Dedicated and generic searches at the LHC…

or…(gold-mining versus fishing)

LHC anticipated discoveries

preparation: Les Houches_2005; glorious departure: CERN-2007…

The inventory of anticipated "LHC-discoveries " almost as impressive as the inventory of Inflation Models:

Models of inflation

old, new, pre-owned,
chaotic, quixotic, ergodic,
ekpyrotic, autoerotic,
faith-based, free-based,
brane, braneless, brainless,
supersymmetric, supercilious,
natural, supernatural, *au natural,*
hybrid, low-bred, white bread,
one-field, two-field, left-field,
eternal, internal, infernal,
self-reproducing, self-promoting,
dilaton, dilettante, ...

Kolb's CERN lectures

"Post-Titanic" LHC-phase - a room for an "down-to-earth" research program e.g.: for generic searches

- **Generic searches:** df: Search for new effects in the data which:

  (1) disregard canonical discovery scenarios,
  (2) independent, as much as it is possible, of precise simulation of the Standard Model processes

- **Past:**

  (1) Pioneered within the H1 collaboration in 1996/1997: e.g. H1 note: H1-06/97-523
  (2) A derived approach implemented within the D0 collaboration (Bruce Knutesson)

- **Present:**

  Tools for the LHC generic-search program are being prepared at the moment (M.W. Krasny et al.):

(1) The gauge-model of configuration of the trigger, data acquisition and off-line analysis (ATLAS communication notes)
(2) The W and Z bosons beams for scrutinizing the electroweak symmetry braking (Phys.Rev)
(3) The targets for the electroweak boson beams (Phys Rev)
(4) The electron beam to monitor partonic momentum distribution and emittances (NIM)
(5) Absolute normalization of LHC processes to 1-2 % (NIM - in preparation)

Generic analysis of Large E_T Processes in Electron-Proton Scattering at HERA

H1 note H1-06/97-523

M.W. Krasny, E. Barrelet, A. Buniatian, M-C. Cousinou,
C. Diacomu, M. Goldberg, B. Heinemann, S. Kermiche,
I. Négri, A.Rostovtsev, J. Spiekerman, C.Vallée, P.Zini

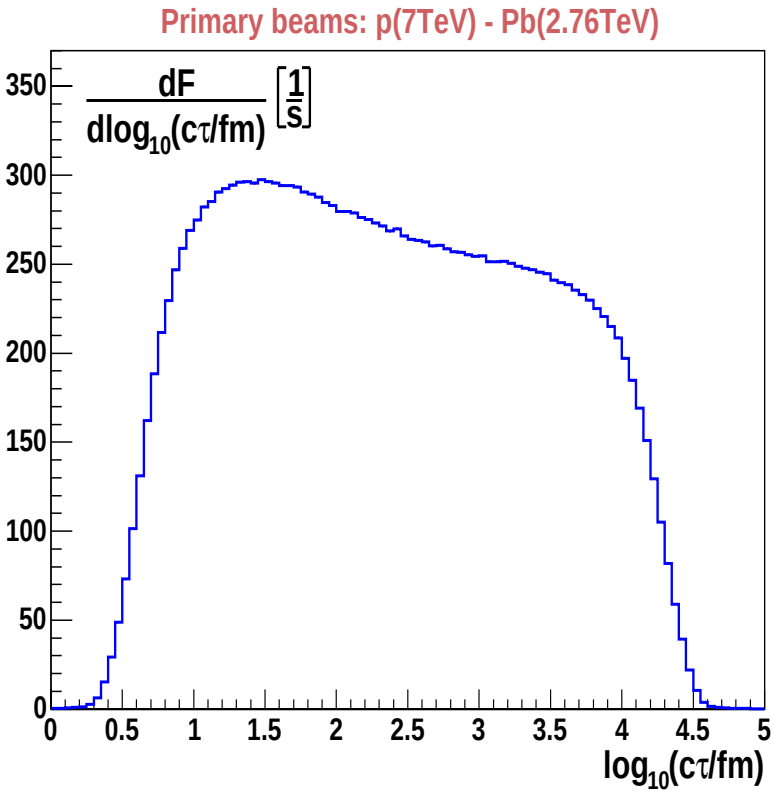
*Coherent analysis of events having 1 or 2 or 3 large ET (ET>25 GeV) objects : **photons, muons, electrons, jets and neutrinos***

Selected goodies of the generic search program at HERA…

- *Resolving anomalies in the proton structure at large x versus anomalies in the matrix elements by simultaneous analysis of photo-production and DIS data*
- *Self-consistency of photon, Z-boson and W-boson mediated processes*
- *Analysis of energy flow anomalies for multi-stage fragmentation process*
- *Analysis of QCD and QED radiation pattern for anomalous events*
- *Soft particles as medium detectors…*
- *…etc*

The LHC as W-nucleon collider

M.W. Krasny, S.Jadach, W.Placzek – submitted to Phys.ReV

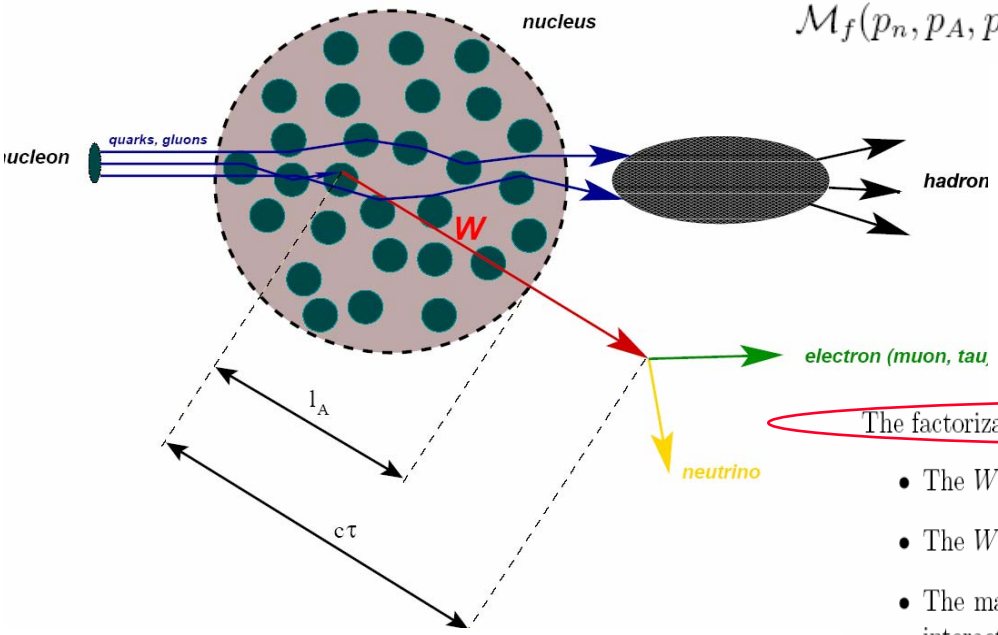


W – boson life-time
(bunch co-moving ref. system)

At LHC W bosons propagate up to 10000 fm – ***can be considered as a beam of free particles for fermi scale targets !!!***
(direct analogy to CERN high energy muon beams)

