DIS2014
XXII International Workshop of Deep Inelastic Scattering and Related Subjects

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Seminarium Zakładu Fizyki Cząstek i Oddziaływań Fundamentalnych

Warszawa, 24.X. 2014

(korzystałam z transparencji DIS2014)

Outline

DIS2014 w liczbach

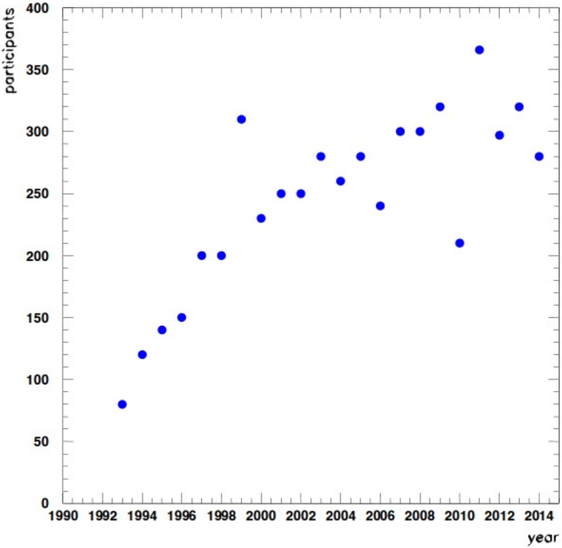
- Pierwszy „HERA workshop” w 1993 roku w Durham (GB); 76 uczest. $\Rightarrow$
- W 2007: + "and Related Subjects" (bo zamknięcie HERy)
- DIS2014: 28 kwietnia – 2 maja, 2014
- Organizatorzy: Wydział Fizyki UW, NCBJ, PTF
- Lokalny komitet Organizacyjny:

  B. Badełek, G. Brona, K. Doroba, J. Kalinowski, M. Kazana, M. Krawczyk, M. Misiura, A. Sandacz, J. Wagner, A.F. Żarnecki, A. Kaczor, S. Małek, „Global Wings”, doktoranci, studenci
- Komitet programowy:

  B. Badełek, A. Bożek, A. Kalinowski, A. Kisiel, K. Kurek, A. Staśto, A. Szczurek, L. Szymanowski, A.F. Żarnecki
- $\sim$300 uczestników z 32 krajów
- 24 referaty plenarne, 241 równoległych; $\gtrsim$ 50% z LHC.

http://dis2014.fuw.edu.pl

DIS2014 w liczbach,...   c.d.



A. Levy

DIS2014 w liczbach,... c.d.

Countries (32)

Argentina, Armenia, Austria, Belgium(10), Canada, Chile, China, Czech, Estonia, Finland, France(17), Germany (52), Greece, India, Iran, Israel, Italy(17), Japan, Korea, Netherland, Poland (41), Portugal, Russia, Serbia, Slovenia, Spain, South Africa, Sweden, Switzerland, Taiwan, UK (24), USA (39).

Experiments (22)

AFTER@LHC, ALICE, ATLAS, AWAKE, BABAR, BELLE, CDF, CMS, COMPASS, D0, EIC, H1, HERMES, JLAB, LHCb, LHeC, NA48/2, NA62, PHENIX, STAR, TOTEM, ZEUS

A. Levy

Pierwsze spotkanie, DIS1993, Durham

HERA WORKSHOP
ST. JOHN'S COLLEGE, DURHAM.
MARCH 1993

XXII spotkanie, DIS2014, Warszawa

Outline

„Sesja otwarta”: niedziela, 27 kwietnia 2014

(C. Jarlskog, J. Friedman, F. Close, studenci, uczniowie...)

Sesje plenarne: poniedziałek, 28 kwietnia 2014

(na niebiesko: związane z QCD i DIS)

1. Higgs and EW physics
2. Hot strong matter
3. Forward and low-x physics
4. Heavy flavours
5. Strategy for DIS
6. Structure functions and parton distributions
7. Precision QCD in the LHC era
8. Beyond the Standard Model
9. Event generators
10. 30 years of spin physics in 30 minutes: past, present, and future

Sesje równoległe: wtorek – czwartek

(na niebiesko: związane z QCD i DIS)

1. Structure functions and parton densities
2. Small-x, diffraction and vector mesons
3. Electroweak physics and beyond the standard model
4. QCD and hadronic final states
5. Heavy flavours
6. Spin physics
7. Future experiments

Sesje plenarne: piątek, 2 maja 2014

Podsumowanie każdej sesji równoległej (7 referatów), oraz

- Particle physics from the European perspective S. Bertolucci (CERN)
- American particle and nuclear physics planning H. Montgomery (JLab)
- Particle physics from the Asian perspective M. Nozaki (KEK/ACFA)

- DIS outlook A. Mueller (Columbia)

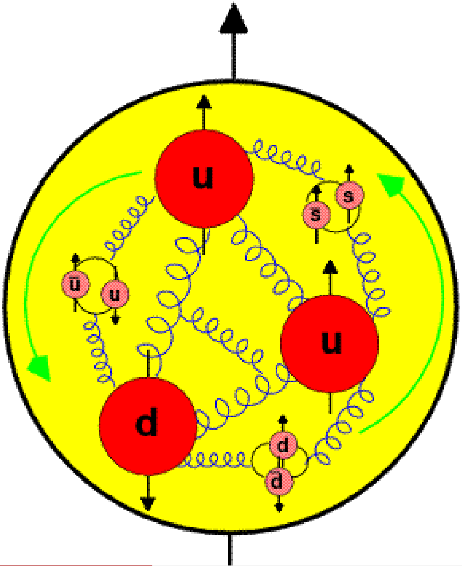
Materiały: publikowane przez PoS, dostępne ze strony DIS2014 oraz

http://pos.sissa.it/cgi-bin/reader/conf.cgi?confid=203

Outline

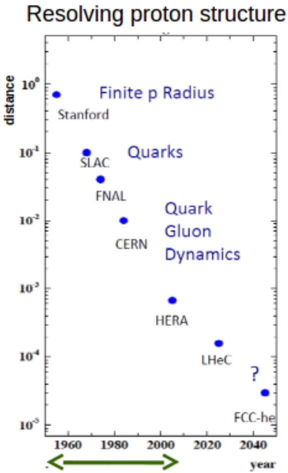
Outline

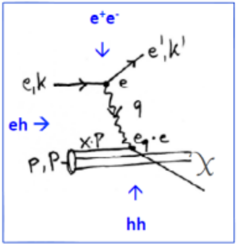
Proton pod „głęboko nieelastycznym” mikroskopem



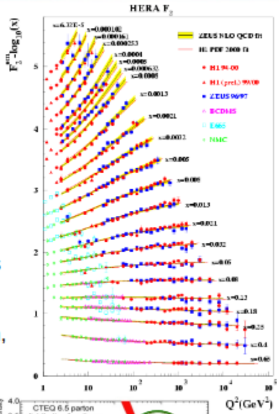
Rysunek: G.Brona

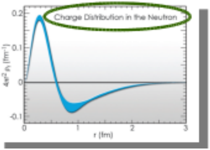
Deep Inelastic Scattering and Related Subjects (R. Ent)

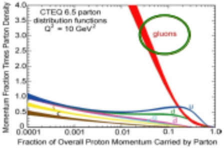




- The role of hh and e⁺e⁻ machines is often to push the discovery.
- The job of DIS/eh machines is often more that of characterization, without which we can not validate understanding.



