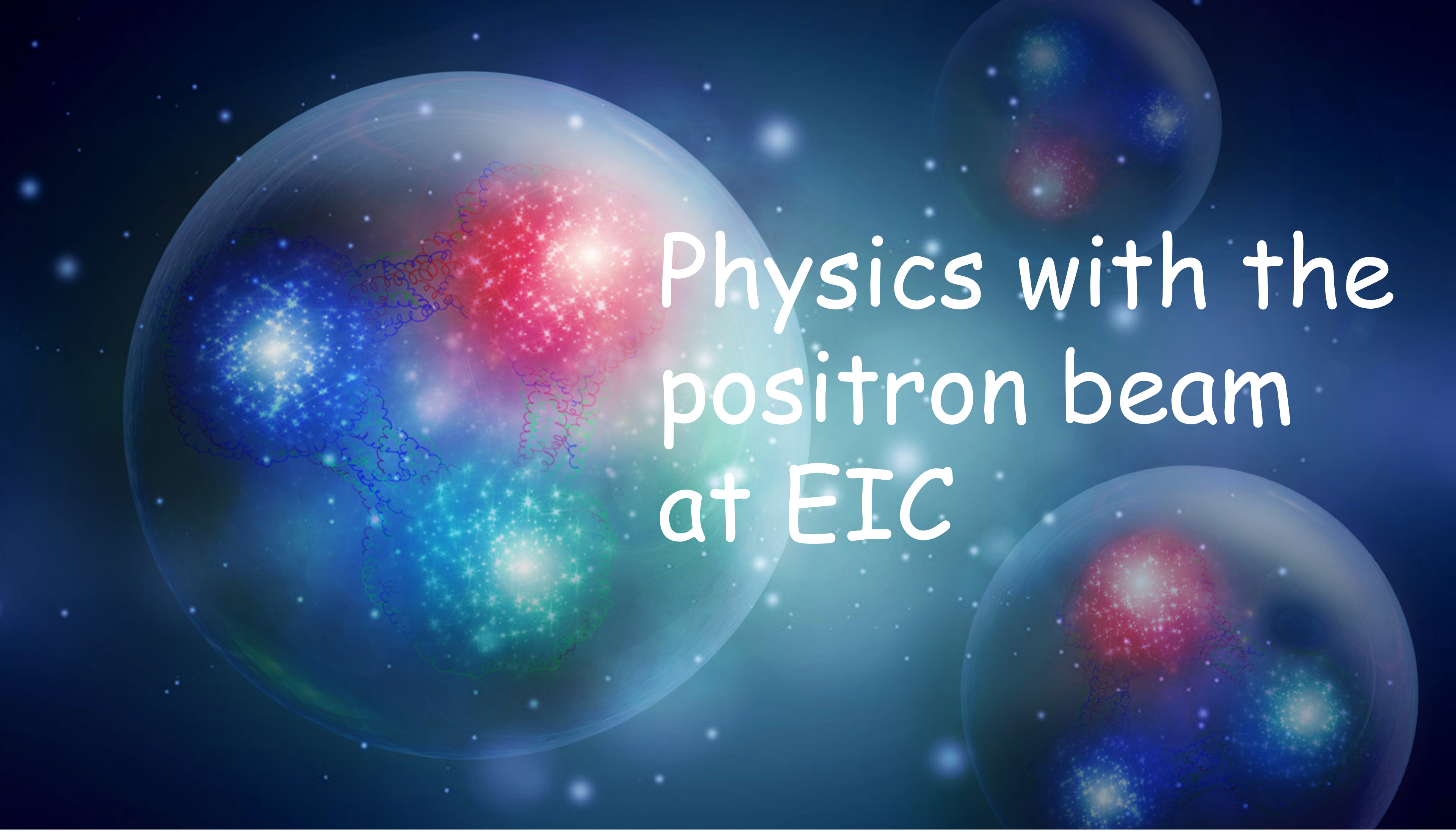


Physics with the positron beam at EIC

Yulia Furletova

On behalf of the Positron Working Group

Outline

- Introduction
- Positron source and beam luminosity
- Physics with positron beam
- Conclusions

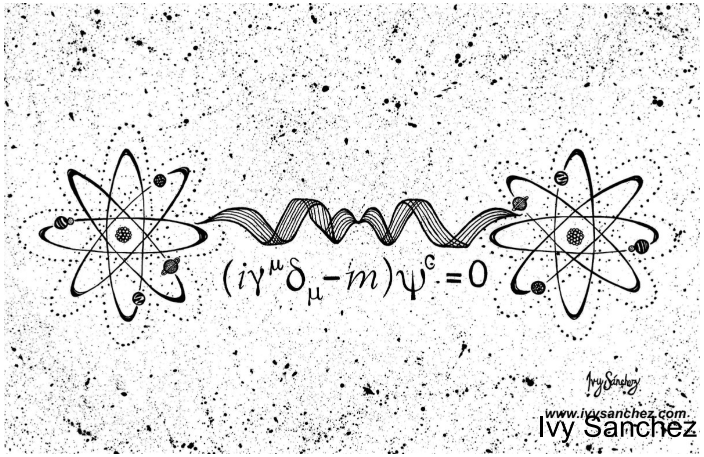
Outline

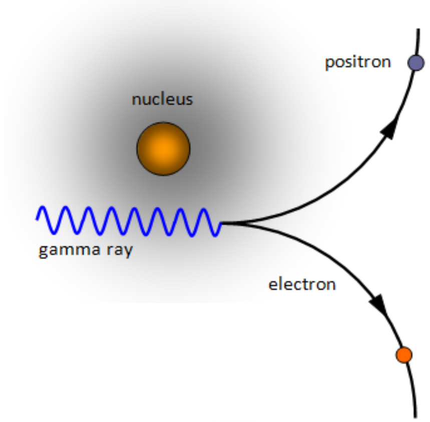
- Introduction
- Positron source and beam luminosity
- Physics with positron beam
- Conclusions

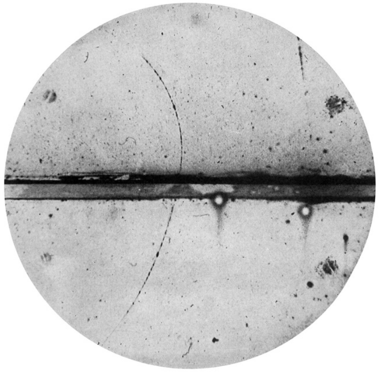
Welcome to JLAB in September 12-15, 2017
for the second
"International Workshop on Physics with Positrons at Jefferson Lab"

Particles and anti-particles

- The history of anti-particles begins from 1928, when Paul Dirac shows equations which predicts the existence of **anti-world**, identical to our world. Dirac's equation had two solution for **electron with positive energy** and for **electron with negative energy** (but energy of the particle should always be positive) . Then the last one he interpreted as a anti-particle, matching a particle exactly, but with **opposite charge**.
- And then a search for **antiparticles** began:
- **Dmitri Skobeltsyn** in 1929, tried to detect gamma radiation in cosmic rays using a cloud chamber and observed particles that acted like electrons but curved in the opposite direction in magnetic field
- **Chung-Yao Chao** in 1930 studied the scattering of gamma rays in lead noticed some anomalous results.
- **Carl David Anderson** discovered the **positron** in 1932, for which he won the Nobel Prize.
- Anti-proton was discovered 22 years later…





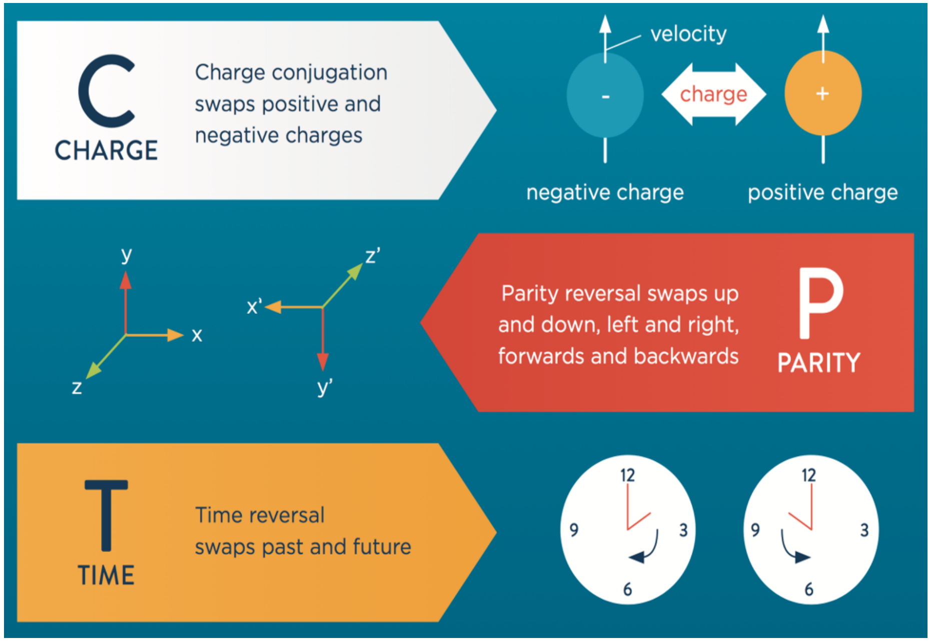


Anti-matter and Symmetry

- Every particle has its own anti-particles with the same mass and with opposite charge and other quantum numbers (exception, γ , π^0 are the own antiparticles)
- To replace matter by antimatter we need to simultaneously apply both C and P symmetries.
- But CP is not an exact symmetry of nature: **particles and antiparticles do behave differently**. In our current picture of particle physics, the weak nuclear force is responsible for this difference.
- Nowadays anti-matter is not something unusual (but still the most expensive one on the Earth) ☺

Fundamental symmetries:

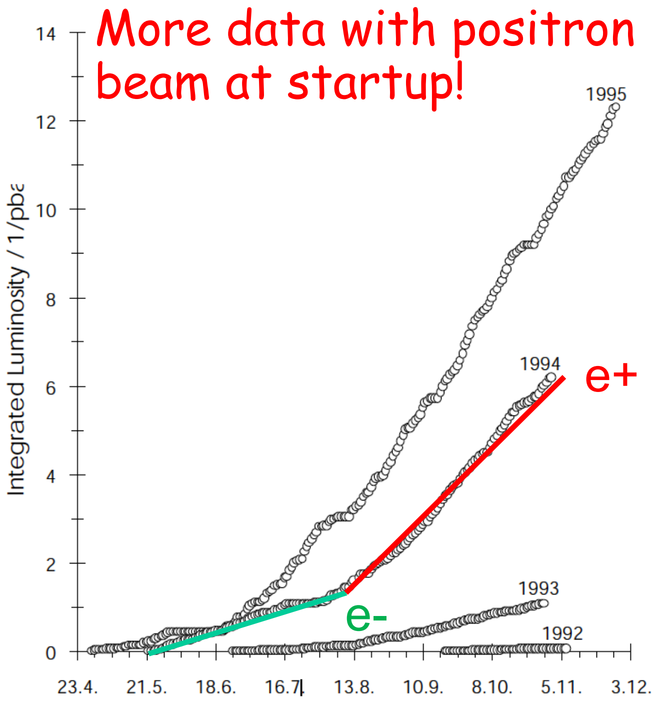
"Antimatter matters" webpage

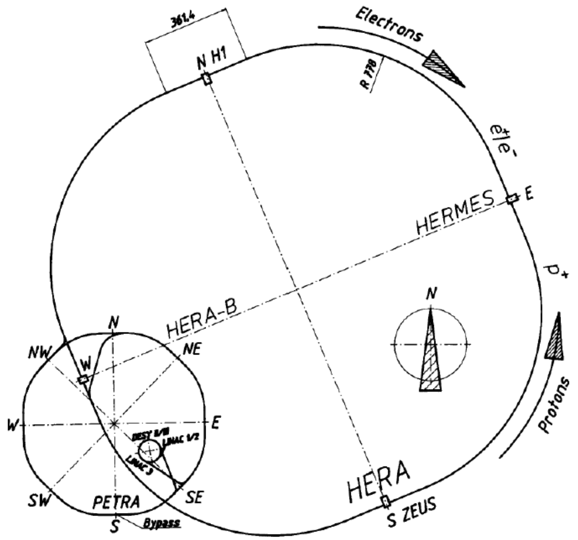


- Open questions:
  - Do we understand how anti-matter interact with matter and with anti-matter?
  - Do we need anti-matter (as a probe) to study a structure of nucleon and/or nuclei? And what would be a benefit ?
- In colliders: e^+e^-, $p\bar{p}$, e^- p (e+p).

HERA-first Positron-proton collider

- First electron (positon)- proton collider: $L \sim 5 \times 10^{31}\ cm^{-2} s^{-1}$
- At HERMES (fixed target experiment) - study the collisions of longitudinally polarized positrons (~60%) with an internal polarized gas target. H1/ZEUS – study e+p vs e-p.
- At startup issue with electron beam life-time => switched to positrons => more data!
- H1+ZEUS **e+p (0.56 fb^{-1})** e−p (0.38 fb^{-1})


More data with positron beam at startup!

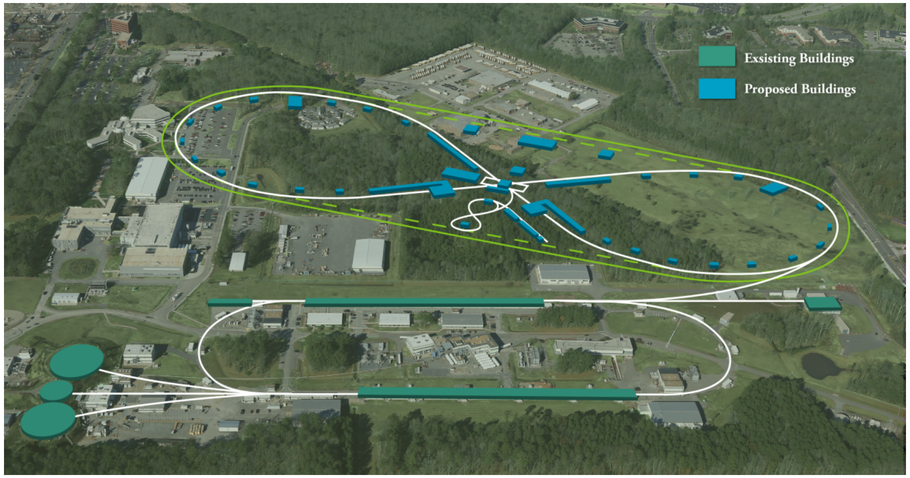


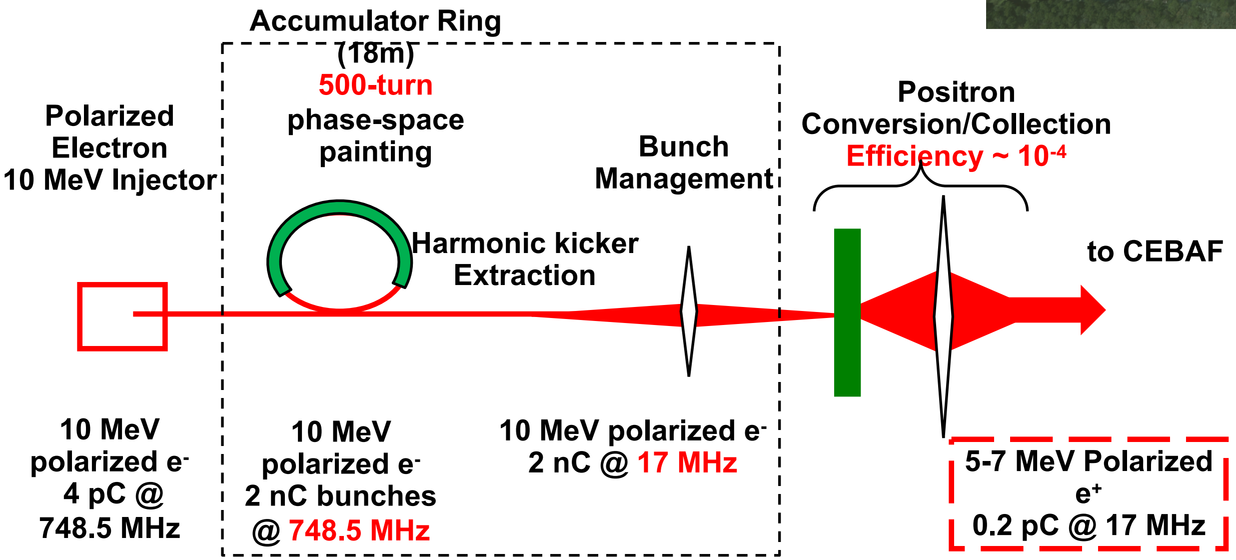
STATUS OF HERA
W. Bialowons

Polarized Positron beam at JLEIC. First polarized e^+A collider.

A group (Joe Grames, Jiquan Guo, Fangley Lin, Vasiliy Morozov, Eric Voutier, Yuhong Zhang) is exploring a polarized positron injector suitable for Jefferson Lab Electron Ion Collider (JLEIC).

$\mathcal{L} \geq 10^{33} cm^{-2}s^{-1}$ $P_{e+} \geq 40\%$





Accumulator Ring (18m)

500-turn phase-space painting

Polarized Electron 10 MeV Injector

Bunch Management

Harmonic kicker Extraction

Positron Conversion/Collection Efficiency ~ 10^{-4}

to CEBAF

10 MeV polarized e^- 4 pC @ 748.5 MHz

10 MeV polarized e^- 2 nC bunches @ 748.5 MHz

10 MeV polarized e^- 2 nC @ 17 MHz

5-7 MeV Polarized e^+ 0.2 pC @ 17 MHz

- High voltage gun ~340kV peak
- Accumulator ring ~500 turns (CERN's LEIR has a design for 75-turn injection of Pb^{54+})
- Harmonic kicker extraction (frequency should match 17MHz)
- Pulsed beam ~10nA current, as required for injection into JLEIC with a reasonably short injection time and reasonably high equilibrium polarization.

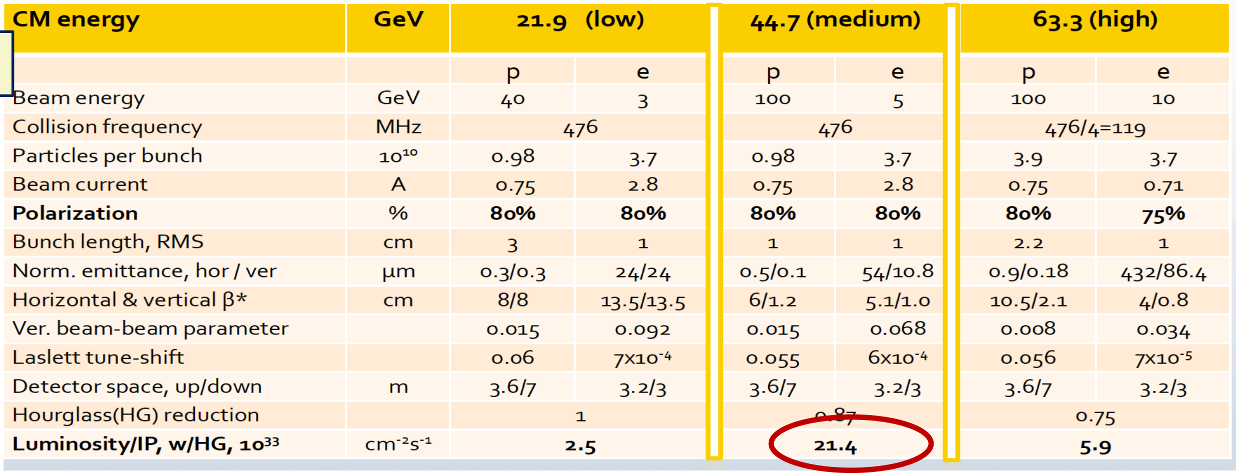
Yulia Furletova (on behalf of PWG group)

JLEIC Primary Positron Beam Parameters

Positron beam

CM energy	GeV	33.5		40		52.9	
		p	*e+*	*p*	*e+*	*p*	*e+*
Beam energy	GeV	70	4	100	4	100	7
Collision frequency	MHz	**476/3=159**		**476/3=159**		**476/3=159**	
Particles per bunch	10^{10}	1.8	**0.59**	1.8	**0.59**	2.0	**0.59**
Beam current	A	0.46	**0.15**	0.46	**0.15**	0.5	**0.15**
Polarization	%	>70%	**>40%**	>70%	**>40%**	>70%	**>40%**
Bunch length, RMS	cm	2	1.2	2	1.2	2	1.2
Norm. emitt., vert./horz.	μm	0.5/0.25	36/18	0.5/0.25	36/18	0.5/0.25	190/95
Horizontal & vertical β^*	cm	4/2	5.8/2.9	2/4	4.1/2.0	7.1/3.55	2.4/1.2
Vert. beam-beam		0.002	0.15	0.002	0.15	0.002	0.03
Laslett tune-shift		0.056	small	0.028	small	0.03	small
Det. space, up/down	m	3.6/7	3/3.2	3.6/7	3/3.2	3.6/7	3/3.2
Hour-glass reduction		0.89		0.87		0.82	
Lumi./IP, w/HG, 10^{33}	$cm^{-2}s^{-1}$	**0.9**		**1.2**		**0.7**	