The factorization of the W-boson production, propagation and decay processes

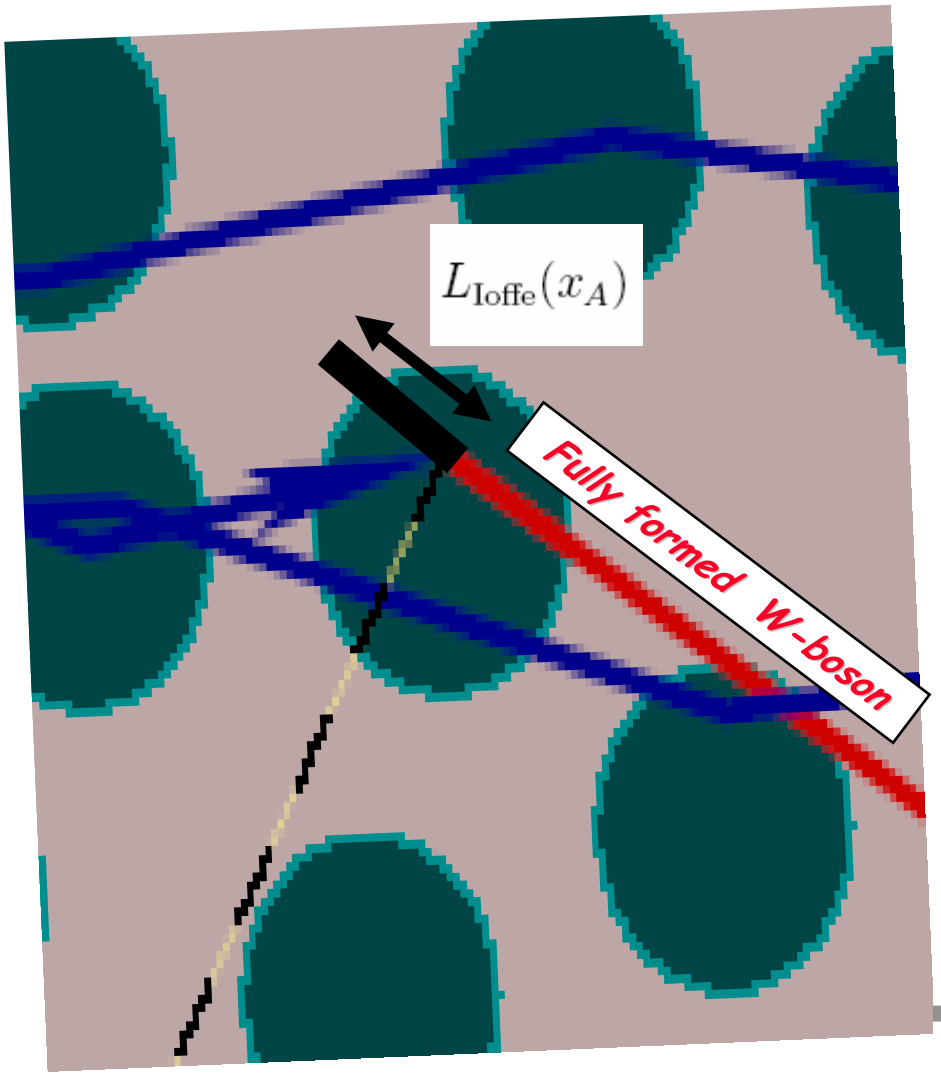
$$\mathcal{M}(p_n, p_A, p_W^{in}, r, p_W^{out}, p_1, p_W^{out} - p_1|A) =$$
$$\mathcal{M}_f(p_n, p_A, p_W^{in}, r|A)\ \mathcal{M}_p\left(p_W^{in}, p_W^{out}, l_A(p_W^{in}, p_A, r)\right)\ \mathcal{M}_d(p_1, p_W^{out} - p_1)$$



The factorization is a direct consequence of the following facts:

- The W-boson is a point-like particle.
- The W-boson is a colour-neutral particle[1].
- The mass of the W-boson is substantially larger than any scale of the strong interactions.
- The LHC energy is sufficiently high for the W-boson decay length to be larger than the total distance between the W-boson creation point and the point where it exits the nuclear medium.
- The W-bosons arriving at the position of the target can be considered as free on-shell particles.

Quantum picture of the W-boson formation



Quantum uncertainty of the Longitudinal position of W-production

$$L_{\rm Ioffe}(x_A) = \frac{1}{2M_A x_A}$$

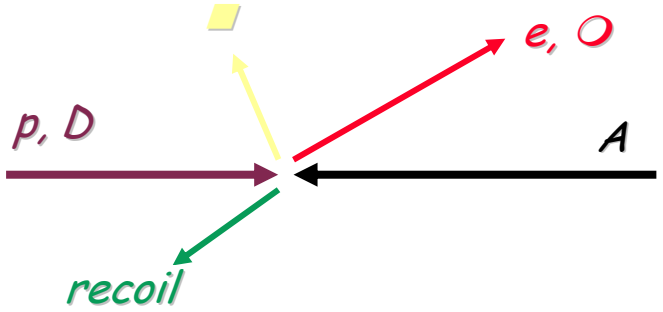
Quantum formation lengths of W-boson

$$\delta z = \gamma_W / M_W$$

Example: *W-boson produced by the valence quark of the nucleus moving in the rest frame of nucleus with γ_b = 100 has the uncertainty of the creation point and the formation lengths below 0.25 fermi*

Unfolding W-collision observables at the LHC

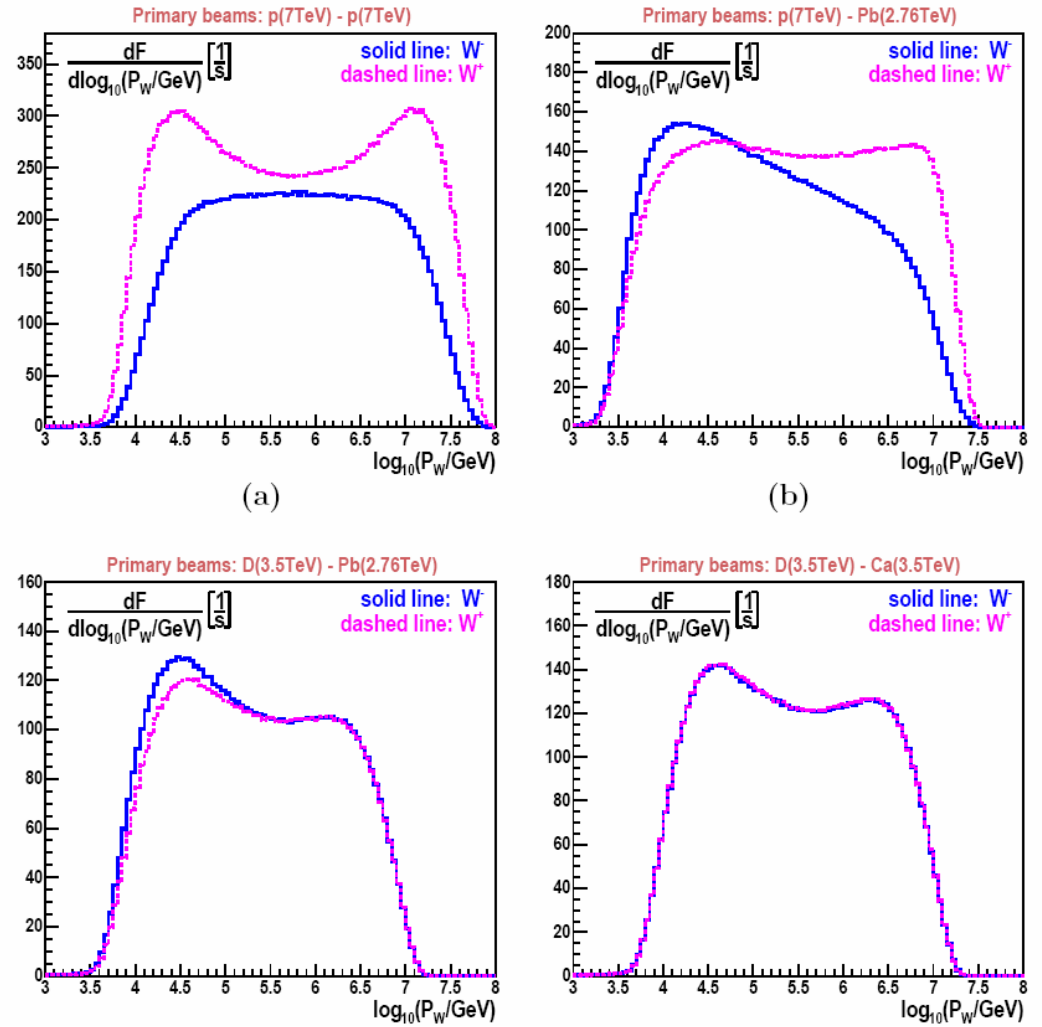
Example: Unfolding spin dependent amplitudes and phases for W-nucleon collisions