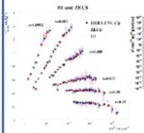


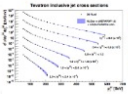


HERAFitter (K. Wichman)

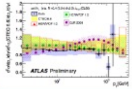
https://www.herafitter.org

experimental input





experiments:
HERA, Tevatron, LHC, fixed target



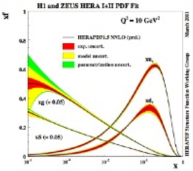
processes:
NC, CC DIS, jets, diffraction, heavy quarks (c,b,t)
Drell-Yan, W production

theoretical calculations/tools

Heavy quark schemes:	MSTW, CTEQ, ABM
Jets, W, Z production:	fastNLO, Applgrid
Top production	NNLO (Hathor)
QCD Evolution	DGLAP (QCDNUM)
	k_T factorisation
Alternative tools	NNPDF reweighting
Other models	Dipole model

+ Different error treatment models
+ Tools for data combination (HERAaverager)

HERAFitter



PDF or uPDF or DPDF

$\alpha_s(M_Z), m_c, m_b, m_t, f_s, ..$

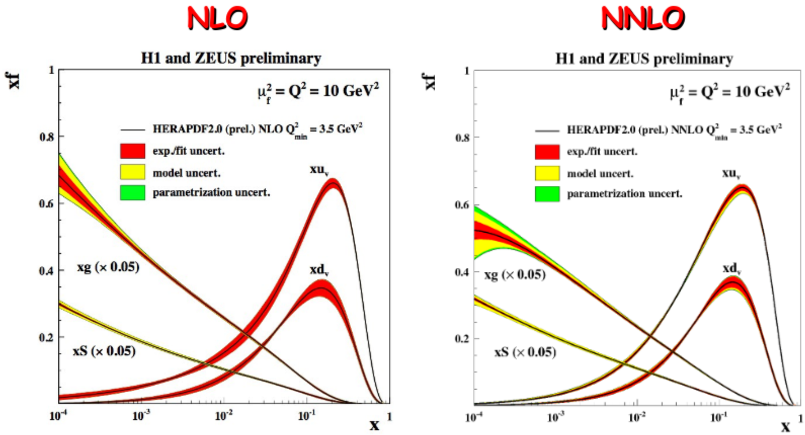
Theory predictions

Benchmarking

Comparison of schemes

HERAFitter... c.d.(K. Wichman)

NLO & NNLO parton densities



For details see V. Radescu talk

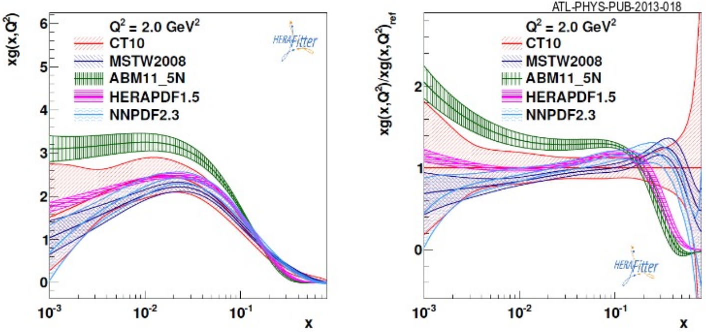
HERAPDF2.0 (prel.) extracted

Outline

Rozkład gluonów; HERAFitter (K. Wichman)

Life starts after 35

- Gluon PDF at large x → significant uncertainties for LHC important processes
- Gluons from different PDF groups differ outside PDF uncertainties

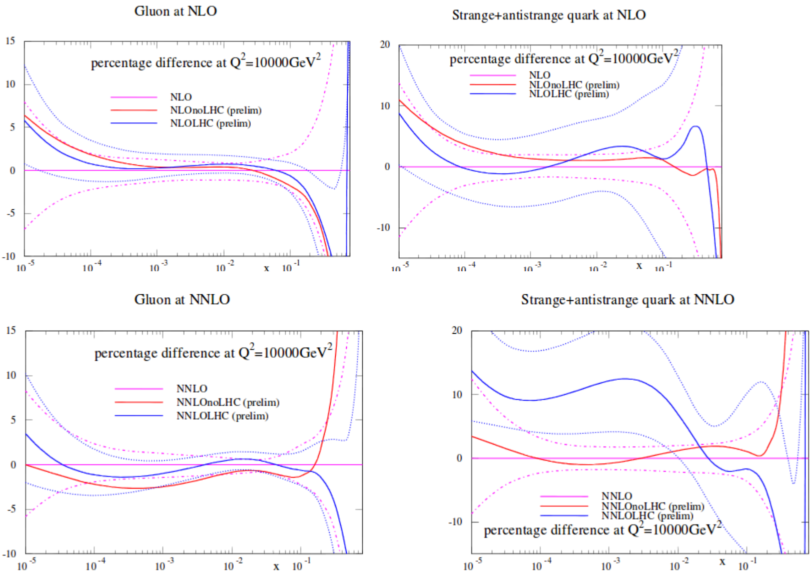


Gluon needs to be better constraint

- (In)direct constrains
  - scaling violation, collider jet data, prompt photon data, total ttbar cross sections

K. Klimek, 28.04.14, Structure functions and parton densities 19

Wyniki LHC (jety, W,Z) a $g(x, Q_0^2)$ (R.Thorne, MSTW)

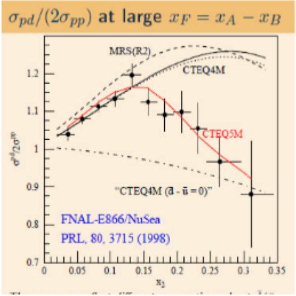


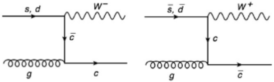
Outline

Symetria SU_3 morza; kwarki dziwne (R.Ent, K. Wichman)

- Violation of Gottfried Sum Rule in μN DIS data

FNAL Drell-Yan ⇒ $\bar{d}(x) \neq \bar{u}(x)$



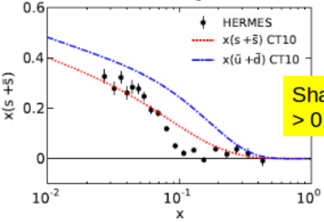


SU(3)-symmetric light-quark sea hypothesis supported

- Strangeness constraints $\bar{s} < \bar{d}$ originally from νN and $\bar{\nu}$N DIS di-muon data

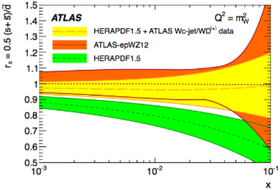
Strange sea s more (data) challenged

- HERMES SIDIS @ $Q^2 = 2.5$ GeV^2



Shape x > 0.1?

- LHC W/Z Production preference for $\bar{s} \sim \bar{d}$

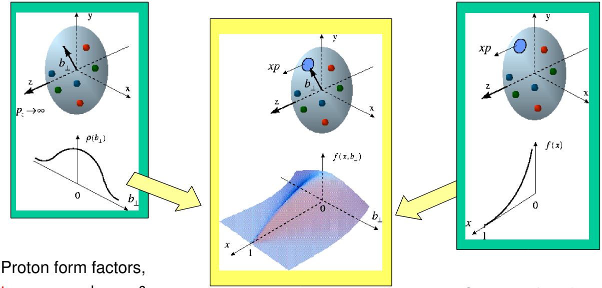


$$r_s \equiv 0.5(s+\bar{s})/\bar{d} = 0.96\,^{+0.16}_{-0.18}\,^{+0.21}_{-0.24}$$

Outline

3D picturing of the proton *via* GPD

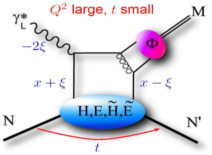
D. Mueller, X. Ji, A. Radyushkin, A. Belitsky, …
M. Burkardt, … Interpretation in impact parameter space



Proton form factors, transverse charge & current densities

Correlated quark momentum and helicity distributions in transverse space - GPDs

Structure functions, quark longitudinal momentum & helicity distributions



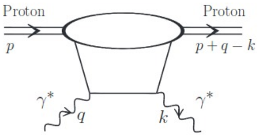
Deeply Virtual Compton Scattering

- Four GDPs $(H, E, \widetilde{H}, \widetilde{E})$ for each flavour and for gluons
- All depend on 3 variables: x, ξ, t;   DIS @ $\xi = t = 0$
- $H, \widetilde{H}$ conserve nucleon helicity; $E, \widetilde{E}$ flip nucleon helicity
- H, E refer to unpolarised distributions; $\widetilde{H}, \widetilde{E}$ refer to polarised distr.

After V.D. Volker, LANL 2007

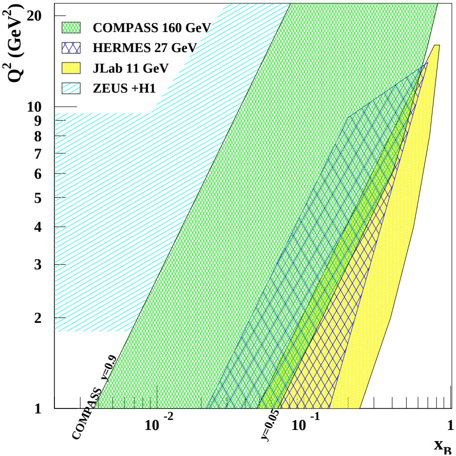
DIS *vs* DVCS *vs* elastyczne czynniki postaci

- Partony w QCD tylko w układzie nieskończonego pędu protonu ("physical" gauge)
- Można im więc przypisać położenie poprzeczne lecz NIE podłużne!
- reprezentacja „mieszana": pęd podłużny i współrzędna poprzeczna (zależna od skali)
- DVCS: proces elastyczny! Możliwy pomiar $\Delta_\perp$ sprzężony z $r_\perp$ kwarku.
- Jaka różnica z położeniem kwarku otrzymanym z elastycznych f.f. (Hofstadter, HAPPEX)?
  DVCS: można ustalić Q^2 i x i mierzyć $\Delta_\perp$.
  Transformacja Fouriera $\Delta_\perp \to r_\perp$:
  rozkład przestrzenny o rozdzielczości $\Delta r_\perp \sim 1/Q$
  W elastycznych f.f. Q^2 i $\Delta_\perp$ są ze sobą związane



- COMPASS, JLab $\longrightarrow$ poprzeczne rozkłady kwarków walencyjnych.
  Gluony i morze $\longrightarrow$ EIC.