Electron beam



CM energy	**GeV**	**21.9 (low)**		**44.7 (medium)**		**63.3 (high)**	
		p	e	p	e	p	e
Beam energy	GeV	40	3	100	5	100	10
Collision frequency	MHz	476		476		476/4=119	
Particles per bunch	10^{10}	0.98	3.7	0.98	3.7	3.9	3.7
Beam current	A	0.75	2.8	0.75	2.8	0.75	0.71
Polarization	%	**80%**	**80%**	**80%**	**80%**	**80%**	**75%**
Bunch length, RMS	cm	3	1	1	1	2.2	1
Norm. emittance, hor / ver	μm	0.3/0.3	24/24	0.5/0.1	54/10.8	0.9/0.18	432/86.4
Horizontal & vertical β*	cm	8/8	13.5/13.5	6/1.2	5.1/1.0	10.5/2.1	4/0.8
Ver. beam-beam parameter		0.015	0.092	0.015	0.068	0.008	0.034
Laslett tune-shift		0.06	$7x10^{-4}$	0.055	$6x10^{-4}$	0.056	$7x10^{-5}$
Detector space, up/down	m	3.6/7	3.2/3	3.6/7	3.2/3	3.6/7	3.2/3
Hourglass(HG) reduction		1		0.87		0.75	
Luminosity/IP, w/HG, 10^{33}	$cm^{-2}s^{-1}$	**2.5**		**21.4**		**5.9**	

Physics with positrons

- Two-photon physics
- Generalized parton distributions

Interference physics

- Deep inelastic scattering: NC and CC
- Charm production
- Pion/Kaon structures

Structure functions

- Search for dark photon
- Charge conjugation violation
- Leptoquarks, leptoqluons, W_R^+ ,etc.

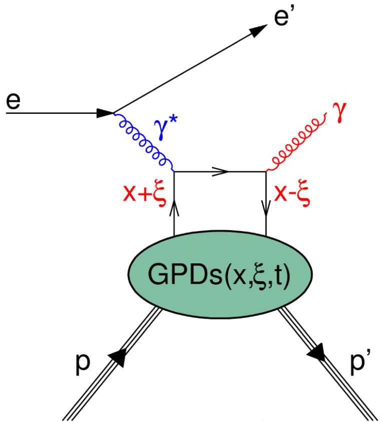
Test of the Standard Model and BSM

- Positron annihilation spectroscopy

Positron applications

Positron Working Group (PWG): http://wiki.jlab.org/pwg
pwg@jlab.org

DVCS,GPD and Beam-Charge asymmetry



DVCS

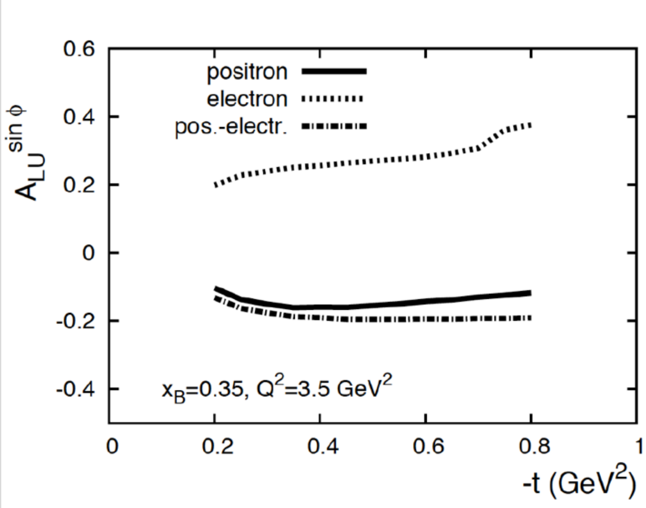
- **Beam Spin Asymmetries:**

$$\mathcal{A}_{\mathrm{LU}}^{\mathrm{DVCS}}(\phi) = \frac{1}{\mathcal{D}(\phi)} \cdot \frac{x_B^2 t \mathcal{P}_1(\phi)\mathcal{P}_2(\phi)}{Q^2} s_1^{\mathrm{DVCS}} \sin(\phi)$$

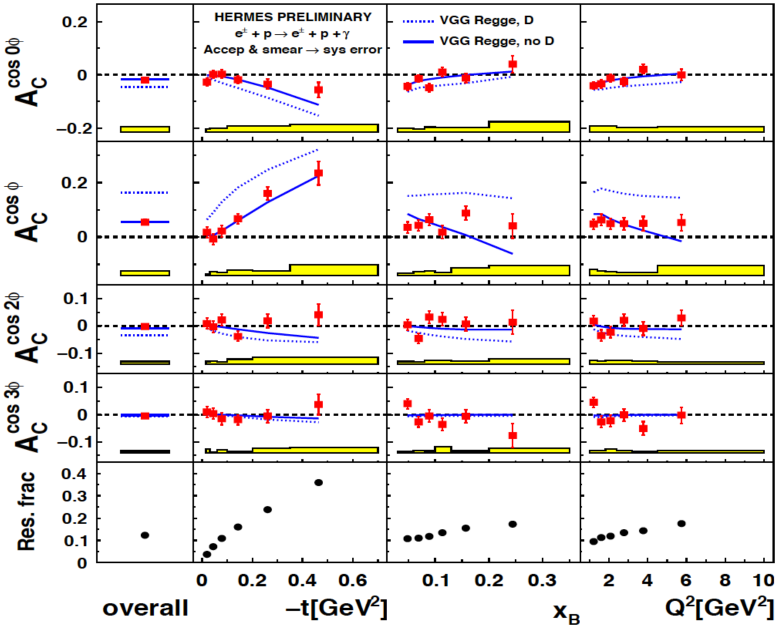
$$\mathcal{A}_{\mathrm{LU}}^{\mathcal{I}}(\phi) = \frac{1}{\mathcal{D}(\phi)} \cdot \frac{x_B}{Q^2} \left[s_1^{\mathcal{I}} \sin(\phi) + s_2^{\mathcal{I}} \sin(2\phi)\right]$$

- **Beam Charge Asymmetry:**

$$\mathcal{A}_{\mathrm{C}}(\phi) = -\frac{1}{\mathcal{D}(\phi)} \cdot \frac{x_B}{y} \left[c_0^{\mathcal{I}} + c_1^{\mathcal{I}} \cos(\phi) + c_2^{\mathcal{I}} \cos(2\phi) + c_3^{\mathcal{I}} \cos(3\phi)\right]$$



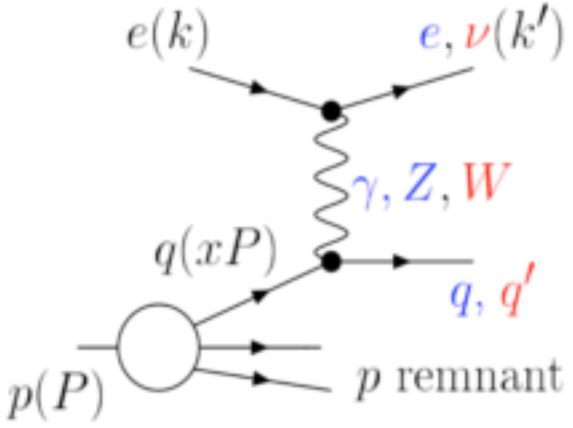
H. Avakian, V. Burkert, V. Guzey, JPos09, AIP 1160 (2009) 43



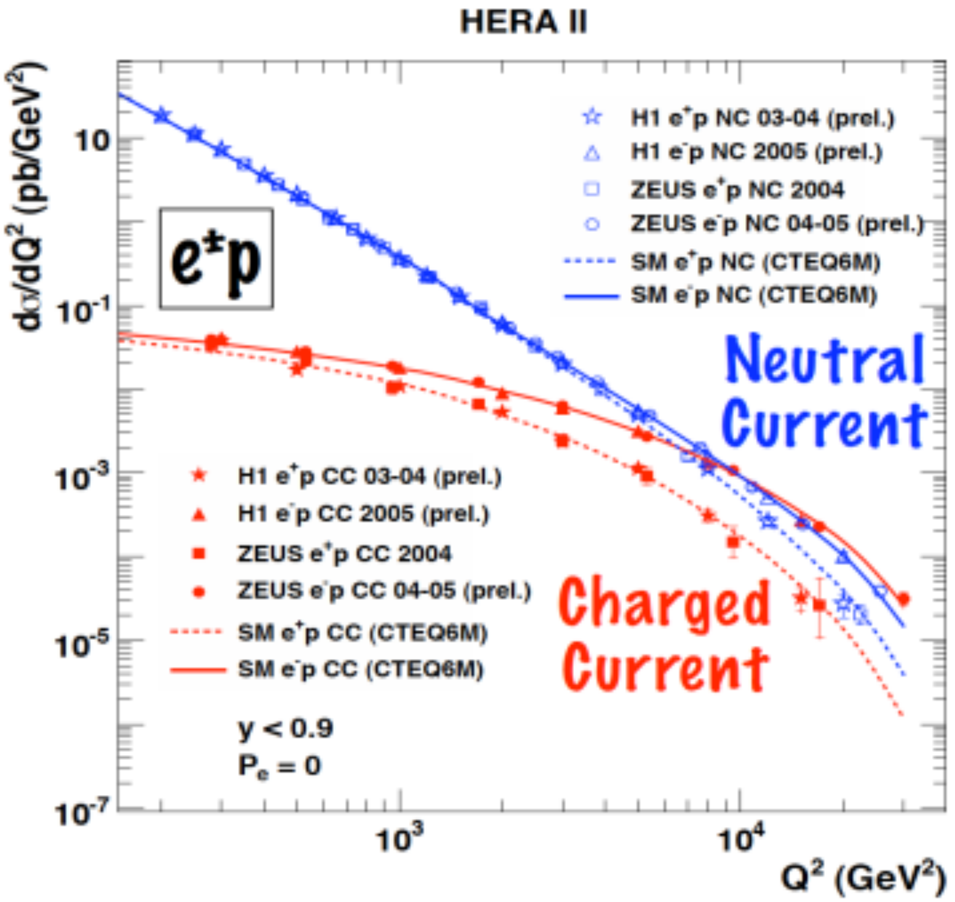
Links to the imaginary part of the interference amplitude and express the important benefit of a polarized positron beam for GPD