Analyze A-dependent rates of events with W-boson signatures

$$\mathcal{N}^{pol}_{\rm LHC}(p_n, p_A, p_T^{\rm recoil}, p_T^{\nu}, p_T^{l}, |p_l|, \phi_l^t)\,|A) =$$
$$\frac{3}{4\pi}\sum_{\mu,\nu}\sum_{\lambda_{in},\lambda_1,\lambda_2}\int d^3p_W^{in}\int d^3p_W^{out}\,\delta^{(2)}(p_T^{W,in}-p_T^{\rm recoil})\,\delta^{(2)}(p_T^{\nu}+p_T^{l}-p_T^{W,out})$$
$$\times\mathcal{F}_W^{\lambda_{in}}(p_n,p_A,p_W^{in}\,|A)\left[1-\sigma_{tot}^{abs}(p_{in}^W)\right]\langle l_A(p_{in}^W,p_A)\rangle\;\rho_A(p_A)\Big]$$
$$\times\mathcal{S}_{Wn}^{\lambda_{in},\lambda_1}(p_W^{in},p_W^{out})\;\mathcal{S}_{Wn}^{*\lambda_{in},\lambda_2}(p_W^{in},p_W^{out})\;\langle l_A(p_{in}^W,p_A)\rangle\;\rho_A(p_A)$$
$$\times|\mathcal{T}^{\mu\nu}|^2\;D^{1*}_{\lambda_1(\mu-\nu)}(\cos\theta,\phi)\;D^{1}_{\lambda_2(\mu-\nu)}(\cos\theta,\phi)$$

The W-boson fluxes *(surface integrated)*



WINHAC
a dedicated program for W-fluxes at the LHC
By: W. Placzek

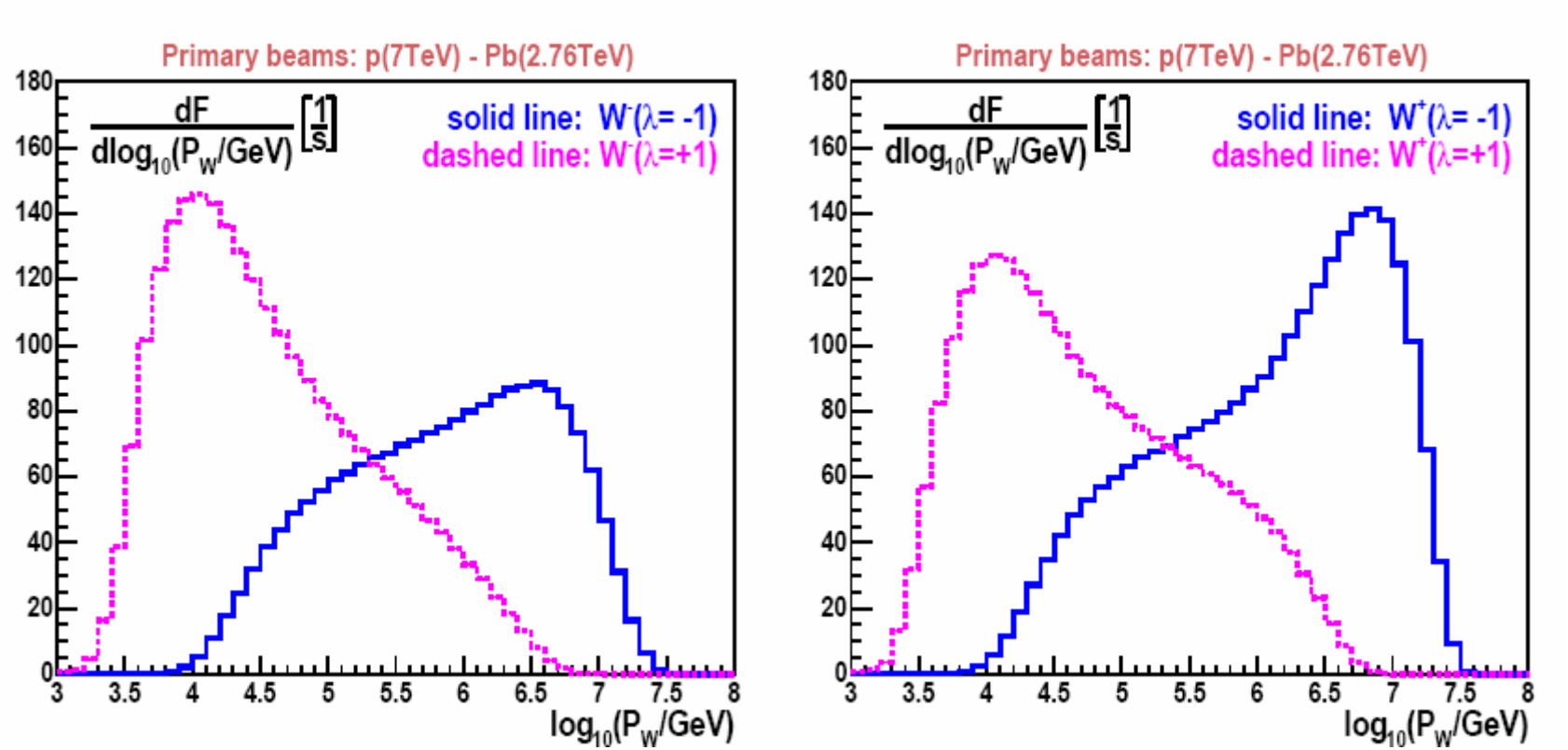
$$E_{\mathrm{beam}} = 7\,\frac{Z}{A}\ \mathrm{TeV}$$

$$L_{A_1 A_2} = \frac{L_{pp}}{A_1 A_2}$$

$L_{pp} = 10^{34}\ cm^{-2}\ s^{-1}$

The role of iso-scalars!!!!

