 2004 32 nm 2006 13 nm

PETRA-III - 2010 - 21 beamlines, 45 end stations in 300 m long hall

XFEL - 2017, 3.4 km, 17.5 GeV, 3 beamlines simultaneous

DESY-II synchrotron remains as injector to PETRA-III but mostly e^- these days

DESY-II synchrotron also used for test beam facility

Possibility for an extracted e^- and e^+ beam facility

PETRA-IV - 2029 (- ?) 30 beamlines, 1-10 nm

More opportunities for an extracted e^- and e^+ beam facility


PETRA III
European XFEL
DESY II
PIA
LINAC II
FLASH2
FLASH1

DESY - has a long, established history with electrons and positrons

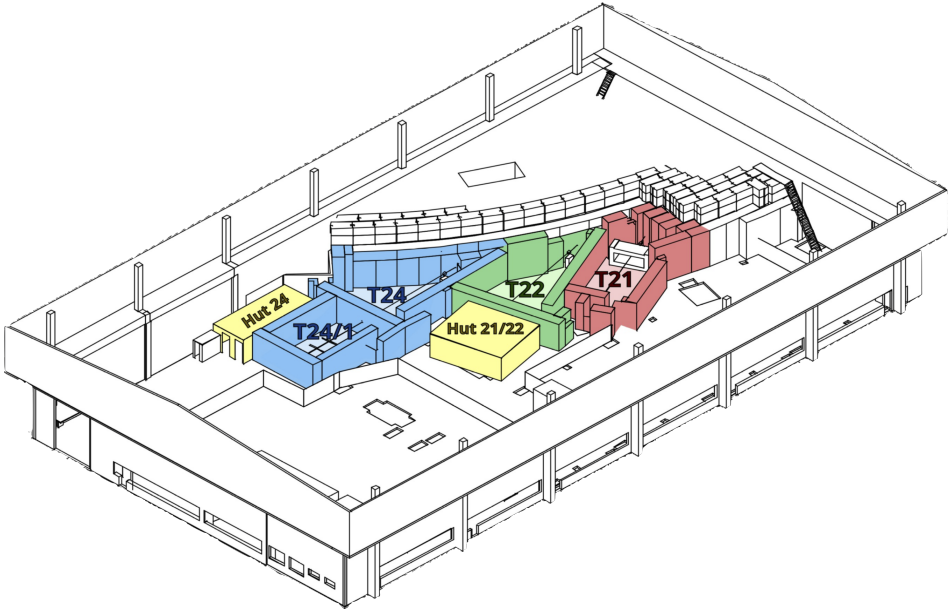
DESY-II synchrotron still capable of producing e^- and e^+

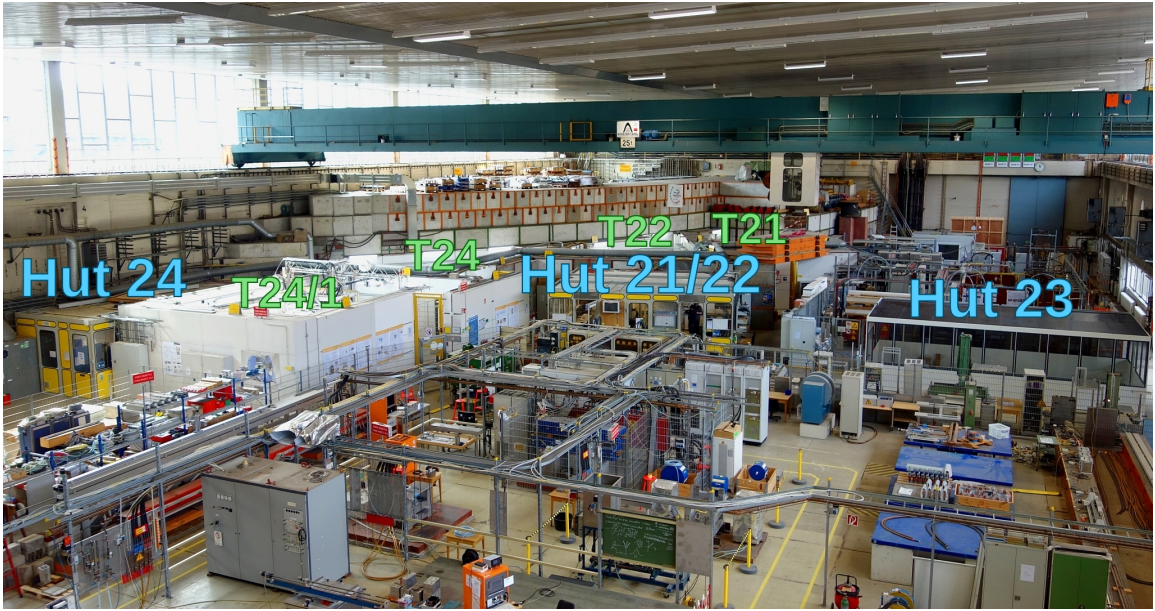
- 0.5–6.3 GeV beam energy
- 60 nA electrons, 30 nA positrons
- 12.5 Hz bunch frequency