Andreas Mussgiller
C.Riedl

DIS with e^-p and e^+p beam unpolarised



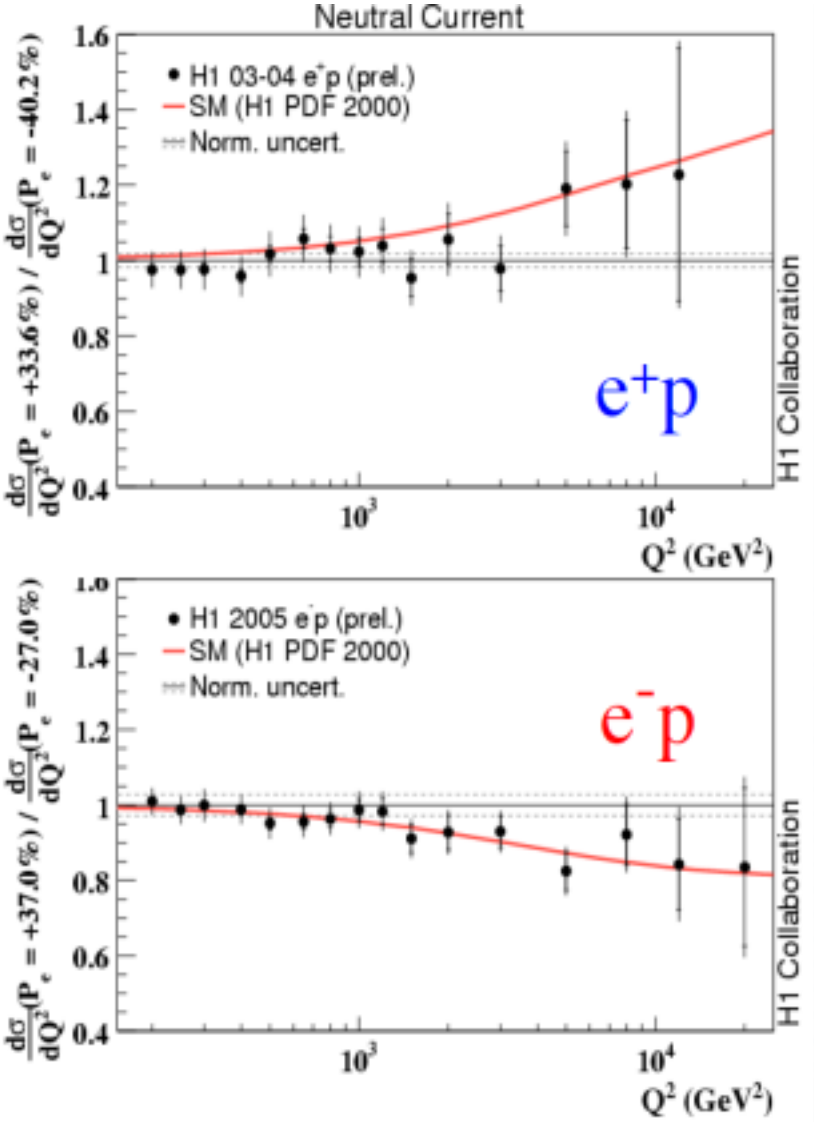
e^+p and e^-p CC difference:
less favorable helicity factor $(1 - y)^2$ in the case of e^+p collisions and the difference between the up and down quark distributions in the proton.



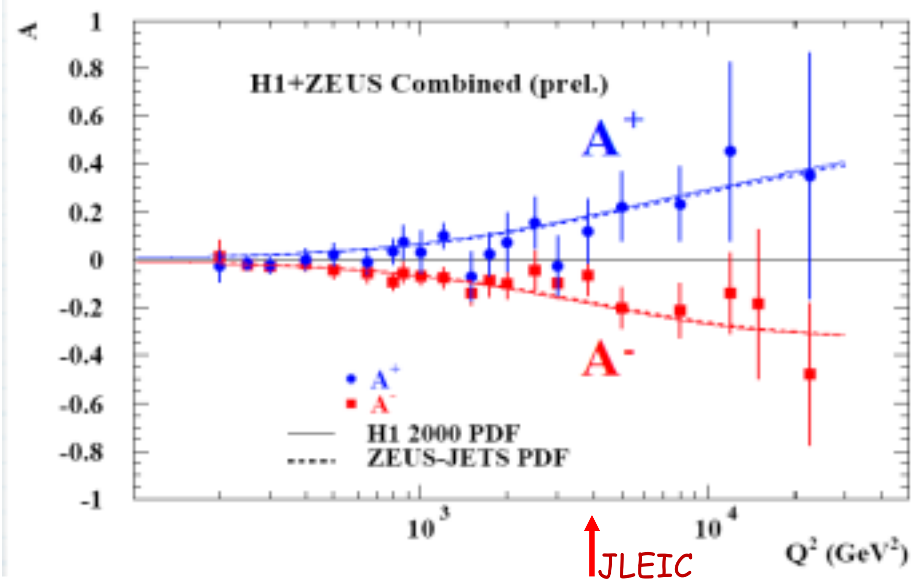
$$\frac{d^2\sigma^{NC}}{dxdQ^2} \sim \left|\frac{A}{Q^2} + \frac{B}{Q^2+M_Z^2}\right|^2 \times \mathrm{pdf's}$$

$$\frac{d^2\sigma^{CC}}{dxdQ^2} \sim G_F^2\left(\frac{M_W^2}{M_W^2+Q^2}\right)^2 \times \mathrm{pdf's}$$

Polarization asymmetry in NC DIS



$$A^{\pm} = \frac{2}{P_R - P_L} \cdot \frac{\sigma^{\pm}_{NC}(P_R) - \sigma^{\pm}_{NC}(P_L)}{\sigma^{\pm}_{NC}(P_R) + \sigma^{\pm}_{NC}(P_L)} \qquad \begin{matrix} P_R > 0 \\ P_L < 0 \end{matrix}$$



The magnitude of the asymmetry is observed to increase with increasing Q2 and is negative in e−p and positive in e+p scattering, in agreement with the SM prediction and confirming **parity violation in neutral current interactions.**

Neutral Weak Coupling C3q Using Polarized Positron and Electron Beams

Xiaochao Zheng, JPOS09
International Workshop on Positrons at JLab

- proton target:

$$\left[\frac{A(l_L^- - l_R^+)}{A(l_L^- - l_R^-)}\right]_p = \frac{y(2-y)}{2}\,\frac{2C_{2u}u_V - C_{2d}d_V + 2C_{3u}u_V - C_{3d}d_V}{2C_{1u}u - C_{1d}(d+s) + Y(2C_{2u}u_V - C_{2d}d_V)} \qquad y=\frac{\nu}{E}$$

$$\longrightarrow\quad A_p(e_L^- - e_R^+) = \left(\frac{3G_F Q^2}{2\sqrt{2}\pi\alpha}\right)\frac{y(2-y)}{2}\,\frac{2C_{2u}u_V - C_{2d}d_V + 2C_{3u}u_V - C_{3d}d_V}{4u+d+s}$$

- deuteron target:

$$\left[\frac{A(l_L^- - l_R^+)}{A(l_L^- - l_R^-)}\right]_d = \frac{y(2-y)}{2}\,\frac{\left(2C_{2u} - C_{2d} + 2C_{3u} - C_{3d}\right)R_V}{2C_{1u} - C_{1d} + Y(2C_{2u} - C_{2d})R_V}$$

$$\longrightarrow\quad A_d(e_L^- - e_R^+) = \left(\frac{3G_F Q^2}{2\sqrt{2}\pi\alpha}\right)\frac{y(2-y)}{2}\,\frac{\left(\overset{\approx -0.1}{\boxed{2C_{2u} - C_{2d}}} + \overset{\approx -1.5\ \text{(dominant)}}{\boxed{2C_{3u} - C_{3d}}}\right)R_V}{5+R_s+4R_c}$$

$$\approx (108\,ppm)\frac{y(2-y)}{2}\left(2C_{3u} - C_{3d}\right)Q^2 R_V$$

Neutral Current: xF3

$$\frac{d^2\sigma^{NC}(e^\pm p)}{dxdQ^2}=\frac{2\pi\alpha^2}{xQ^4}[Y_+F_2(x,Q^2)\mp Y_- xF_3(x,Q^2)-y^2F_L(x,Q^2)]$$

EM
- PDFs

EW
- important at high Q2,
- changes sign for $e_+/e-$
- sensitiv to γZ interference
- sensitiv to valence quarks

EW
- enegligible at high Q2& x

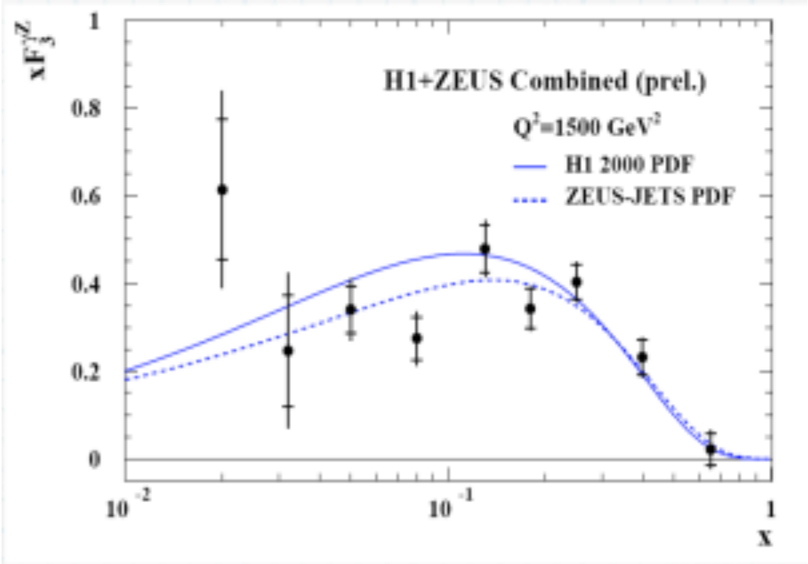
$$\boxed{x\tilde{F}_3=\frac{Y_+}{2Y_-}[\tilde{\sigma}(e^-p)-\tilde{\sigma}(e^+p)]}$$

$$Y_\pm=1\pm(1-y)^2$$

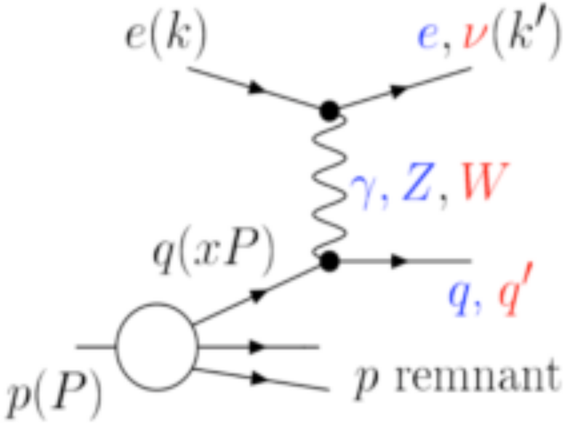
$$\begin{aligned}
F_2^{\gamma Z} &= 2e_f v_f \Sigma_i x[q_f+\overline{q_f}]\\
F_2^{Z} &= (v_f^2+a_f^2)\Sigma_i x[q_f+\overline{q_f}]\\
F_3^{\gamma Z} &= 2e_f a_f \Sigma_i x[q_f-\overline{q_f}]\\
F_3^{Z} &= 2v_f a_f \Sigma_i x[q_f-\overline{q_f}]
\end{aligned}$$

- Four lepton beams (+ and -, L and R) give vector- and axial-vector coupling of quarks (mainly u and d quarks)

- The difference between the e+p and e-p NC cross sections give direct access to the structure function xF3 .