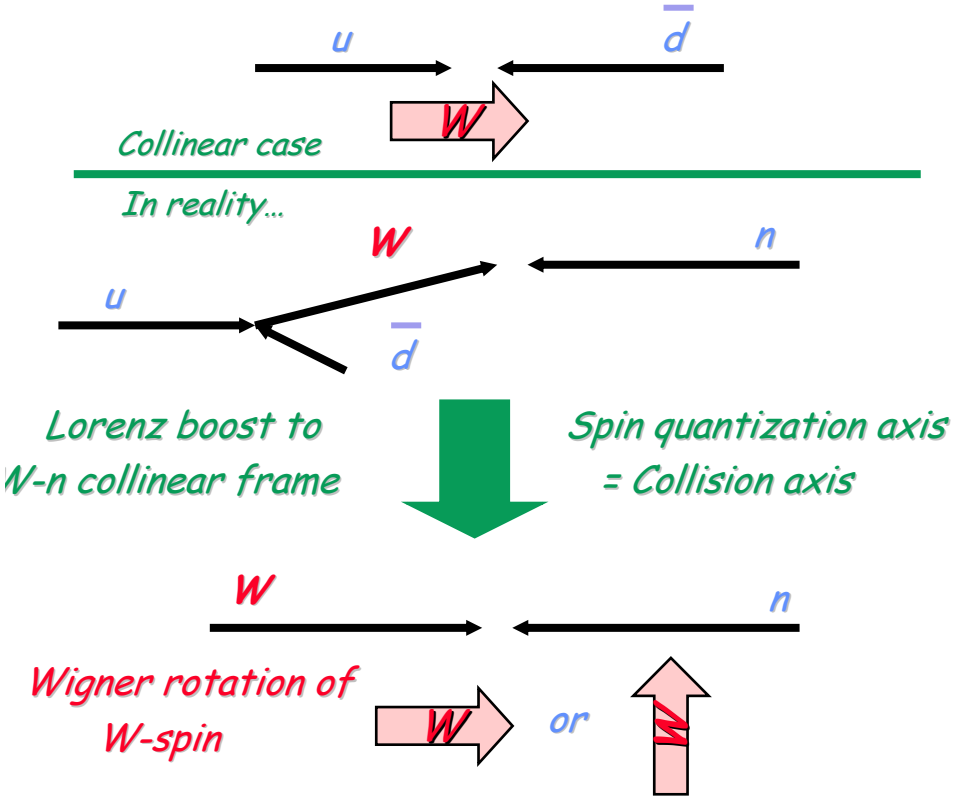
Polarization of W bosons *(transverse polarization)*

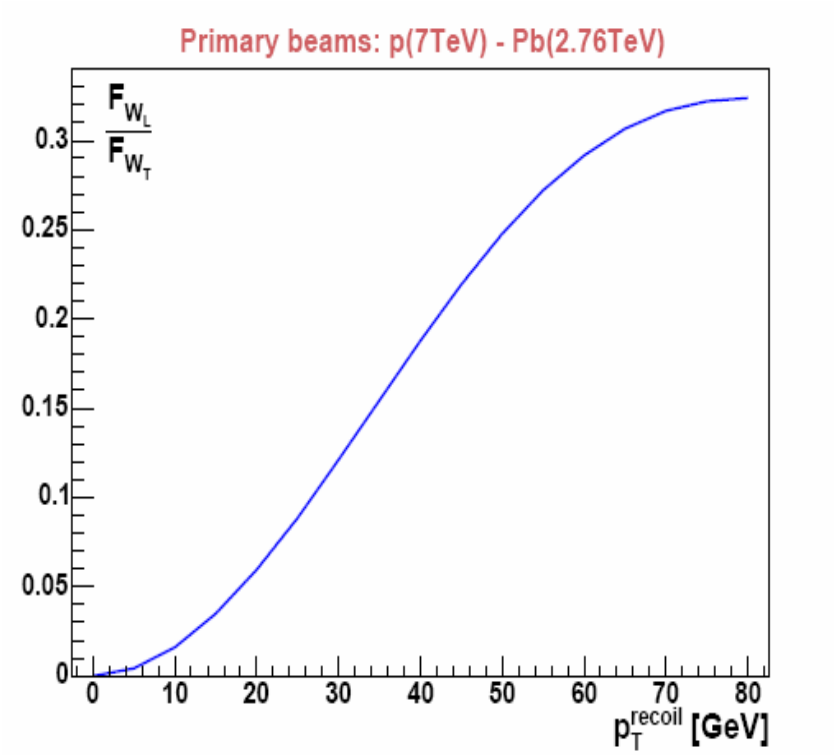


The polarization of the W-beam is a direct consequence of the V-A coupling of W-bosons to quarks. If quarks would be perfectly Collinear, and mass-less , W-bosons would be transversely polarized

Longitudinal polarization and Wigner rotations

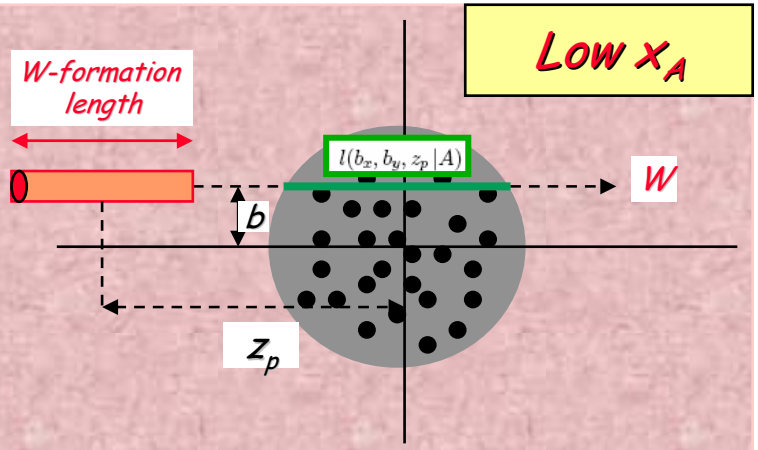
Longitudinal polarization is driven by the transverse momentum of quarks annihilating into W-boson





… Controlled experimentally by choosing the transverse momentum of the W-recoil …

The W-boson targets



$$\langle l_A(p_{in}^W)\rangle = \int db_x \int db_y\, \rho_A^n(b_x,b_y) \int dz_p\, \mathcal{P}_W^b\left(z_p(p_{in}^W)\right)\, l(b_x,b_y,z_p|A$$

$\mathcal{P}_W^b\left(z_p(p_{in}^W)\right)$ — *Probability of W boson formation in the cell centered at (z_p, b_x, b_y)*

$\rho_A^n(b_x,b_y)$ — *Transverse (b_x, b_y) density of nucleons in the nucleus*

$l(b_x,b_y,z_p|A)$ — *The geometrical, nuclear size-dependent path-length of W-boson in nuclear matter*

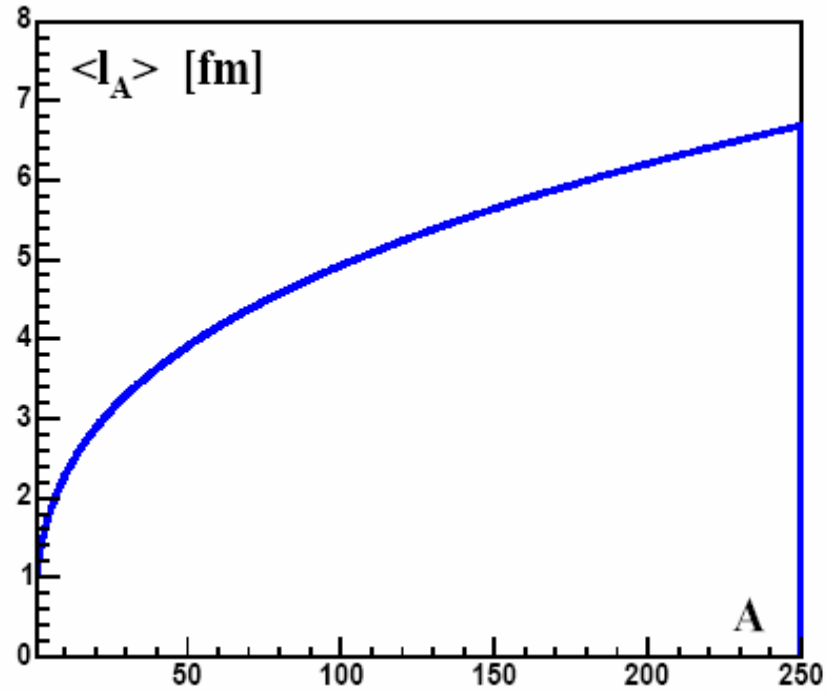
Detailed mapping of (b, z, Q2) dependent partonic densities, which allow to determine $\mathcal{P}_W^b\left(z_p(p_{in}^W)\right)$ *was one of the goals of the nuclear program for the HERA collider proposed at DESY in 1997 .*