GPD at COMPASS: data taking in 2016-17



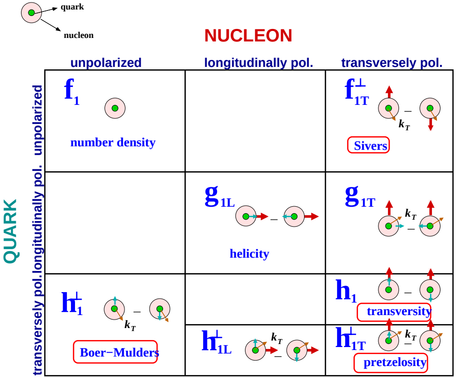
- CERN high energy muon beam
  - 100 - 190 GeV
  - 80% polarisation
  - $\mu^{+\leftarrow}$ and $\mu^{-\rightarrow}$ beams
- Kinematic range
  - between HERA and HERMES/JLab12
  - intermediate x (sea and valence)
- Separation
  - pure B-H @ low $x_{\rm B}$
  - predominant DVCS @ high $x_{\rm B}$
- Plans
  - DVCS
  - DVMP
- Goals
  - from unpolarised target: H (Phase 1)
  - from $\perp$ polarised target: E (Phase 2)

Test runs: 2008-9 and 2012; DVCS signal seen, full setup evaluated

Outline

Partonic structure of the nucleon; distribution functions

- In LT and considering k_T, 8 PDF describe the nucleon
- QCD-TMD approach valid $k_\mathrm{T} \ll \sqrt{Q^2}$
- After integrating over k_T only 3 survive: f_1, g_1, h_1
- TMD accessed in SIDIS and DY by measuring azimuthal asymmetries
- SIDIS: e.g. $A_\mathrm{Sivers} \propto$ PDF $\otimes$FF
- DY: e.g. $A_\mathrm{Sivers} \propto$ PDF$^\mathrm{beam}\otimes$ PDF$^\mathrm{target}$

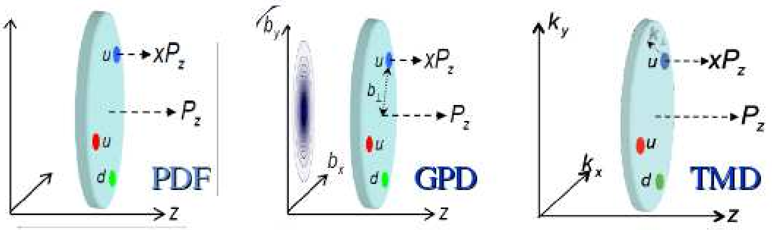


- OBS! Boer-Mulders and Sivers PDF are T-odd, i.e. process dependent

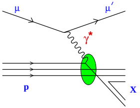
$$h_1^\perp(\mathrm{SIDIS}) = -h_1^\perp(\mathrm{DY}) \qquad f_{1\mathrm{T}}^\perp(\mathrm{SIDIS}) = -f_{1\mathrm{T}}^\perp(\mathrm{DY})$$

- OBS! transversity PDF is chiral-odd (may only be measured with another chiral-odd partner, e.g. fragmentation function.
- Boer-Mulders, Sivers and transversity $(h_1^\perp, f_{1\mathrm{T}}^\perp, h_1)$ will be measured in COMPASS II

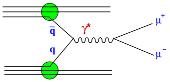
Transverse Momentum Dependent (TMD) distributions



- parton intrinsic k_{T} taken into account
- related to quark angular momentum, L!
- at COMPASS studied in 2 ways:
  - semi-inclusive DIS (polarised muons on unpolarised/transversely polarised target)
  - In the future: Drell-Yan process (π beam on unpolarised/transversely polarised tgt.)



SIDIS

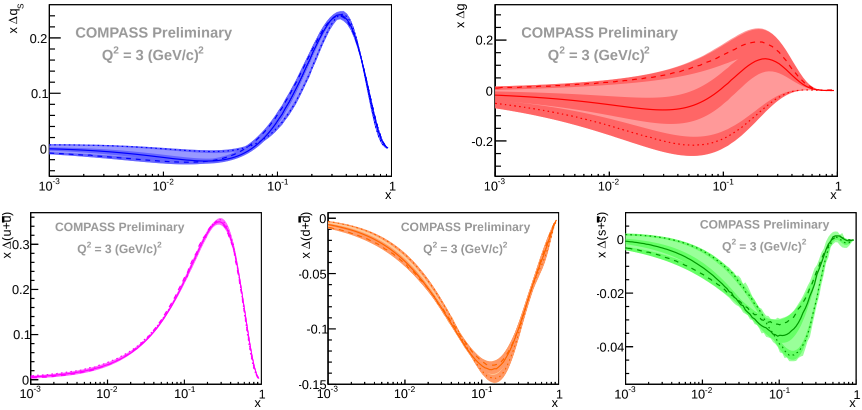


DY

Outline

Polaryzacja kwarków dziwnych

COMPASS NLO fit to g_1 world data (preliminary)

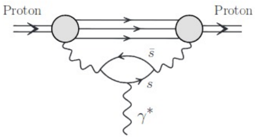


Polaryzacja kwarków dziwnych z asymetrii semi-inkluzywnych jest ≈ 0.

Funkcje fragmentacji???

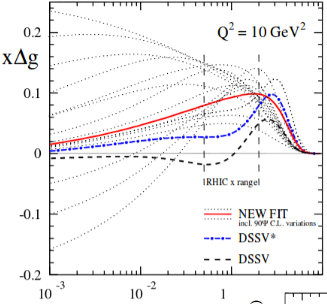
$1/2 = 1/2\Delta\Sigma + \Delta G + L_q + L_g$

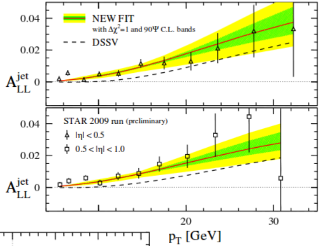
- Model Kwarkowy
  - dobry opis momentów magnetycznych barionów i stałej rozpadów słabych G_A, $\Longrightarrow$ opis odpowiednika G_A w SU$_3$, $\Sigma = \Delta u + \Delta d + \Delta s$
  - Poprawki relatywistyczne $\Longrightarrow$ Σ = 0.6 - 0.7, ale Σ = 0.3 – 0.4 więc model nie działa dla spinu
  - Ale uwaga: $\Sigma = \Delta u + \Delta d + \Delta s$ odnosi się do kwarków–partonów !
- EMC: $\Sigma \approx 0$ oraz Δs jest około 20%...
- Teraz Δs dość małe.
  Ale czy wpływa na statyczną strukturę protonu ?

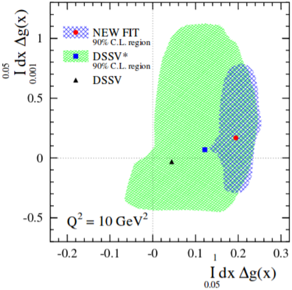


HAPEX w JLab sugeruje $G_E^s \approx G_M^s \approx 0$.
Tylko kwarki u i d oraz gluony determinują strukturę protonu.