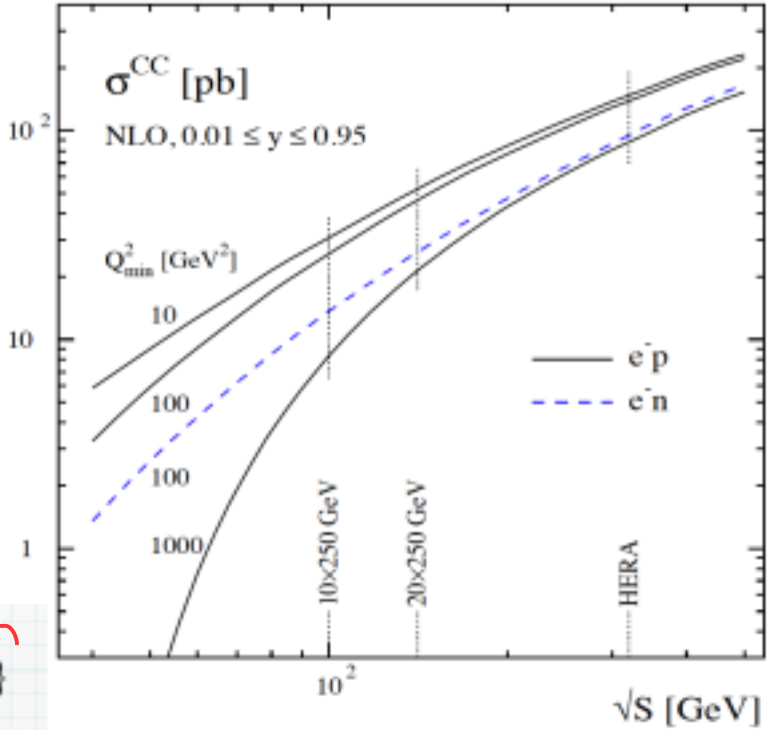
Charged Current DIS



$$\frac{d^2\sigma(e^+p)}{dxdQ^2} = \frac{G_F{}^2}{2\pi}\left(\frac{M_W{}^2}{M_W{}^2+Q^2}\right)^2\{(\bar{u}+\bar{c})+(1-y)^2\overbrace{(d+s)}\}$$

$$\frac{d^2\sigma(e^-p)}{dxdQ^2} = \frac{G_F{}^2}{2\pi}\left(\frac{M_W{}^2}{M_W{}^2+Q^2}\right)^2\{\underbrace{(u+c)}+(1-y)^2(\bar{d}+\bar{s})\}$$

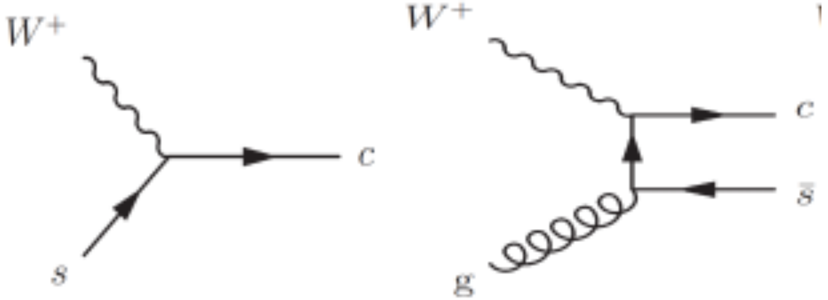
Elke Aschenauer



In CC DIS up-type or down-type flavors could be extracted using e+ or e- data

At EIC energies, the cross section is lower (compared to HERA), but could be compensated by higher luminosity

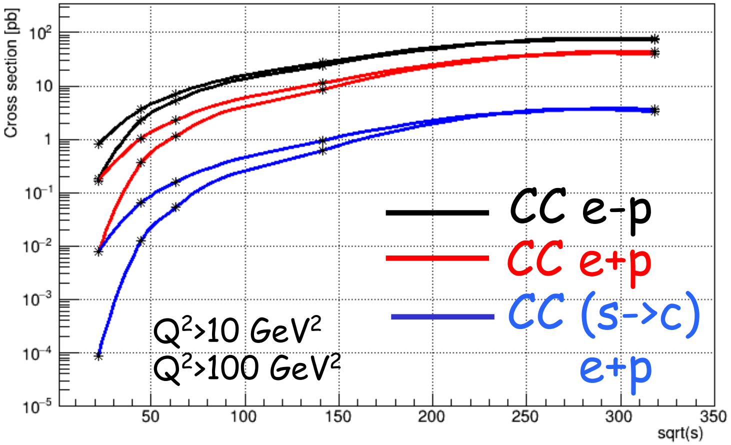
Charm production in Charged Current DIS

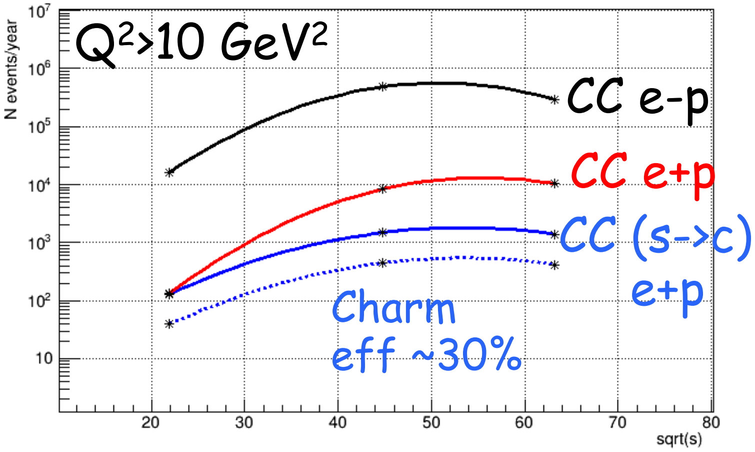


- Measurements of strange distribution (+polarization)
  W^+ s -> c
  | Vsc| =0.97
- Flavor mixing
  W^+ d -> c
  |Vcd| =0.224
- BGF
  W^+ g -> c s

HERA (Q^2>200GeV^2):
σ(e+p -> ν_e + X) ~ 50pb
σ(e+p -> ν_e +c +X) ~ 5pb

At EIC (Q^2>10GeV^2):
σ(e+p -> ν_e + X ~ 10 pb
σ(e+p -> ν_e +c +X) ~ 0.15 pb
⇒ with 10fb^{-1} /year
⇒ ~ 1500 events/year

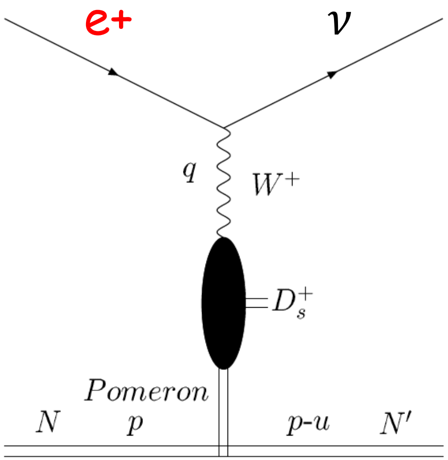


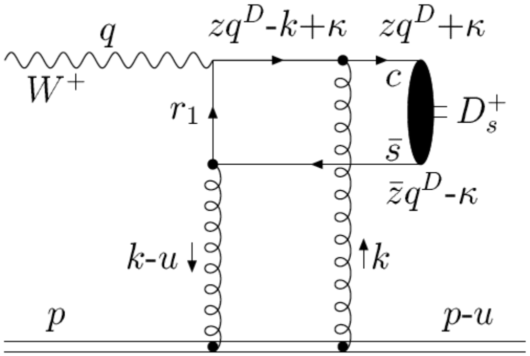


The charm and anti-charm production in charged current DIS to extract **strange and anti-strange** distributions.

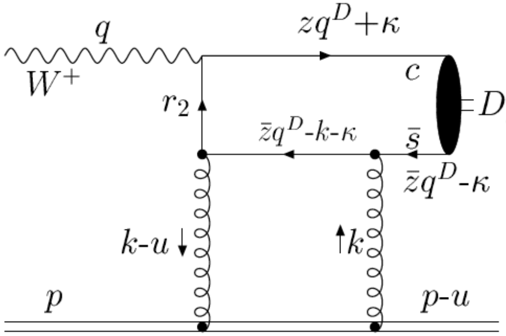
The production of charm mesons in diffractive charged current DIS

Zhongzhi Song, Kuang-Ta Chao
Physics Letters B 529 (2002) 77–81





(a)

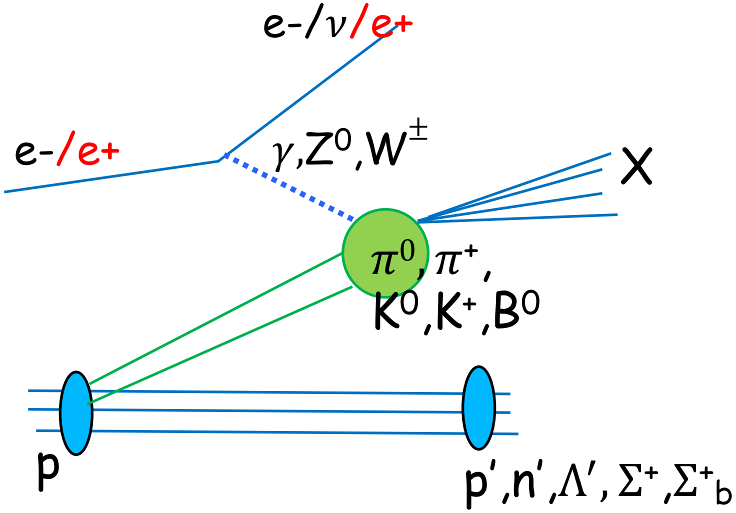


(b)