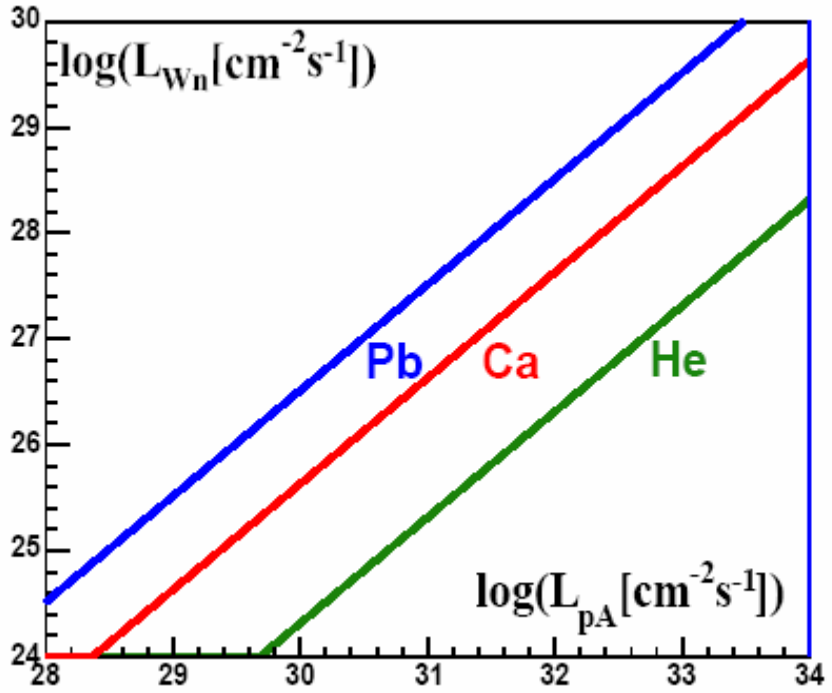
It is one of the goals of the eRHIC program at BNL...

...can be partially done at the LHC using parasitic electron beam

Luminosity

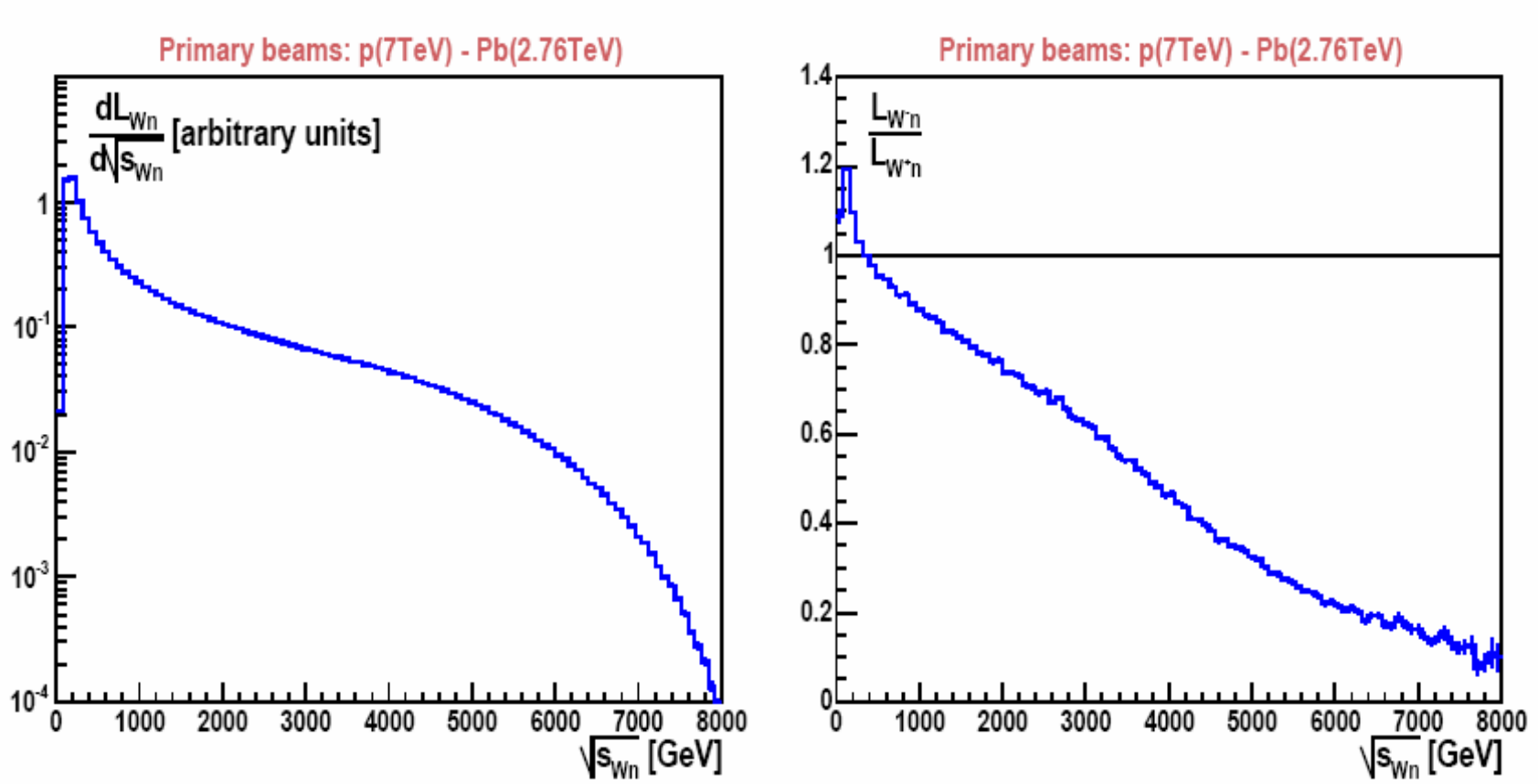
For W-bosons produced by the valence quarks of the nucleus the average path -length of W boson in nuclear matter and the corresponding W-n luminosity can be directly calculated





Note: the sample of N events in which the W-boson traveled the total distance $l_A(N) = \sum_{i=1,N} l_A(i)$ is, in the limit of large N, equivalent to the sample of N events in which each produced W-boson traveled the distance $\langle l_A \rangle$

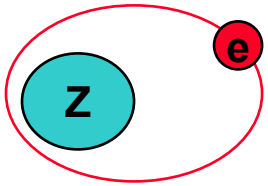
Luminosity spectrum

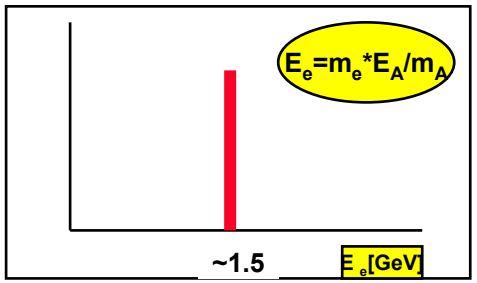


Search for energy dependent anomalies in charge asymmetries…

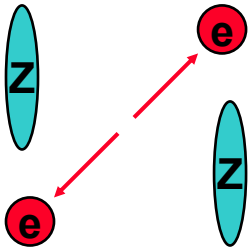
"Cheap" electrons for high-precision monitoring of partonic fluxes and emittances