Nowy fit globalny DSSV, arXiv:1404.4293







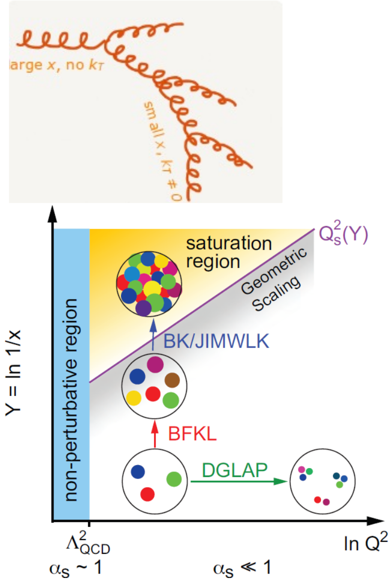
DSSV

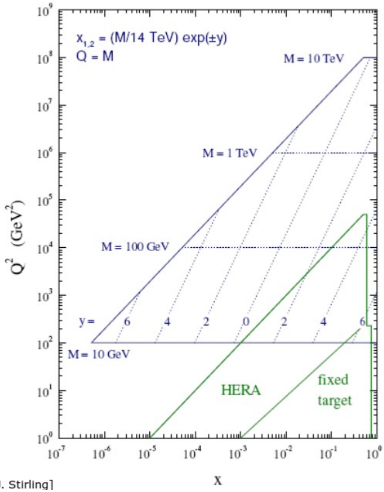
(inclusive jet and π^0 production at STAR and PHENIX

Clearly $\Delta G > 0$!

Outline

Typy ewolucji w QCD





Szukanie efektów BFKL (P. Van Mechelen)

Mueller-Navelet dijet decorrelation

BFKL predicts azimuthal angle de-correlations with increasing jet separations

- Measure average cosines (Fourier coefficients in an expansion of the Δφ distribution)

$$\langle \cos(n(\pi - \Delta\phi)) \rangle$$

  - For back-to-back jets <cos> = 1
  - BFKL predicts an increasing number of partons with increasing rapidity interval between MN jets ⇒ <cos> < 1
- Average cosines reflect properties of BFKL evolution equation, absent in DGLAP
- Ratios of average cosines further suppress DGLAP contributions

Experimental analysis

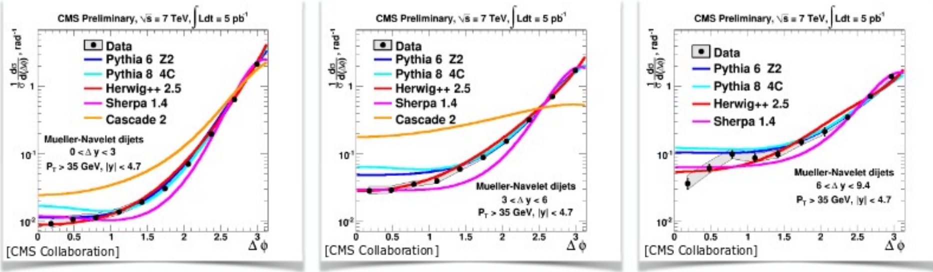
- Select events with at least two jets with $p_T > 35$ GeV and $|y| < 4.7$
- MN jet pair is the pair of jets with the largest rapidity separation

Szukanie efektów BFKL (P. Van Mechelen)

Mueller-Navelet dijet decorrelation

Δφ distribution

$\Delta y < 3$ | $3 < \Delta y < 6$ | $6 < \Delta y < 9.4$

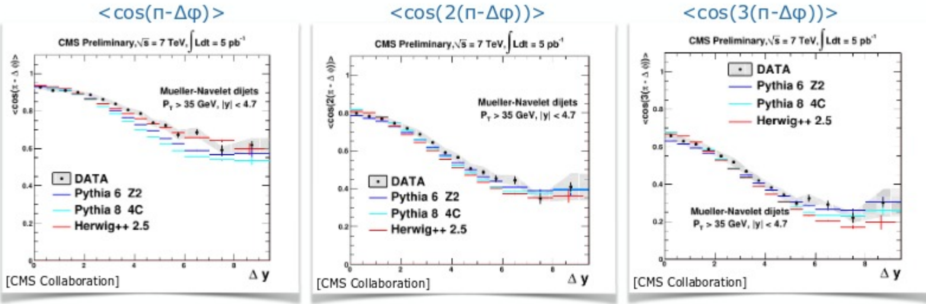


- Decorrelation increases with rapidity separation
- DGLAP models (especially HERWIG) give reasonable description of data
- BFKL-inspired CASCADE model predicts too strong decorrelations

Szukanie efektów BFKL (P. Van Mechelen)

Mueller-Navelet dijet decorrelation

Average cosines vs. rapidity separation



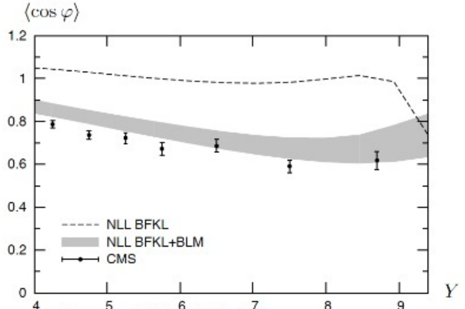
- Well described by DGLAP models...

Szukanie efektów BFKL (P. Van Mechelen)

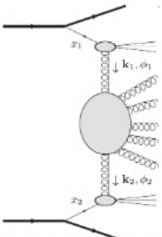
MN dijet decorrelations

NLL calculation by Szymanowski, Wallon, Ducloué

- NLL BFKL kernel
- NLO impact factors
- Brodsky-Lepage-Mackenzie procedure to fix scale for α_S



[Szymanowski, Wallon, Ducloué]



[Szymanowski, Wallon, Ducloué]

See talk by
- B. Ducloué (WG2+4, Wed. a.m.)

Szukanie efektów BFKL (P. Van Mechelen)

(Personal) summary of BFKL discussion

No sign for BFKL in experimental data...

- are we looking at the right observables?

"State of the art" BFKL resembles DGLAP: coincidence?

- probably not, to infinite order, both should give the same answer
- both are being fudged until they describe the data
  - DGLAP needs k_T from parton showers, multi-parton interactions, angular ordering
  - BFKL needs NLO/NLL corrections...

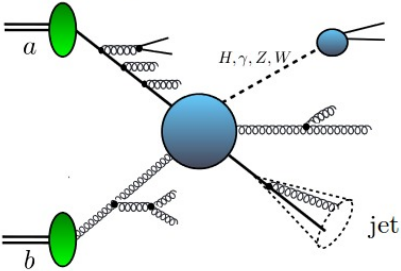
Is the whole BFKL/DGLAP debate obsolete in view of higher order, multi-leg matrix calculations?

▸ **Still, at high energy, BFKL must be the right theory for low *x* QCD ...**

Outline

W erze LHC ...

- In the LHC era, QCD is everywhere!



non-perturbative parton distributions

$$d\sigma = \sum_{ab} \int dx_a \int dx_b \, f_a(x_a, \mu_F^2) f_b(x_b, \mu_F^2) \times d\hat{\sigma}_{ab}(x_a, x_b, Q^2, \alpha_s(\mu_R^2)) + \mathcal{O}\left(\left(\frac{\Lambda}{Q}\right)^m\right)$$

perturbative partonic cross-section

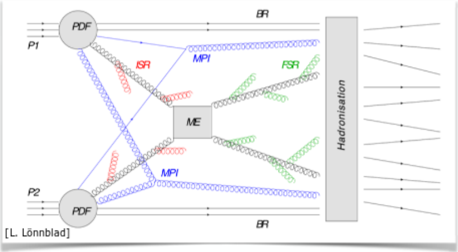
Partonic cross-section: expansion in $\alpha_s(\mu_R^2) \ll 1$ $\quad d\hat{\sigma} = \alpha_s^n \, d\hat{\sigma}^{(0)} + \alpha_s^{n+1} \, d\hat{\sigma}^{(1)} + \ldots$

- Require precision for perturbative and non-perturbative contribution

Oddziaływania wielopartonowe (P. Van Mechelen)

The underlying event

The Underlying Event (UE) is everything except the hard scattering (ME)



Multi-parton interactions (MPI) are well established in the description of the underlying event

- Most convincing argument is high multiplicity observed in hadronic collisions ▸ this is very difficult to explain without MPI

Understanding the UE is crucial for precision measurements of the SM and for the search for new physics, but its dynamics is not well understood

- Phenomenological models involve parameters which must be tuned to data

Pierre Van Mechelen – Universiteit Antwerpen 26/34

Outline

Outline

S. Bertoluccci, CERN

European Strategy for Particle Physics: high-priority large-scale scientific activities (I)

Europe's top priority should be the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors with a view to collecting ten times more data than in the initial design, by around 2030.

LHC continued

Four main results from LHC Run-1

1) We have consolidated the Standard Model
(wealth of measurements at 7-8 TeV, including the rare, and very sensitive to New Physics, B_s ▭ μμ decay)
▭ it works BEAUTIFULLY …

2) We have completed the Standard Model: Discovery of the messenger of the BEH-field, the Higgs boson discovery
(over 50 years of theoretical and experimental efforts !)