The production of Ds+ mesons in diffractive charged current DIS - information on the gluon structure of the diffraction mechanism in QCD

Pion and kaon structure functions and a further progress towards a flavor decomposition

Tanja Horn
Kijun Park



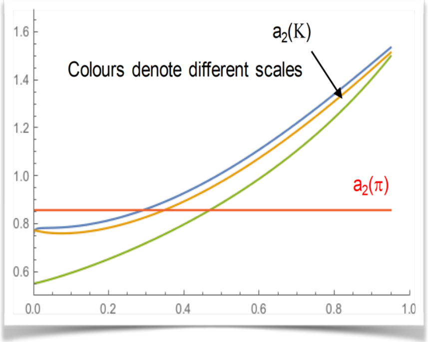
- Sullivan process:
hard electron/positron scattering from pion(meson) cloud of nucleon
- Meson (pion/kaon) structure

Neutral-Current Parity-violating asymmetry A_{PV}

$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$$

$$a_{2\pi}(x) = \frac{2\sum_q e_q\, g_V^q\,(q+\bar{q})}{\sum_q e_q^2\,(q+\bar{q})} \simeq \frac{6\,u_\pi^+ + 3\,d_\pi^+}{4\,u_\pi^+ + d_\pi^+} - 4\sin^2\theta_W,$$

$$a_{2K}(x) = \frac{2\sum_q e_q\, g_V^q\,(q+\bar{q})}{\sum_q e_q^2\,(q+\bar{q})} \simeq \frac{6\,u_K^+ + 3\,s_K^+}{4\,u_K^+ + s_K^+} - 4\sin^2\theta_W$$



Flavor decomposition with Charged current

$$\phi_{\rm CC}^+ = x\left[(\bar{u}+\bar{c}) + (1-y)^2(d+s)\right]$$

$$\phi_{\rm CC}^- = x\left[(u+c) + (1-y)^2(d+\bar{s})\right]$$

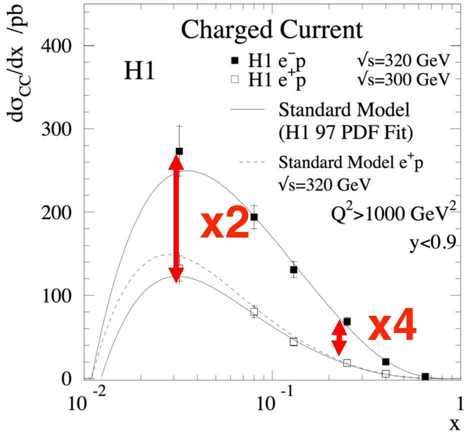
In proton - suppression due to d-quark by $(1\text{-}y)^2$

Similar for pion/kaons?

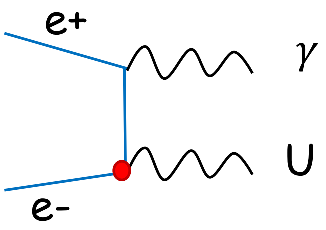
Comparison of electron vs positron interactions

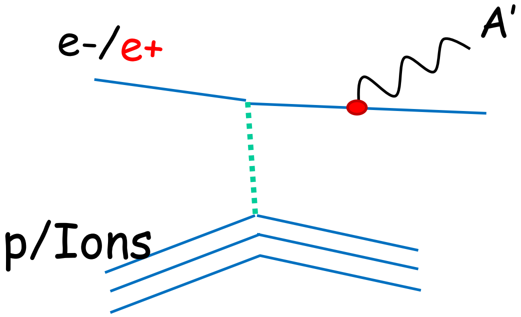
$$A = \frac{\sigma_R^{{\rm CC},e^+} \pm \sigma_L^{{\rm CC},e^-}}{\sigma_R^{\rm NC} + \sigma_L^{\rm NC}}$$

$$A = \frac{G_F^2\,Q^4}{32\,\pi^2\,\alpha_e^2}\left[\frac{F_2^{W^+} \pm F_2^{W^-}}{F_2^\gamma} - \frac{1-(1-y)^2}{1+(1-y)^2}\,\frac{xF_3^{W^+} \mp xF_3^{W^-}}{F_2^\gamma}\right]$$



Dark Photon Searches With e^+ Beams





- Dark Photon (U,A'): new mediator to a sector of Dark Matter particles (MeV-GeV mass)

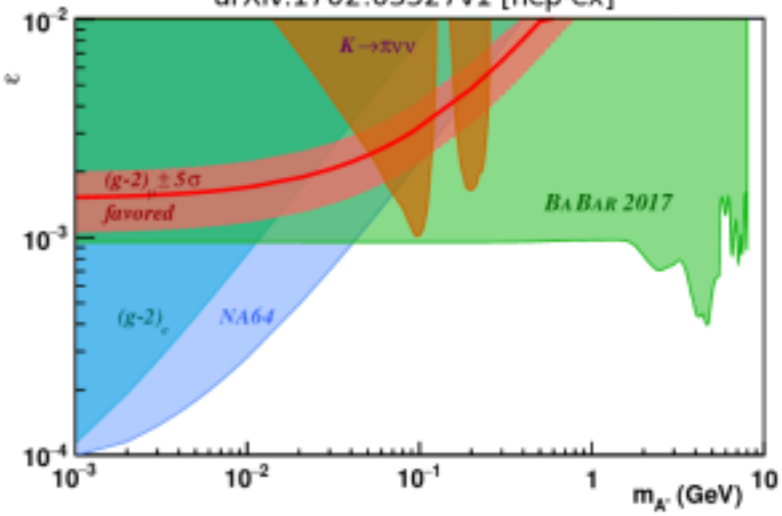
- Weakly coupled to Standard Model through kinetic mixing with ordinary photon → production in e^+e^- annihilation.

- A' can be probed with $e^{+/-}$ p(Ions) (e.g. target experiments PADME at LNF, Adv. High Energy Phys. 2014:959802; VEPP-3, arXiv:1207.5089 [hep-ex])

- Detection via decay into SM particles (e+/e-)

- High luminosity is needed

arXiv:1702.03327v1 [hep-ex]



Testing the chiral structure of the weak interaction with Charged Current DIS

- Clear linear dependence:

$$\sigma_{CC}^{e^{\pm}p}(P_e) = (1 \pm P_e) \cdot \sigma_{CC}^{e^{\pm}p}(P_e = 0)$$

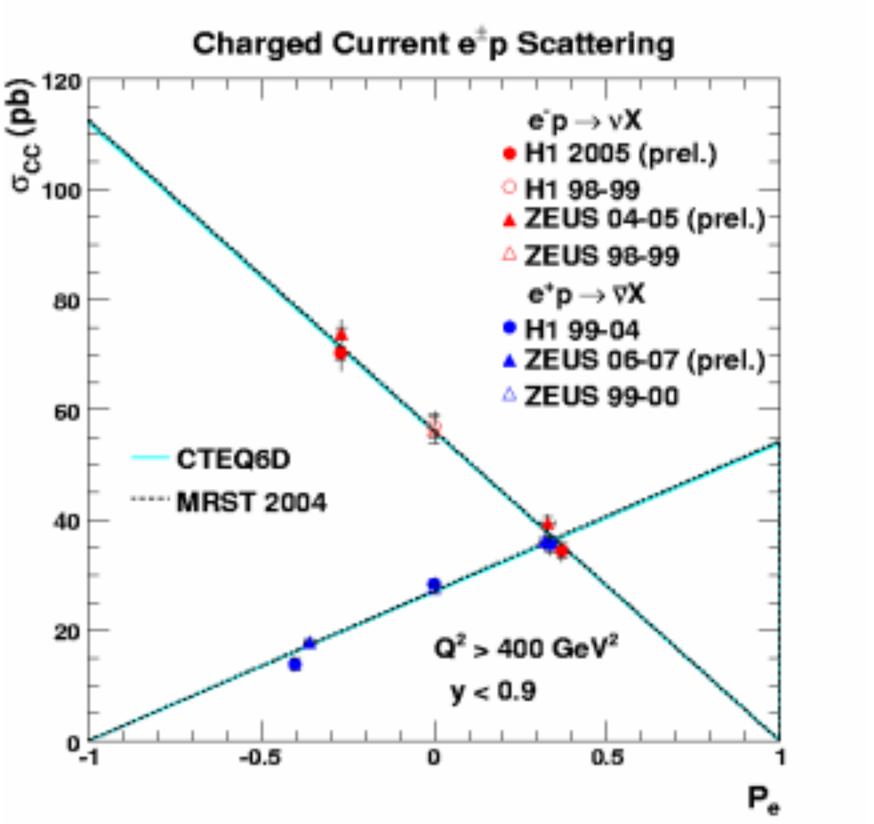
Clear left-handed nature of weak currents (W_L):

extrapolation to $P_{e^+} = -1$:

► $\sigma_{CC}^{\text{tot}} = -1.0 \pm 1.8_{\text{stat}} \pm 1.1_{\text{sys}}$ pb

If not 0 for e- @P=1 or e+@ P=-1
=> new physics

Extrapolation to P=±1 => limits on W_R



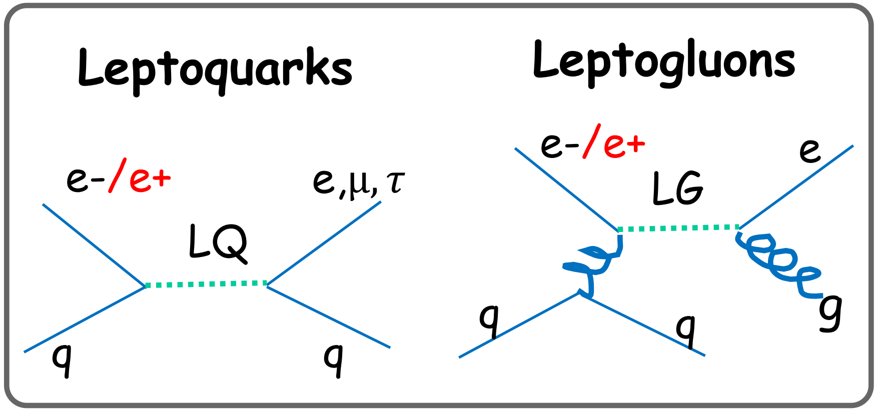
- High energy, high luminosity and high polarization are needed