But no facility for extracting the full current into an experimental area

DESY needs projects and collaborators to justify an extracted beamline

- two options: area in Hall 2 or new building off the R-weg (successful test 2021)


Hut 24
T24/1
T24
T22
T21
Hut 21/22


Hut 24
T24/1
T24
T22
T21
Hut 21/22
Hut 23

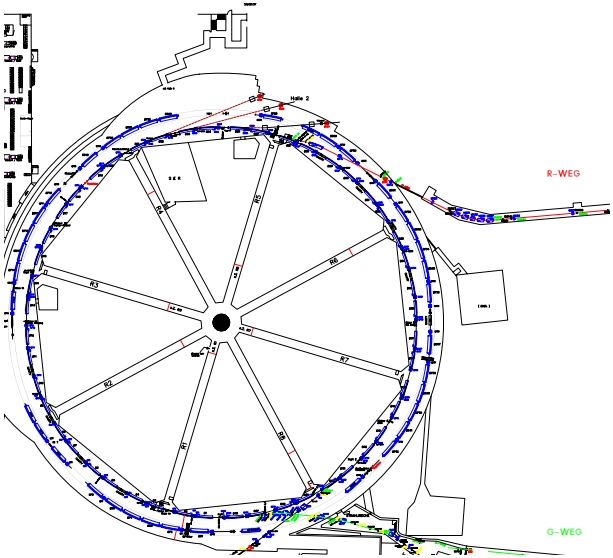
Hall-II is probably the easiest way to an extracted beam facility

Requires:

- move the kicker around the ring from serving the R-Weg to the new beamline
- modify the synchrotron sheilding wall to allow a beamline
- relocate the existing RF test/storage area or relocate the magnet test area
- design and install a new beamline
- provide shielded experimental area, services, interlock, and counting room
- install a beamdump

RF area would provide approximately 7×8 m^2 experimental area

Magnet area would provide a large experimental area


R-WEG
G-WEG


R23

A new hall and beamline from the R-Weg is the most useful facility

Requires:

- build a new building
- include overhead crane, services, shielding, interlock, counting room, and beamdump
- design and install a new beamline
- possibly have more than one beamline with a switch yard

More space, more flexibility

Problems

Current positron source removed

- after long service, rather radioactive, and easier to remove than work around it
- could be reinstalled or replaced with a new source if someone was interested

DESY-II currently fills PETRA-III as a priority and uses just electrons

- test beam uses wires in the halo of the stored beam, scraps off a few thousand electrons
- in top-up mode PETRA-III is filled every 30 seconds, no time to switch to extracted mode
- in non-top-up mode can easily switch between filling PETRA-III and extracted e^- beam

PETRA-III typically has a 3 month shutdown each summer, opportunity for e^+ running

I don't see these as insurmountable

PETRA-IV Complications / Opportunities

DESY is at the beginning of a major expansion effort

- PETRA-IV is a billion euro project looking for approval in 2024
- hope to be realised by 2029
- means there is a window for extracted beam facility before 2029

but also

- PETRA-IV needs a new injector with smaller emittance
- possibly build above current DESY-II synchrotron or maybe scrap DESY-II
- test beam facility is too popular to shutdown
- either DESY-II becomes available for test beam and extracted running exclusively
- or a new synchrotron is built to service test beam and extracted facility also exclusively
- maybe 1-2 years with no test beam or extracted beam

DESY is not JLab - Sorry

No huge spectrometers or large acceptance detectors

- more modest detectors, have to be shipped to Germany
- laboratory is no longer just down the road

However

- DESY bureaucracy is much easier than JLab or BNL
- infrastructure and technical support is excellent
- hostel is 31 euro a night
- guest bureau helps with long term and off-site housing

DESY has a long, established history running electron and positron

Two-Photon Exchange eXperiment, TPEX, Proposal

Using extracted e^- and e^+ beams from DESY synchrotron

- 60 nA e^- and 30 nA e^+ on 20 cm long liquid hydrogen target

$\Rightarrow$ Luminosity ~ 200 times that of OLYMPUS measurement

Ten calorimeters of 5×5 arrays of $PbWO_4$ crystals $2 \times 2 \times 20$ cm^3

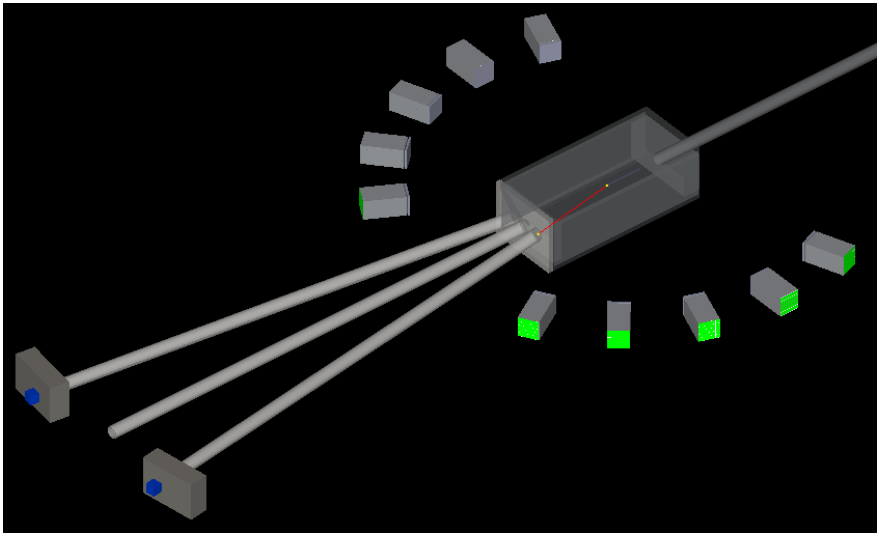
- at 30°, 50°, 70°, 90°, and 110° left and right of the beam axis
- pairs of GEM detectors before each calorimeter for tracking
- symmetric Møller / Bhabha detectors at $\pm 8°$for normalisation