3) We found interesting properties of the hot dense matter

4) We have NO evidence of new physics

Note: the last point implies that, if New Physics exists at the TeV scale and is discovered at √s ~ 14 TeV in 2015++, its spectrum is quite heavy ▭ it will require a lot of luminosity (▭ HL-LHC 3000 fb^{-1}) and energy to study it in detail ▭ implications for future machines

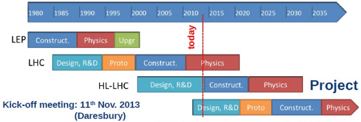
Extending the reach…

- Weak boson scattering
- Higgs properties
- Supersymmetry searches and measurements
- Exotics
- t properties
- Rare decays
- CPV
- ..etc

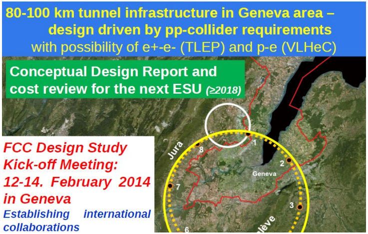
S. Bertoluccci, CERN, ... c.d.

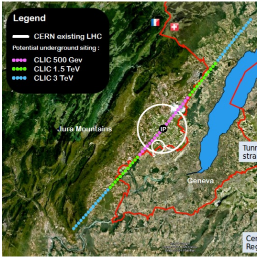
European Strategy for Particle Physics: high-priority large-scale scientific activities (II)

CERN should undertake design studies for accelerator projects in a global context, with emphasis on proton-proton and electron-positron high energy frontier machines.



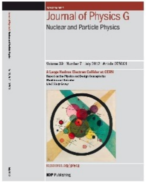
FCC: Future Circular Colliders

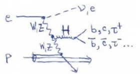




⟸ CLIC

LHeC ⟹





Continuing activity on
Physics
Detector
ERL

Goal: L~10^{34} cm^{-2}s^{-1}

S. Bertoluccci, CERN, ... c.d.

European Strategy for Particle Physics: high-priority large-scale scientific activities (III)

The Technical Design Report of the International Linear Collider (ILC) has been completed, with large European participation. The initiative from the Japanese particle physics community to host the ILC in Japan is most welcome, and European groups are eager to participate. ***Europe looks forward to a proposal from Japan to discuss a possible participation.***

CERN should develop a neutrino programme to pave the way for a substantial European role in future long-baseline experiments. Europe should explore the possibility of major participation in leading long-baseline neutrino projects in the US and Japan.

S. Bertoluccci, CERN, ... c.d.

The Particle Physics Landscape at CERN: The importance of diversity

High Energy Frontier

LHC

Hadronic Matter

deconfinement

non-perturbative QCD

hadron structure

Low Energy

heavy flavours / rare decays

neutrino oscillations

anti-matter

Non-accelerator

dark matter

astroparticles

Multidisciplinary

climate, medicine

Non-LHC Particle Physics = o(1000) physicists / o(20) experiments

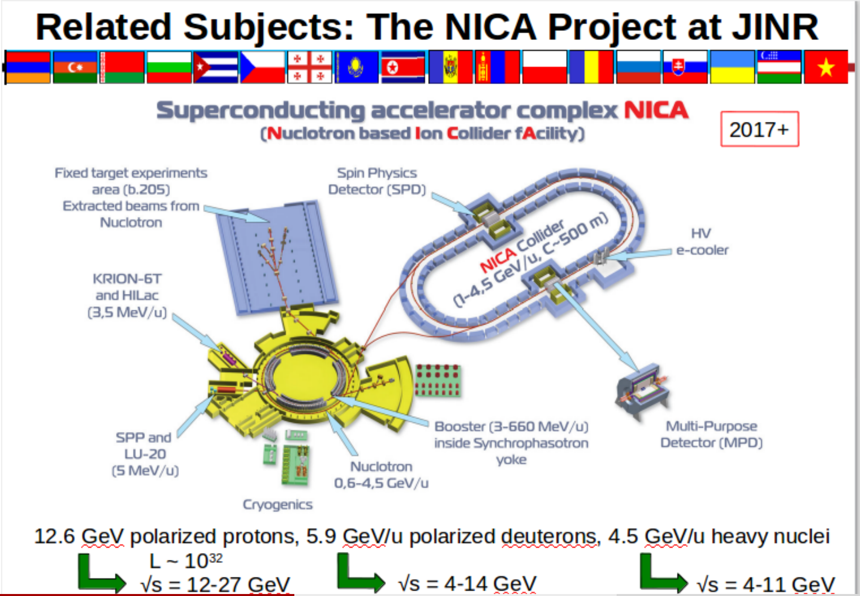
In the past years

Several breakthroughs

Steady progress of other programs

New mid-term and long-term projects started or in discussion

Plany Rosji (R.Ent)



Outline

H. Montgomery, Jefferson Lab.

- Badania finansowane przez: Department of Energy Office of Science (SC)
  + National Science Foudation (NSF)
- SC podzielone na Associate Directorates, m.in.:
  Office of High Energy Physics (OHEP) i Office of Nuclear Physics (ONP)
- Wspólne komitety doradcze SC i NSF: HEPAP i NSAC
- A sub-panel of HEPAP: Particle Physics Project Prioritization Panel (P5)
  $\Longrightarrow$ Snowmass, Minneapolis (2013). Decyzje lada moment!

H

- Zmiany w HEP w USA: zamkniecie Tevatronu (Fermilab) i PEPII (SLAC)
  $\Longrightarrow$ LHC; nadzieje na ILC w USA zawiodły...
- Energy Frontier: LHC (25% ATLAS-a i 30% CMS); YES !!!

E

- Intensity Frontier: neutrina (Fermilab: MINOS, MiniBooNE, NOvA, LBNE); YES ?
  miony w Fermlab-ie (flavour violating, (g-2)$_\mu$); YES

P

- Cosmic Frontier: ciemna materia i energia, ewolucja Wszechświata; YES

H. Montgomery, Jefferson Lab., ... c.d.

Future Fermilab Neutrino Program

NOvA
- On axis, NUMI Beam
- MI Proton Beam 700kW
- 14 kTon, liq. Scint. fine grain
- + Near Detector
- Operational 2014 …

Long Baseline Neutrino Experiment
- New Main Injector Beam
- LAr Detector
- Underground?
- Near Detector
- Beam ~1 MW+
- Operational ~2025

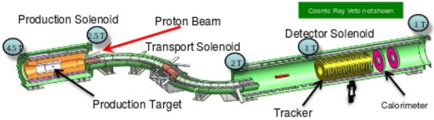
H. Montgomery, Jefferson Lab., ... c.d.

Intensity Frontier

μ2e conversion

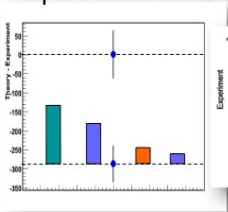
1st data 2019

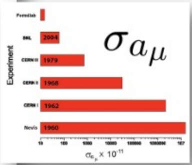
SES 3 10^{-17}



competition from COMET(JPARC) [also SES 3 10^{-17}]

$(g\text{-}2)_\mu$

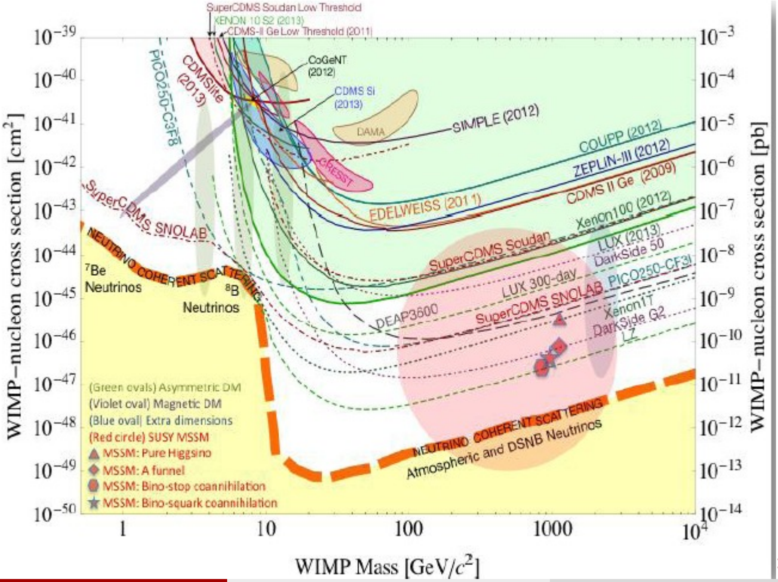




Heavy Photon Search, APEX, Darklight

Searches for A' at Jefferson Lab

H. Montgomery, Jefferson Lab., ... c.d.



H. Montgomery, Jefferson Lab., ... c.d.

- Long Range Plan 2008–2014
  (CEBAF $\Longrightarrow$ 12 GeV, początek
  konstrukcji Facility for Rare Isotope Beams, F RIB,
  neutrina i fundamentalne symetrie, zwiększenie świetlności RHIC-a)
- Wiosna 2014: nowy Long Range Plan, raport NSAC w październiku 2015