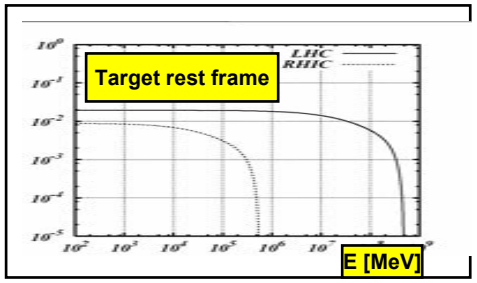
- Partially stripped ions



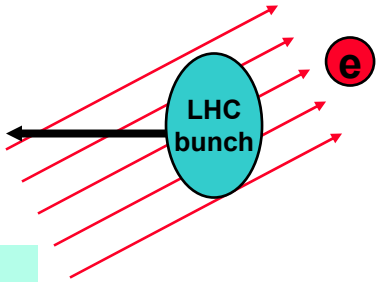


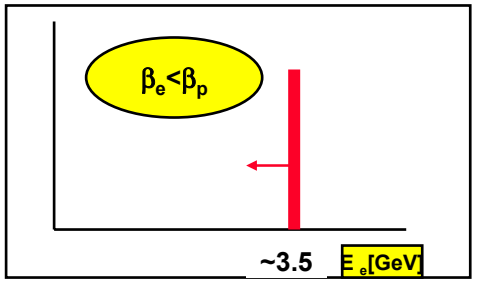
- Coulomb electrons





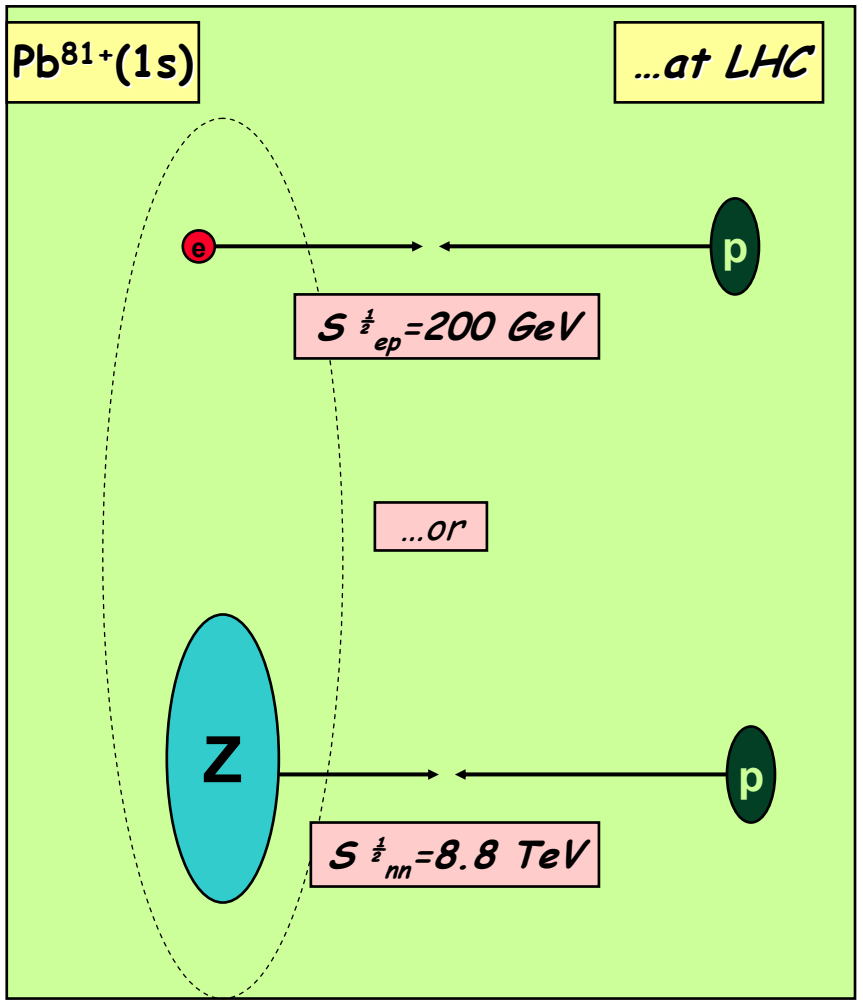
- External electron beam





Link to CLICK R&D– not discussed in this talk

Hybrid, partially stripped ion beams…



- *average distance of the electron to the large Z nucleus d ~ 600 fm (sizably higher than the range of strong interactions)*

- *partially stripped ion beams can be considered as independent electron and nuclear beams as long as the incoming proton scatters with the momentum transfer q >> 300 keV*

Both beams have identical bunch structure (timing and bunch densities), the same β, the same beam emittance – the choice of collision type can be done exclusively by the trigger system (no read-out and event reconstruction adjustments necessary)*

Acceleration, storage and collisions of partially stripped ion beam

- Stripping sequence
- Transport in the LHC lattice
- Beam cooling
- Vacuum in the LHC rings
- Beam-beam collision losses

Stringent constraints on operation of partially stripped ions beams….

A method of delivering the ep (e-light_ion) collisions to the LHC Interaction Points presented and discussed in details at the CERN Accelerator Forum – June 2004 and the BNL Accelerator Forum - May.2004 (see: M.W. Krasny, NIM, March 2005)

Decisive measurements will be made at the BNL RHIC accelerator…
(L.Ahrens, M.W. Krasny, V. MacKay, S.Peggs, D. Trbojevic proposal)

Allowed collision-configurations, beam life-time and luminosity of the PIE collider

(PIE -Parasitic Ion-Electron collider)

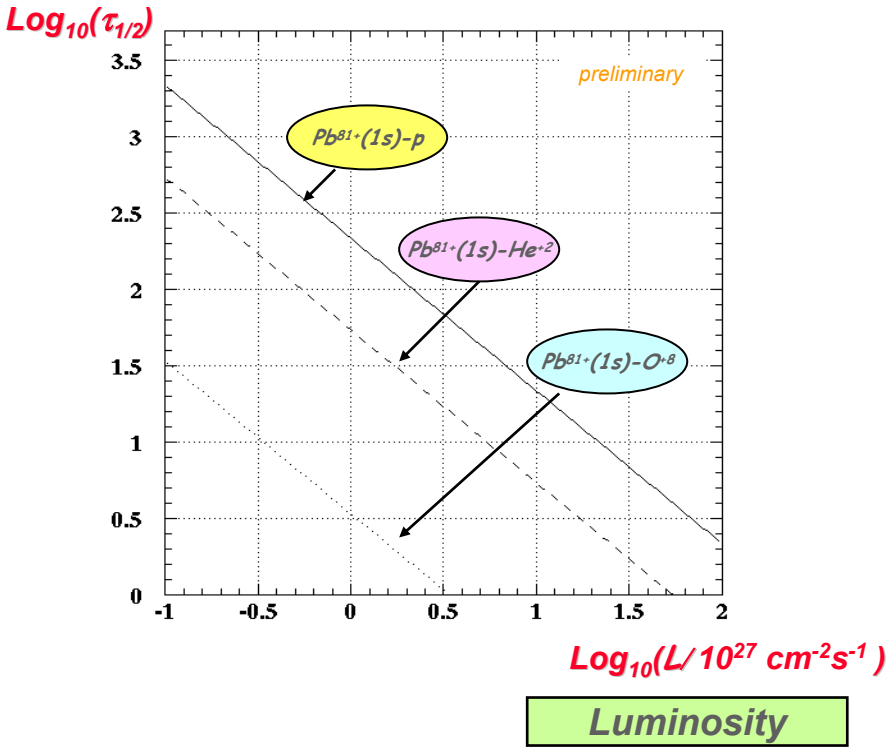
Constraints:

Electrons must be attached to the highest Z ions (e.g. Pb, Au)

The beam of partially stripped ions can collide only with the proton or the fully-stripped light-ion beams

The machine vacuum should not be worse than predicted for the IP-s (Rossi, Hillertet, LHC report 674 (2003)

Beam life-time



Luminosity

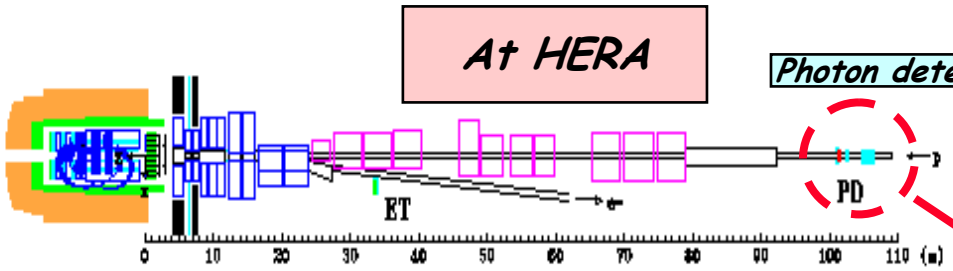
Allowed collision schemes: e.g. $Pb^{81+}(1s)$-p, $Pb^{81+}(1s)$-He^{+2}, $Pb^{81+}(1s)$-O^{+8}

Achievable luminosities: (e.g. for $Pb^{81+}(1s)$-p - $0.4 \times 10^{29}\ cm^{-2}s^{-1}$)

Absolute ep luminosity: radiative ep collisions

Elastic ep ⟶ e p + γ scattering at small angles

Bethe-Heitler spectrum photons depend only on the proton charge – insensitive to its structure



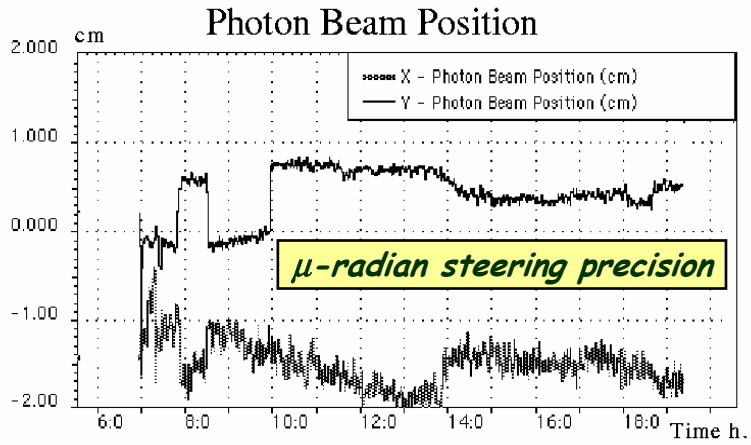
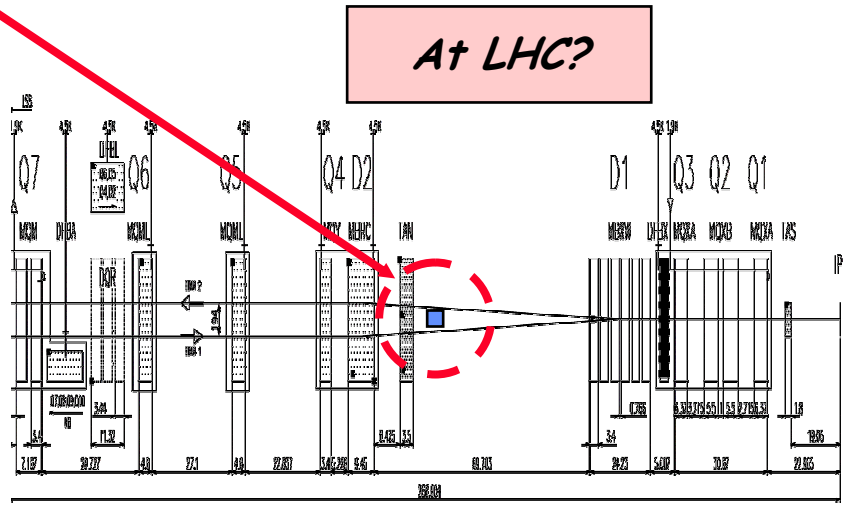
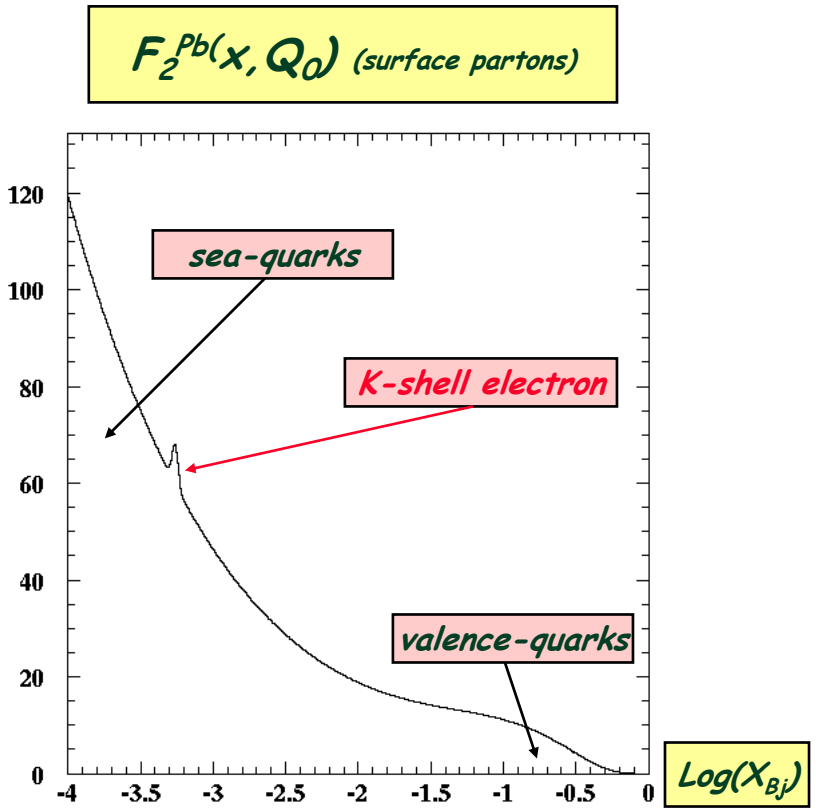


Figure 2: Data provided by the luminosity system during *ep* collisions at HERA. Statistical fluctuations correspond to one measurement every 10 s.