Commission over 2 weeks at 2 GeV, then run for 6 weeks at 3 GeV

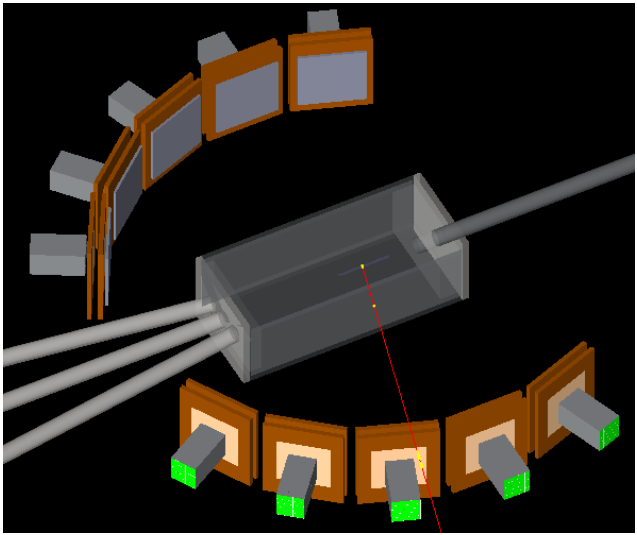
Cross check OLYMPUS result and extend Q^2 reach to 4.6 (Gev/c)^2

Higher Q^2 possible at higher energies with larger back-angle detectors

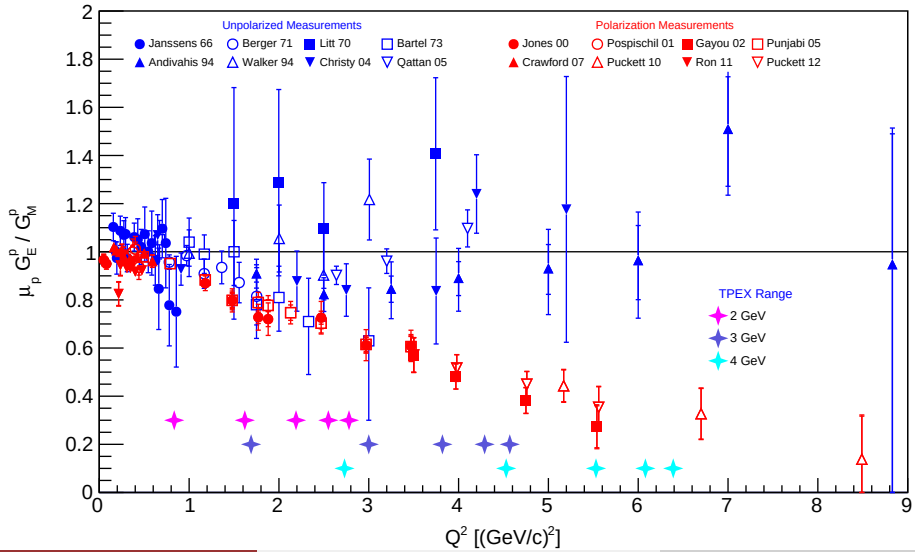
TPEX Detector Schematic



TPEX Detector Schematic with GEM



Reach of Proposed TPEX Measurements



Proposed Two-Photon Exchange Measurements

Proposal submitted August 21, 2020 to the DESY PRC

Recommendation from PRC90, November 5–6, 2020

> *"The PRC endorses the physics motivation for the experiment and, while recognising the technical infrastructure challenges in the test-beam area, encourages the collaboration and DESY management to explore further the potential for realising TPEX at DESY. If implementation looks feasible, PRC encourages the collaboration to prepare a more detailed technical proposal and suggests to hold a review of the status of plans for TPEX in spring 2021."*

US DOE viewed OLYMPUS a success

- TPEX physics case has reviewed well
- DOE is open to a proposal at the level of 1 M$
  - but needs DESY to commit to extract beam, test facility

Need to Promote Extracted Beam Facility at DESY

An extracted $e^{\pm}$ facility at 0.5–6 GeV with 30–60 nA would be popular

Need to encourage DESY to build an extracted beam facility

DESY Research directorate supports this

We are proposing this to NUPECC LRP - March 28, 2023

We also propose a workshop at DESY for physics with extracted $e^{\pm}$

We hope you can join us at DESY in the future