N

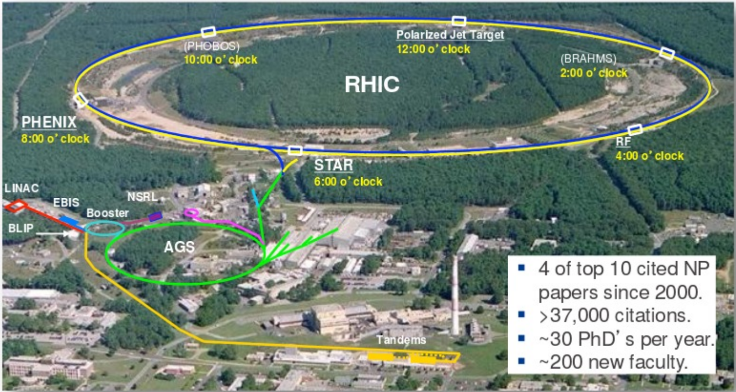
- Low Energy Nuclear Structure
- Relativistic Heavy Ions Physics: LHC, RHIC (zmienna energia!)
  Program QGP, program spinowy.

P

- Medium Energy Physics: CEBAF @ JLab. (świetlność i polaryzacja!)
  Partony walencyjne, przejście do obszaru perturbacyjnego.
  Łamanie parzystości.
- Electron Ion Collider

H. Montgomery, Jefferson Lab., ... c.d.

Relativistic Heavy Ion Collider



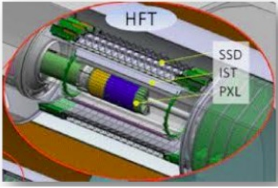
Completing the RHIC science mission

H. Montgomery, Jefferson Lab., ... c.d.

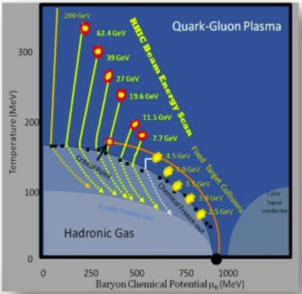
RHIC II Science Program

- RHIC-II upgrade complete
  - Luminosity upgrade via 3-D stochastic cooling
  - EBIS, 56MHz cavity, e-lenses, etc.
  - Si vertex detectors in STAR and PHENIX
- Install low energy e-cooling in 2017
- Install sPHENIX upgrade in 2020
- Complete the RHIC Mission in 3 campaigns:
  - 2014/15/16: Heavy flavor probes of the QGP
  - 2018/19: High intensity Beam Energy Scan II
  - 2021/22: Precision jet and quarkonium physics

Heavy Flavor Tracker enables precision measurements of interactions of heavy quarks in the quark-gluon plasma



Beam Energy Scan II

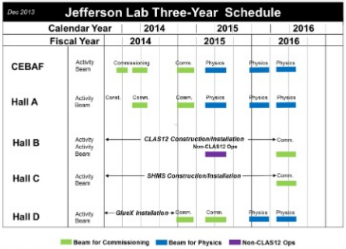


Low-energy e-cooling will improve statistics at $\sqrt{s}$ < 20 GeV for high quality measurements of fluctuation properties in search of critical point in QCD phase diagram

H. Montgomery, Jefferson Lab., ... c.d.

Jefferson Lab CEBAF 12 GeV Upgrade

- Civil Construction essentially complete
- Accelerator in commissioning
  - 5 passes this week, >10 GeV?
- Physics Sub-Project
  - Hall A operational
  - Hall D/GlueX in advanced installation
    - Commissioning starts Fall this year
  - Hall B – detector installation, magnet construction
  - Hall C – infrastructure installation, detectors ready, magnet construction



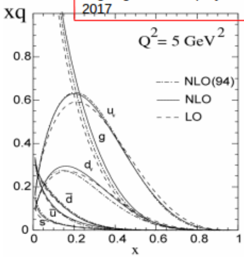
H. Montgomery, Jefferson Lab., ... c.d.

Jefferson Lab CEBAF 12 GeV Physics

- The Hadron spectra as probes of QCD (GluEx and heavy baryon and meson spectroscopy)
- The transverse structure of the hadrons (Elastic and transition Form Factors)
- The longitudinal structure of the hadrons (Unpolarized and polarized parton distribution functions)
- The 3D structure of the hadrons (Generalized Parton Distributions and Transverse Momentum Distributions)
- Hadrons and cold nuclear matter (Medium modification of the nucleons, quark hadronization, N-N correlations, hypernuclear spectroscopy, few-body experiments)
- Low-energy tests of the Standard Model and Fundamental Symmetries

More than 5 years of approved program!

Accelerator commissioning ongoing, all Halls up by 2017



12 GeV

REQUIRES:
- *High beam polarization*
- *High electron current*
- *High target polarization*
- *Large solid angle spectrometers*

H. Montgomery, Jefferson Lab., ... c.d.

Fundamental Symmetries

2013 NSAC LRP Implementation Report

Electric Dipole Moment Searches • *Origin of Matter* • *New Forces* Exp'ts: nEDM	**Neutrinoless Double β-decay Searches** • *Nature of the Neutrino* • *Origin of Matter* Exp'ts: CUORE, EXO, MAJORANA → Tonne
Electron & Muon Properties & Interactions • *New Forces* • *New subatomic particles* Exp'ts: MOLLER, SoLID, Muon g-2	**Radioactive Decays & Other Tests** • *New Forces* • *Neutrino mass* Exp'ts: KATRIN, Nab

Table II-1. Four broad components of the nuclear physics program of fundamental symmetry and neutrino studies. The primary scientific questions addressed by each are given in italics. The proposed and on-going flagship experiments in each area are listed. The tonne scale neutrinoless double β-decay experiment would follow the current generation of measurements.

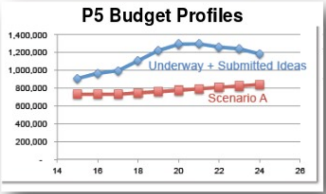
$0\nu\beta\beta$ McKeown Sub-Committee; April 2014

It is the assessment of this Subcommittee that the pursuit of neutrinoless double beta decay addresses urgent scientific questions of the highest importance, and that sufficiently sensitive second generation experiments would have excellent prospects for a major discovery. Furthermore, we recommend that DOE and NSF support this subject at a level appropriate to ensure a leadership position for the US in this next phase of discovery-caliber research.

H. Montgomery, Jefferson Lab., ... c.d.

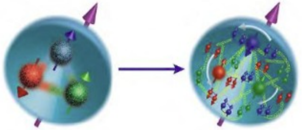
Conclusions

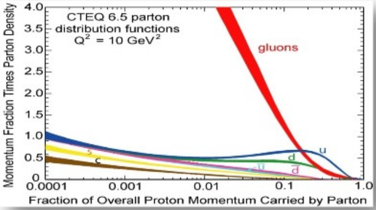
- Budget Constraints force us to make choices in Particle Physics and constrain Nuclear Physics
- In particle physics, the P5 process is close to conclusion
- In nuclear physics, while the field provided guidance on execution of the 2007 Long Range Plan, we are about to embark on the new edition. This will set the scene for developments from FY2015 onwards.
- There is also a DOE Office of Science Facilities document which may appear.