Cross-calibration of processes involving "colored" partons and "color-blind" partons (electrons)

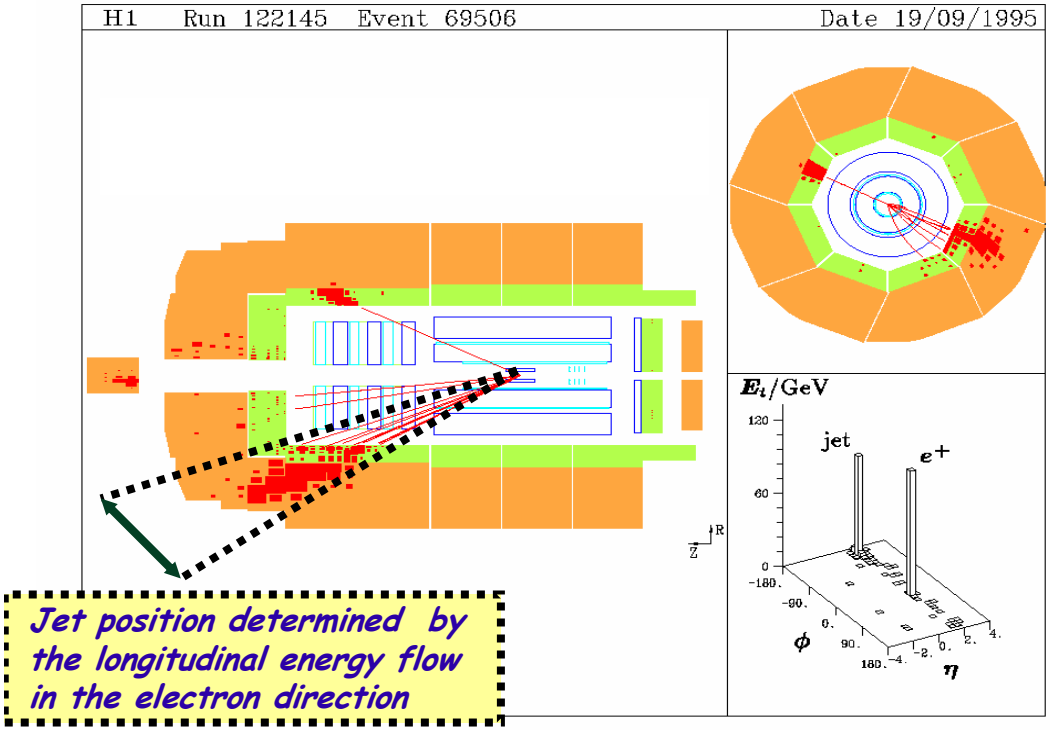


Example: *Longitudinal momentum structure of electrically-charged components of the* $Pb^{81+}(1s)$

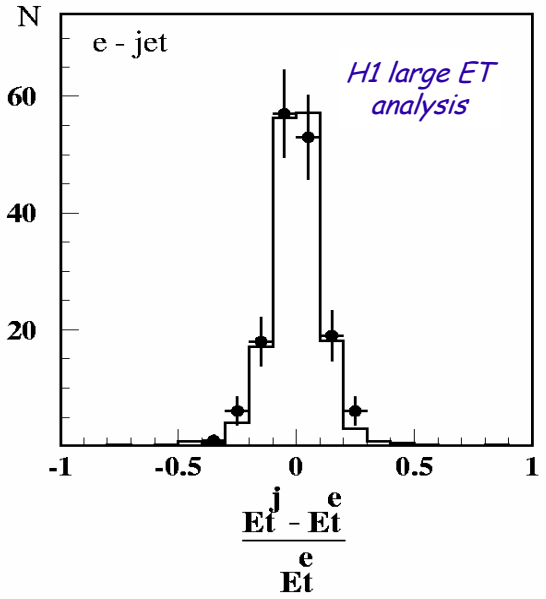
Examples

- Unfolding of the initial-state and the final-state partonic interactions at LHC (crossing t-channel and s-channel)
- Measuring the energy dependence of partonic emittances
- Model independent studies of jet shapes (electron recoil templates)
- Scrutinizing partonic collective effects (higher twists) at the LHC
- Precise detector calibration (e.g. direct model-independent jet calibration)

Complementarities of jet calibration using the e-jet and the Z-jet samples

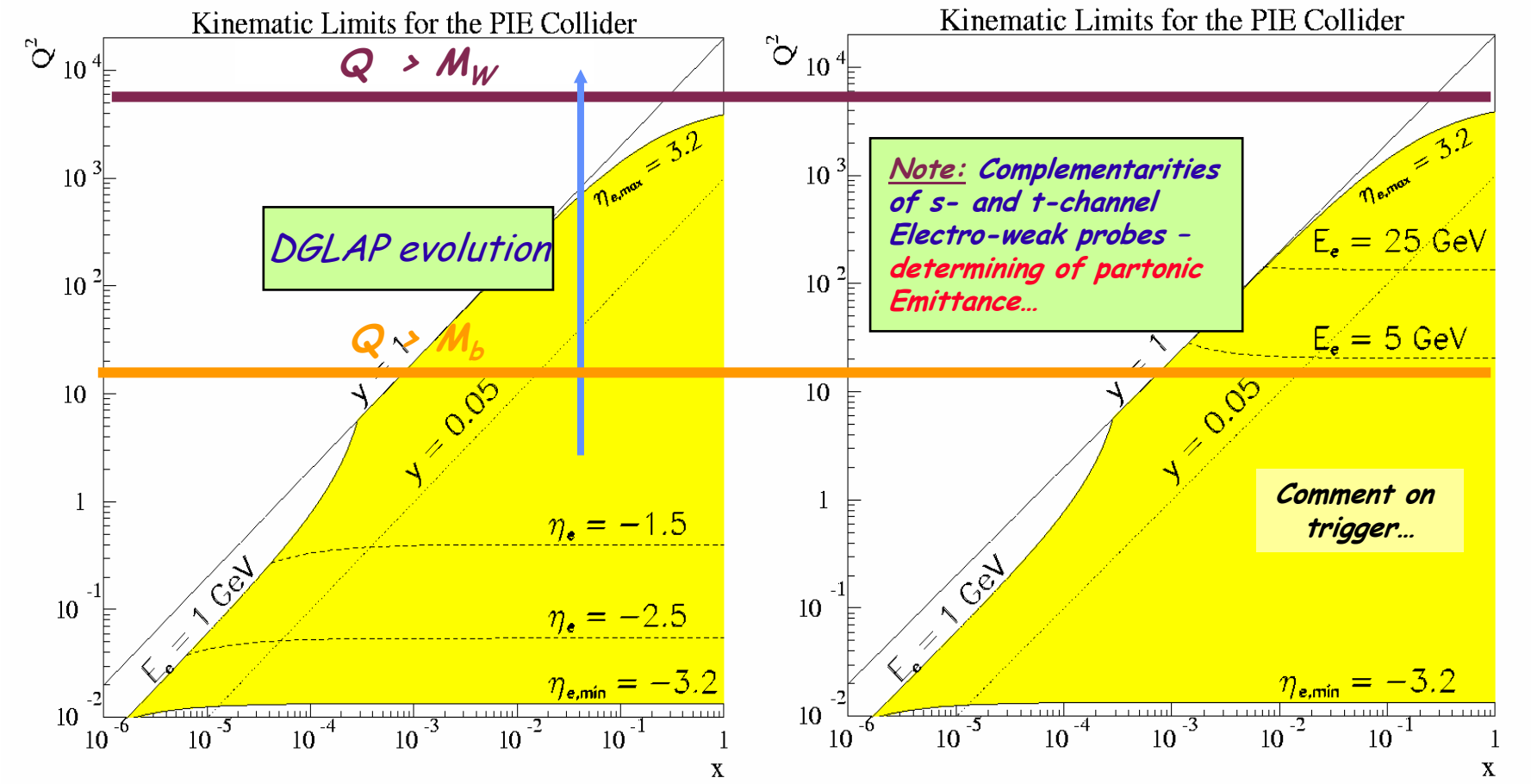


Jet position determined by the longitudinal energy flow in the electron direction



Over-constrained system:
In ep collisions one knows precisely where, in η, the recoil jet is produced (jet templates)

Kinematical domain of the WBPB diagnostic



Note: The ep luminosity used in the first measurement of the Structure Function F_2 at HERA for ($10<Q2<60$ GeV^2) - could be collected in 6 days of the Pb^{81+}-p collision runs at LHC

Ongoing work not discussed in this talk

- The gauge-model of the data selection and the data analysis for the LHC

- The tools for high precision absolute normalization of the LHC measurements