Search for exotics

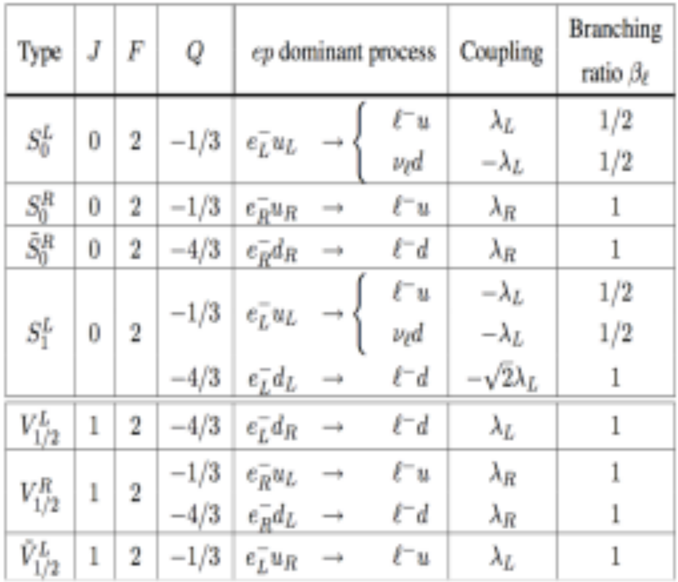
- High luminosity (100-1000 more then at HERA)
- High polarized beams
- Electron and positron beam:

  electron-proton collisions, mainly F=2 LQs produced
  positron-proton collisions, mainly F=0 LQs produced
- Deuterium

  e+/e- D (deuterium) vs e+/e- p (proton) collisions

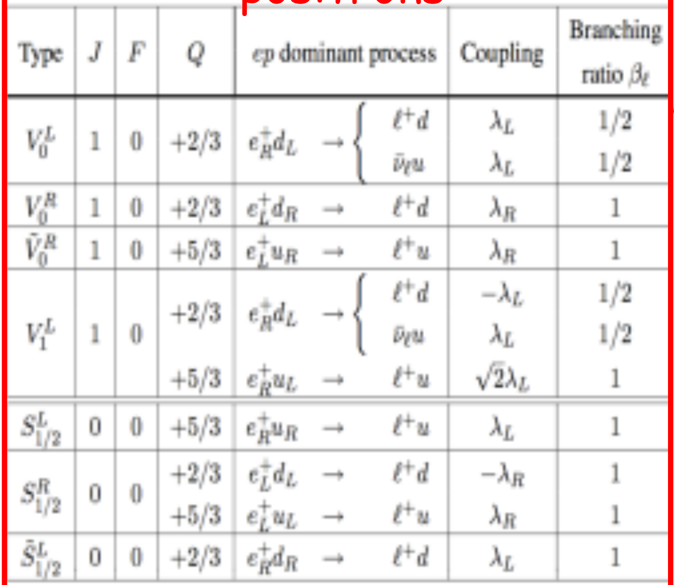


Leptoquarks:

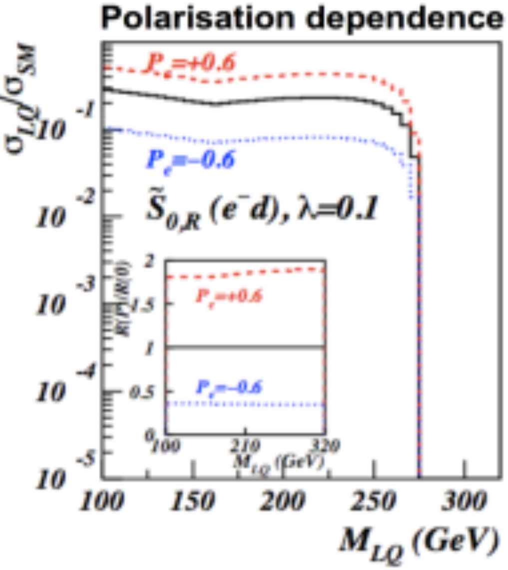


Type	J	F	Q	ep dominant process	Coupling	Branching ratio β_ℓ
S_0^L	0	2	$-1/3$	$e_L^- u_L \to \ell^- u$	λ_L	1/2
				$\to \nu_\ell d$	$-\lambda_L$	1/2
S_0^R	0	2	$-1/3$	$e_R^- u_R \to \ell^- u$	λ_R	1
$\tilde{S}_0^R$	0	2	$-4/3$	$e_R^- d_R \to \ell^- d$	λ_R	1
S_1^L	0	2	$-1/3$	$e_L^- u_L \to \ell^- u$	$-\lambda_L$	1/2
				$\to \nu_\ell d$	$-\lambda_L$	1/2
			$-4/3$	$e_L^- d_L \to \ell^- d$	$-\sqrt{2}\lambda_L$	1
$V_{1/2}^L$	1	2	$-4/3$	$e_L^- d_R \to \ell^- d$	λ_L	1
$V_{1/2}^R$	1	2	$-1/3$	$e_R^- u_L \to \ell^- u$	λ_R	1
			$-4/3$	$e_R^- d_L \to \ell^- d$	λ_R	1
$\tilde{V}_{1/2}^L$	1	2	$-1/3$	$e_L^- u_R \to \ell^- u$	λ_L	1

positrons



Type	J	F	Q	ep dominant process	Coupling	Branching ratio β_ℓ
V_0^L	1	0	$+2/3$	$e_R^+ d_L \to \ell^+ d$	λ_L	1/2
				$\to \bar{\nu}_\ell u$	λ_L	1/2
V_0^R	1	0	$+2/3$	$e_L^+ d_R \to \ell^+ d$	λ_R	1
$\tilde{V}_0^R$	1	0	$+5/3$	$e_L^+ u_R \to \ell^+ u$	λ_R	1
V_1^L	1	0	$+2/3$	$e_R^+ d_L \to \ell^+ d$	$-\lambda_L$	1/2
				$\to \bar{\nu}_\ell u$	λ_L	1/2
			$+5/3$	$e_R^+ u_L \to \ell^+ u$	$\sqrt{2}\lambda_L$	1
$S_{1/2}^L$	0	0	$+5/3$	$e_R^+ u_R \to \ell^+ u$	λ_L	1
$S_{1/2}^R$	0	0	$+2/3$	$e_L^+ d_L \to \ell^+ d$	$-\lambda_R$	1
			$+5/3$	$e_L^+ u_L \to \ell^+ u$	λ_R	1
$\tilde{S}_{1/2}^L$	0	0	$+2/3$	$e_R^+ d_R \to \ell^+ d$	λ_L	1



International Workshop on Physics with Positrons (JPOS17)

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September 12-15, 2017

www.jlab.org/conferences/JPos2017

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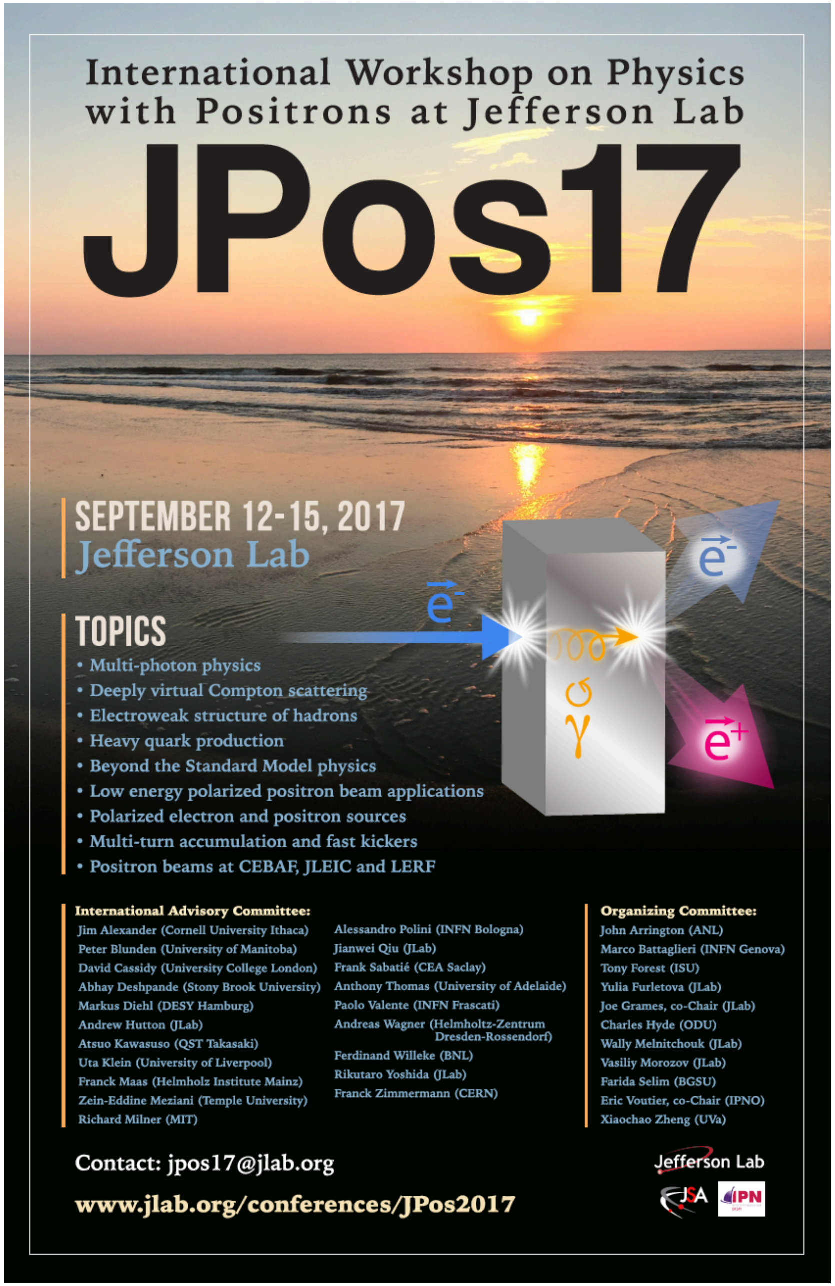
Summary

- **A positron beam** could provide additional and unique probe to study a nucleon and nucleus structures
- **Positron beam** could be used to study Meson (π,K…) Structure Functions
- **Positron beam** will give a possibility to test a Standard Model and to make possible a search for a physics Beyond the Standard Model.

Proceedings of JPos17 will be the basis for the Positron Physics White Paper.

Please join us!!!