H. Montgomery, Jefferson Lab., ... c.d.

Electron Ion Collider: A QCD Laboratory





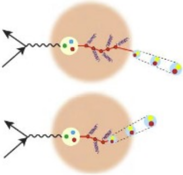
Understanding the "99%", the glue that binds us

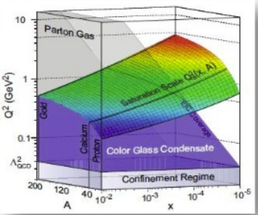
Tomography of the nucleus

Gluon spin

QCD at high gluon density

Quark hadronization in depth

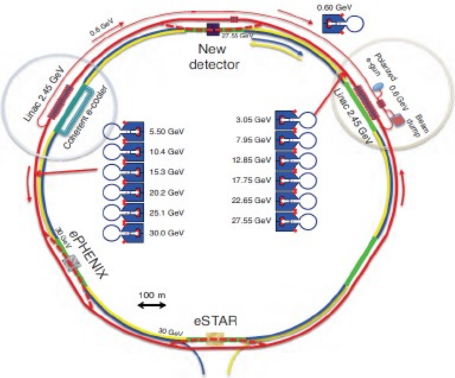




e-p machine, EIC, planned at BNL or JLab

BNL

Electron beam facility needed
(inside RHIC tunnel)



JLab

ELIC + injector needed

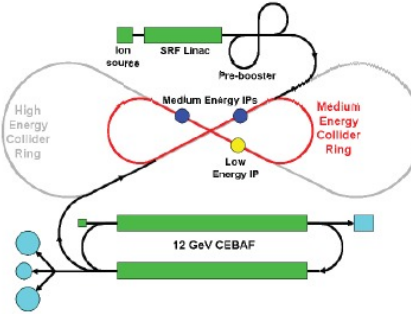
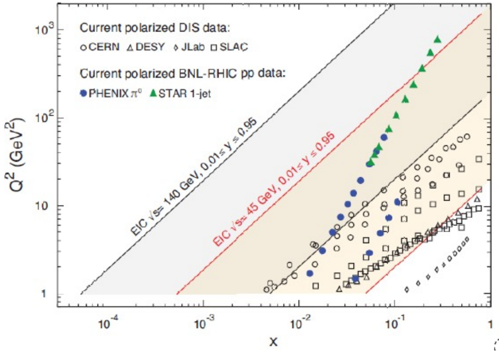


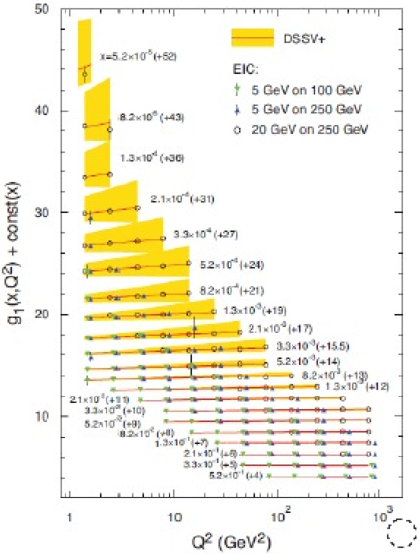
figure from The White Paper, arXiv:1212.1701

EIC: main features

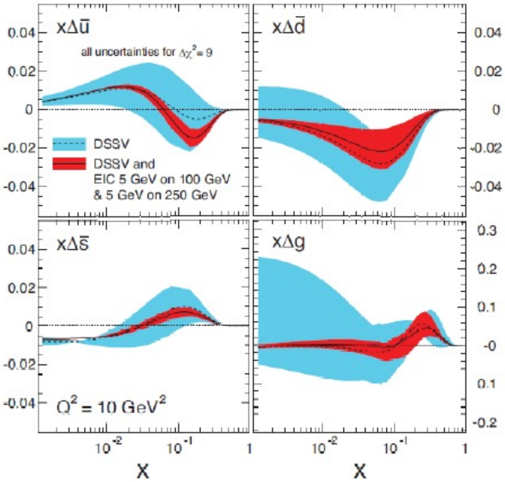
- Highly polarised ($\sim$ 70%) e, N beams
- ions from deuteron to uranium (lead ?)
- variable $\sqrt{s}$ from $\sim$ 20 GeV to $\sim$ 100 (150) GeV
- high luminosity: $\sim 10^{33-34}$ cm^{-2} s^{-1} (cooling of hadronic beam !)
- more than one interaction region
- limits of current technology $\Longrightarrow$ R & D!
- staged realisation; first stage: $\sqrt{s}$ = 60 - 100 GeV and high luminosity.

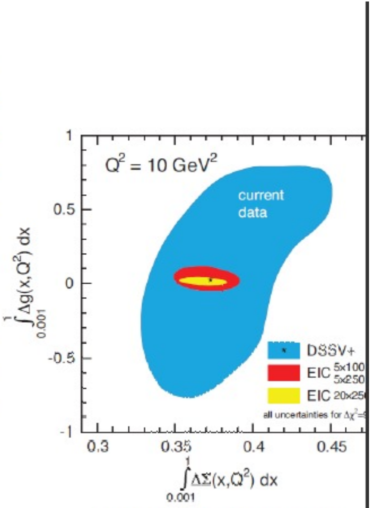
Acceptance of present spin experiments and EIC





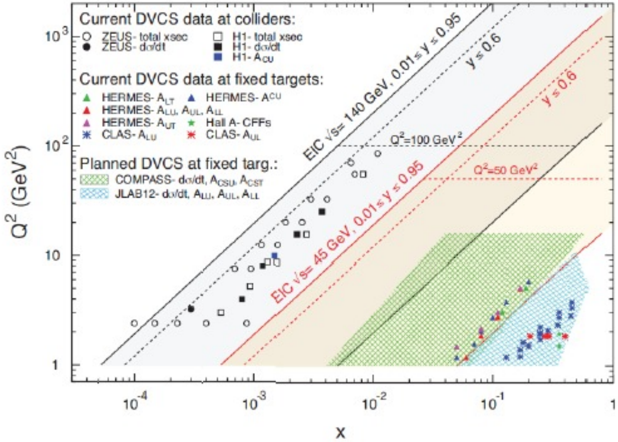
EIC pseudo-data (inclusive and semi-inclusive)





From "White paper", arXiv:1212.1701

Acceptance of present and EIC DVCS

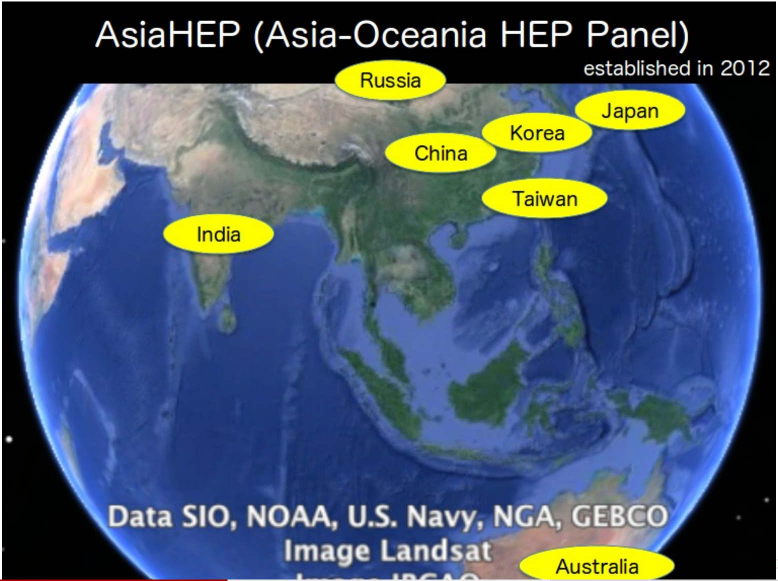


From "White paper", arXiv:1212

Outline

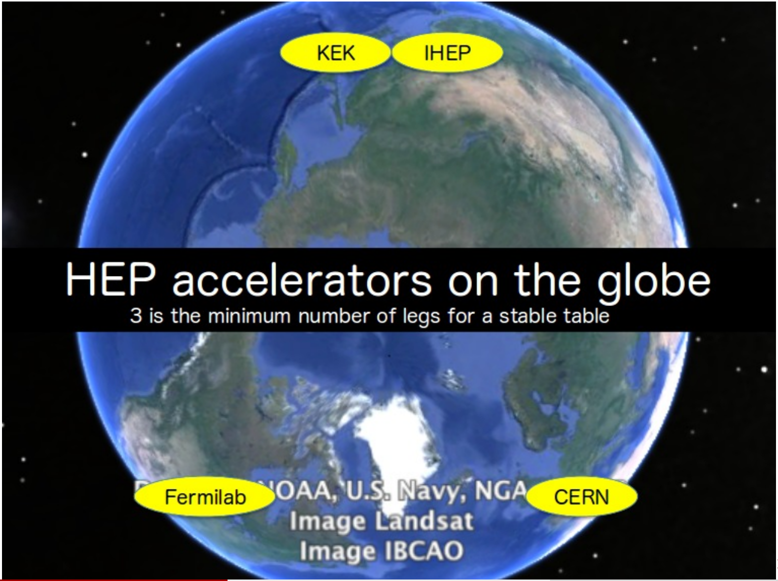
M. Nozaki, KEK/ACFA

M. Nozaki, KEK/ACFA, , ... c.d.



M. Nozaki, KEK/ACFA, ... c.d.

M. Nozaki, KEK/ACFA, ... c.d.



M. Nozaki, KEK/ACFA, ... c.d.

Roadmap

C h i n y

- Explore the full potential of BESIII
- Continue the flavor physics & QCD studies: PANDA, BELLE II
- Actively involved in the energy frontier: LHC & ILC
- Thinking about the future machine in China after BEPCII/BESIII: Circular Higgs Factory + pp Collider
- Continue the reactor neutrino physics: Daya Bay ➔JUNO
- Neutrino oscillation ➔ flavor changing process ➔ COMET
- Start to explore neutrino-less $\beta\beta$ decay: EXO ➔ nEXO
- Maintain the possibility for the future: Jinping lab & exp. there
- High altitude cosmic-ray physics: ASγ & ARGO ➔ LHAASO
- Explore in space: AMS/HXMT ➔ HERD/XTP

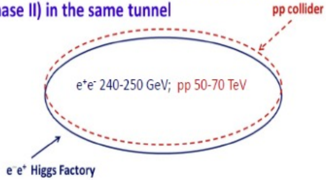
M. Nozaki, KEK/ACFA, ... c.d.