International Workshop on Physics with Positrons at Jefferson Lab

JPos17

SEPTEMBER 12-15, 2017
Jefferson Lab

TOPICS

- Multi-photon physics
- Deeply virtual Compton scattering
- Electroweak structure of hadrons
- Heavy quark production
- Beyond the Standard Model physics
- Low energy polarized positron beam applications
- Polarized electron and positron sources
- Multi-turn accumulation and fast kickers
- Positron beams at CEBAF, JLEIC and LERF

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Contact: jpos17@jlab.org

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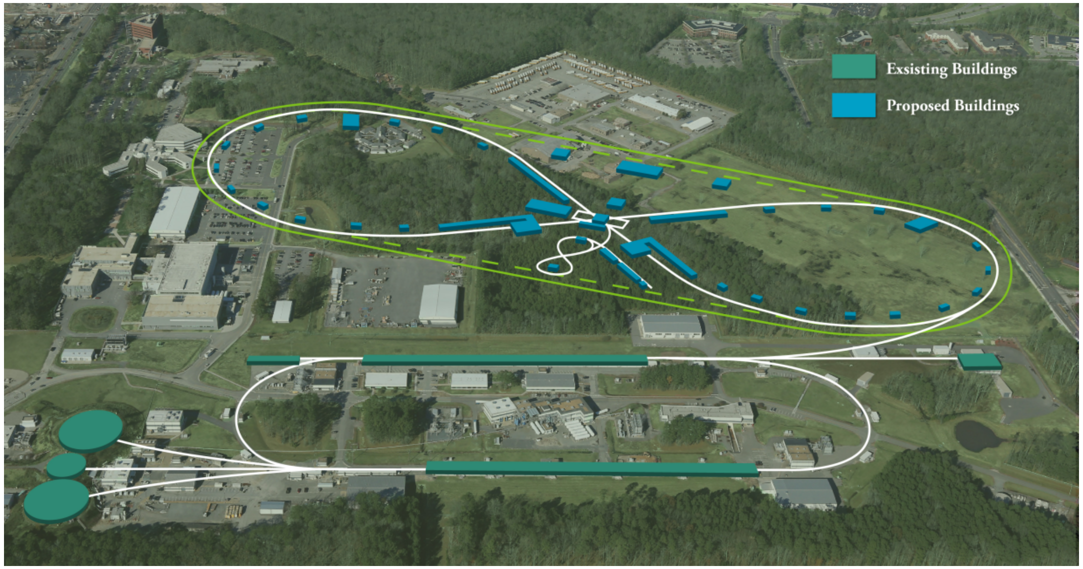
- Backup

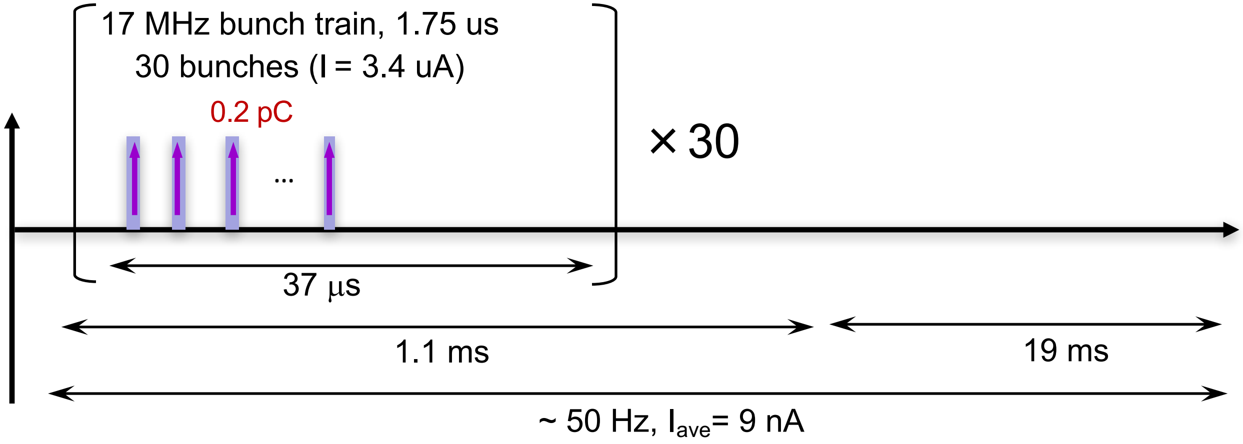
First polarized e^+A collider.
Polarizied Positron beam at JLEIC.

A group (Joe Grames, Jiquan Guo, Fangley Lin, Vasiliy Morozov, Eric Voutier, Yuhong Zhang) is exploring a polarized positron injector suitable for Jefferson Lab Electron Ion Collider (JLEIC).



$\mathcal{L} \geq 10^{33} cm^{-2}s^{-1}$ $P_{e+} \geq 40\%$

Bunch structure from the injector:



17 MHz bunch train, 1.75 us

30 bunches (I = 3.4 uA)

0.2 pC

…

× 30

37 μs

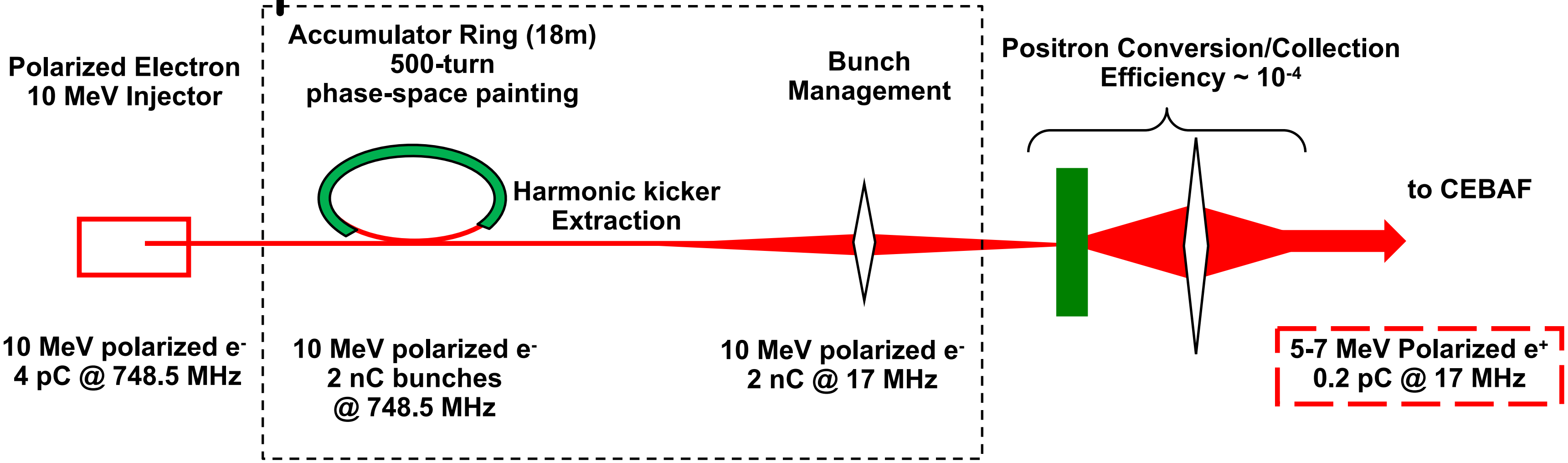
1.1 ms

19 ms

~ 50 Hz, I_{ave}= 9 nA

A pulsed beam with low average current (~10 nA) is required for injection into JLEIC with a reasonably short injection time and reasonably high equilibrium polarization.

Positron production scheme

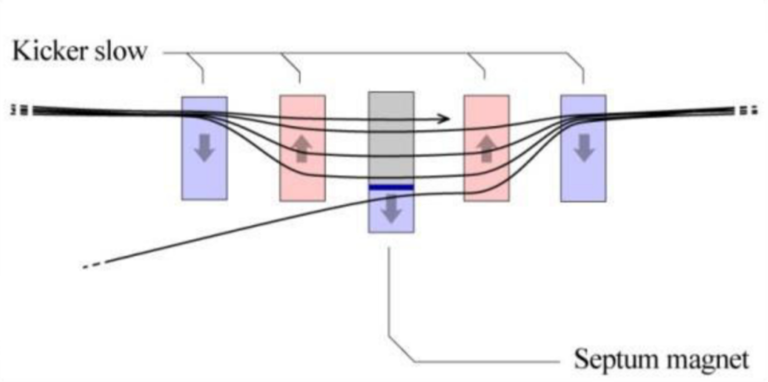


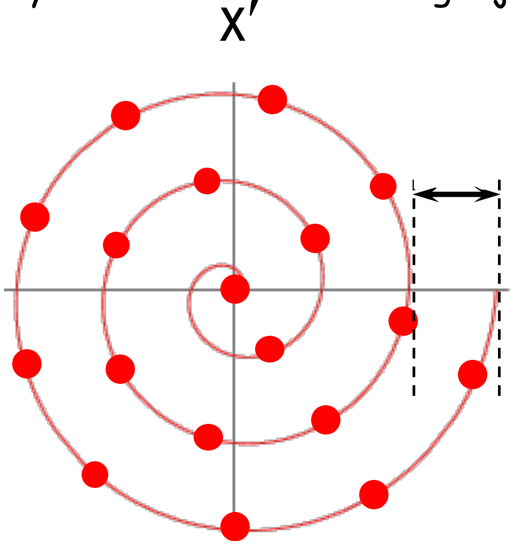
Polarized Electron Source	Accumulator Ring	Electrons at Converter	Polarized Positron Source	R&D Challenge
4 pC @ 748.5MHz 3 mA peak Up to 0.09mA avg ~40ns × 500 × 30 train	748.5 MHz 1.5 A peak 30/45 bunches 20ns gap	17MHz 34mA peak up to 0.09mA avg 1.75µs, 525m train	17 MHz 3.4µA peak up to 9nA avg 1.75µs, 525m train	Electron accumulator Harmonic extraction Target: 340 kV peak

20ns gap allows more reasonable kicker rise time
17MHz allows reducing collider ring bunch reprate by factor of 4, may help increase luminosity for low beam current/high energy collision cases, when beam-beam is not a bottleneck.

Multi-Turn injector

- Concept: an orbit bump created near a septum and then slowly reduced as beam being injected (phase-space painting)





- A number of painting schemes have been developed
- Process can also be simultaneously occurring in vertical and longitudinal dimensions
- CERN's LEIR has a design for 75-turn injection of Pb^{54+}, we plan to push this number to a few hundred to a thousand using low electron emittance
- Main injection system components
  - Magnetic or electrostatic septum
  - Four bumper magnets with ~1 μs rise time, reasonably fast fall-off time and ~10 mrad maximum deflection