Chiny

CEPC+SppC

- We are looking for a machine after BEPCII
- A circular Higgs factory fits our strategic needs in terms of timing, science goal, technological & economical scale, manpower reality, etc.
- Its life can be extended to a pp collider: great for the future

- Circular Higgs factory (phase I) + super pp collider (phase II) in the same tunnel



- Circular Higgs factory is complementary to ILC
  - Push-pull option
  - Low energy vs high energy

We hope to collaborate with anyone who is willing to host this machine. Even if the machine is not built in China, the process will help us to build the HEP in China

M. Nozaki, KEK/ACFA, ... c.d.

J a p o n i a

KEK Roadmap at a glance

- J-PARC with nominal intensity (750kW)
  - to answer remaining questions of ν together with other experiments
    - Different baselines, ν & anti-ν, reactor
    - Mass hierarchy, lepton CP, maximal θ_{23}
  - Medium/small size experiments such as KOTO, LFV, EDM, g-2 etc.
  - Next generation ν facility: HK & liq. Ar TPC R&D
- SuperKEKB with 40xKEKB luminosity
  - Physics goal shifts from CP violation by direct B-quark production to search for BSM via indirect processes.
- ATLAS/LHC upgrade
- ILC
  - A central role in R&D, engineering, organizational design toward the ILC hosted in Japan
- Accelerator/detector technologies
  - Collaboration with other science area such as astroparticle physics
  - Industrial and medical applications

M. Nozaki, KEK/ACFA, ... c.d.

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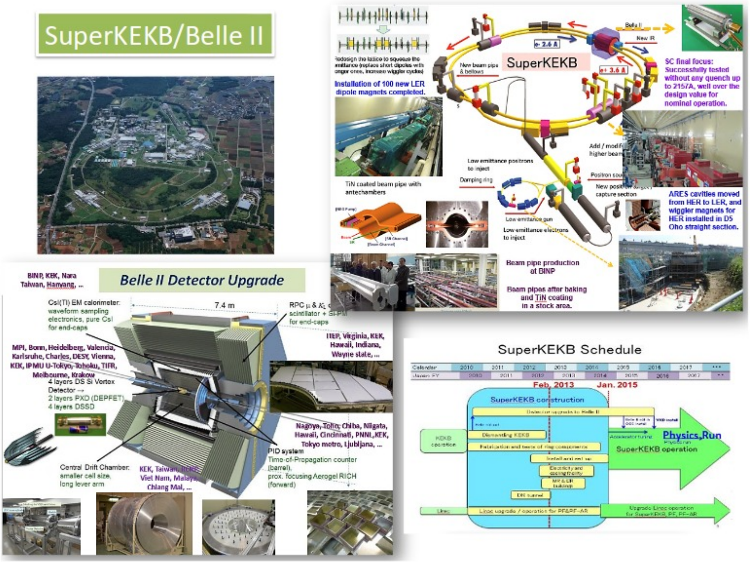


M. Nozaki, KEK/ACFA, ... c.d.

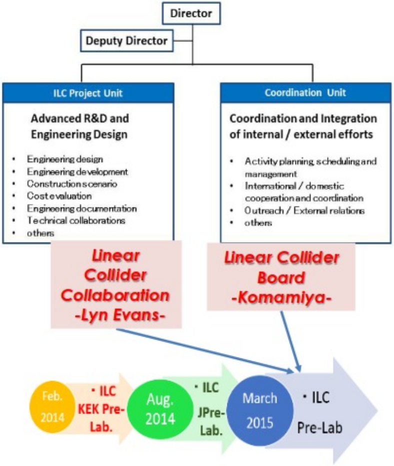
J a p o n i a

Preparation Office for promoting the ILC project was set up in KEK (February 2014)

AROUND THE WORLD

From KEK: KEK sets up Planning Office for the International Linear Collider

Tsukuba, 6 ~~January~~ February 2014. KEK, Japan's High Energy Accelerator Research Organization, has set up a Planning Office for the International Linear Collider. The office will be headed by Atsuto Suzuki, Director General of KEK, and will oversee a broad range of activities required for realisation of the ILC, in addition to the ongoing efforts.



M. Nozaki, KEK/ACFA, ... c.d.

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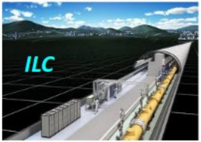
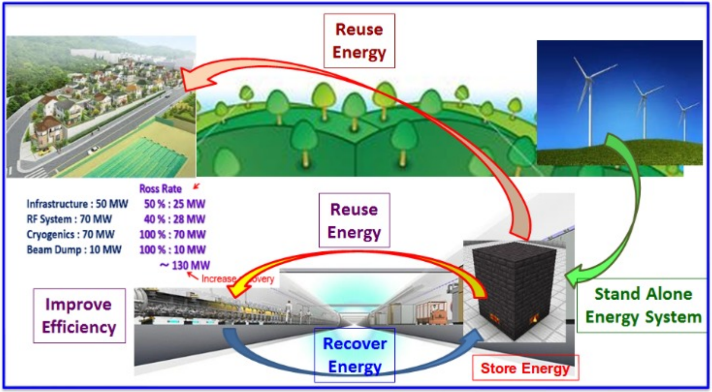


GREEN ILC

Advanced Accelerator Association
Promoting Science & Technology

Collaboration with industry



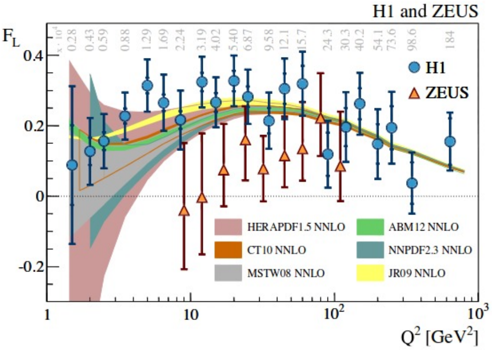
M. Nozaki, KEK/ACFA, ... c.d.

Summary

- Ample research opportunities in Asia.
  - T2K, KOTO, COMET etc. @J-PARC
  - e^+e^-: Belle II @SuperKEKB and BES III @BEPC II
  - Neutrino: JUNO @Taishan and HK @Kamioka + RENO in Korea and INO in India
- Future colliders have been proposed.
  - Linear e+e- collider in Japan
    - TDR completed, technically ready to go.
  - Circular e+e- (pp) collider in China
    - Design study started.
- Asian lab/community is accumulating experience in hosting large international projects.

BACKUP

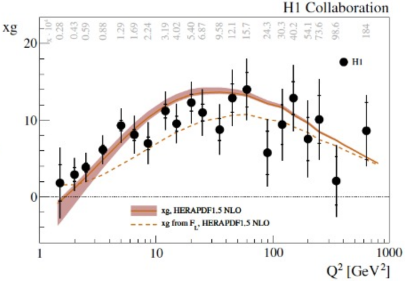
Problem? F_L z H1 i ZEUS-a



$R=\sigma_L/\sigma_T=F_L/(F_2-F_L)$ = 0.23±0.04 (H1)
R=0.105+0.055-0.037 (ZEUS)

approximate relation between F_L and gluon (order of α_s, with a=1)

$$xg(x,Q^2) \approx 1.77 \frac{3\pi}{2\alpha_S(Q^2)} F_L(ax,Q^2)$$



A dedicated EIC detector

- Acceptance -5 $< \eta <$ 5 (large, comparable to CMS forward)
- PID: π, K, p, leptons
- Low material density (minimal multiple scattering and bremsstrahlung)
- Hadron beams: proton to lead

From "White paper", arXiv:1212.1