Particle Physics Perspective

Halina Abramowicz
Tel Aviv University

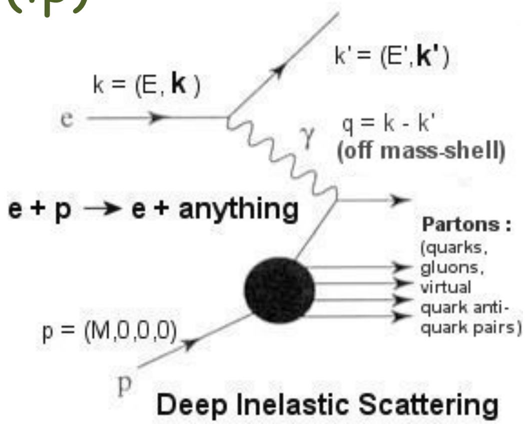
My assignment

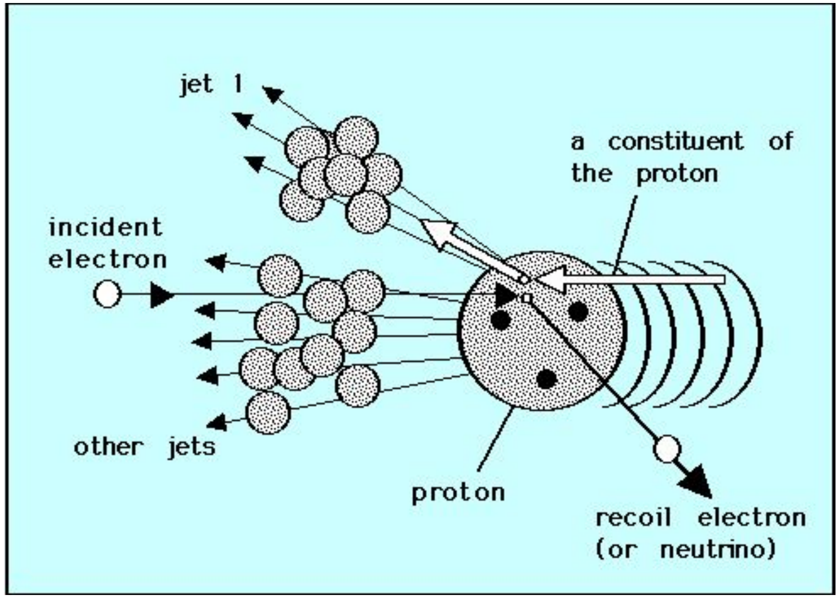
"This is meant to be a mixture of overall conference summary and your personal view on the future of high energy physics (and deep-inelastic scattering in particular)."

Best wishes,
Olaf Behnke (Chair of the Local Orga Team)
Stefan Schmitt

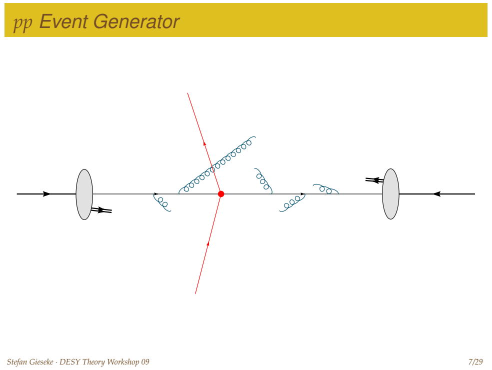
Particle Physics Perspective

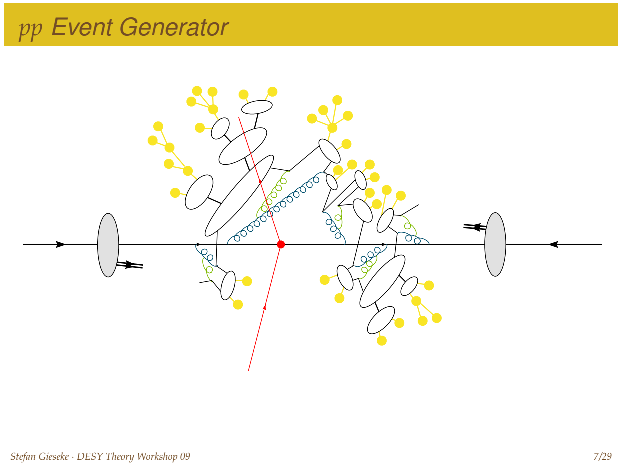
DIS (lp)

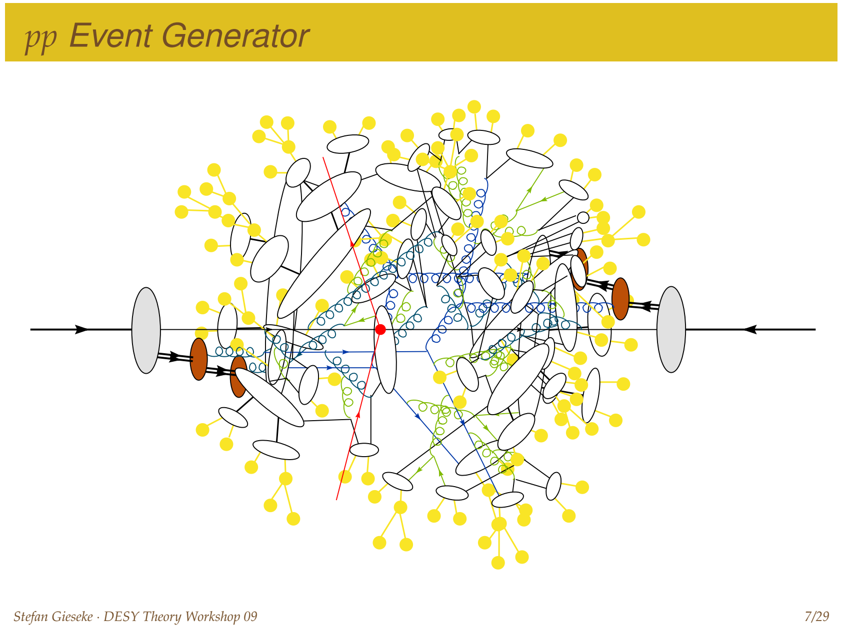




And related subjects (pp)







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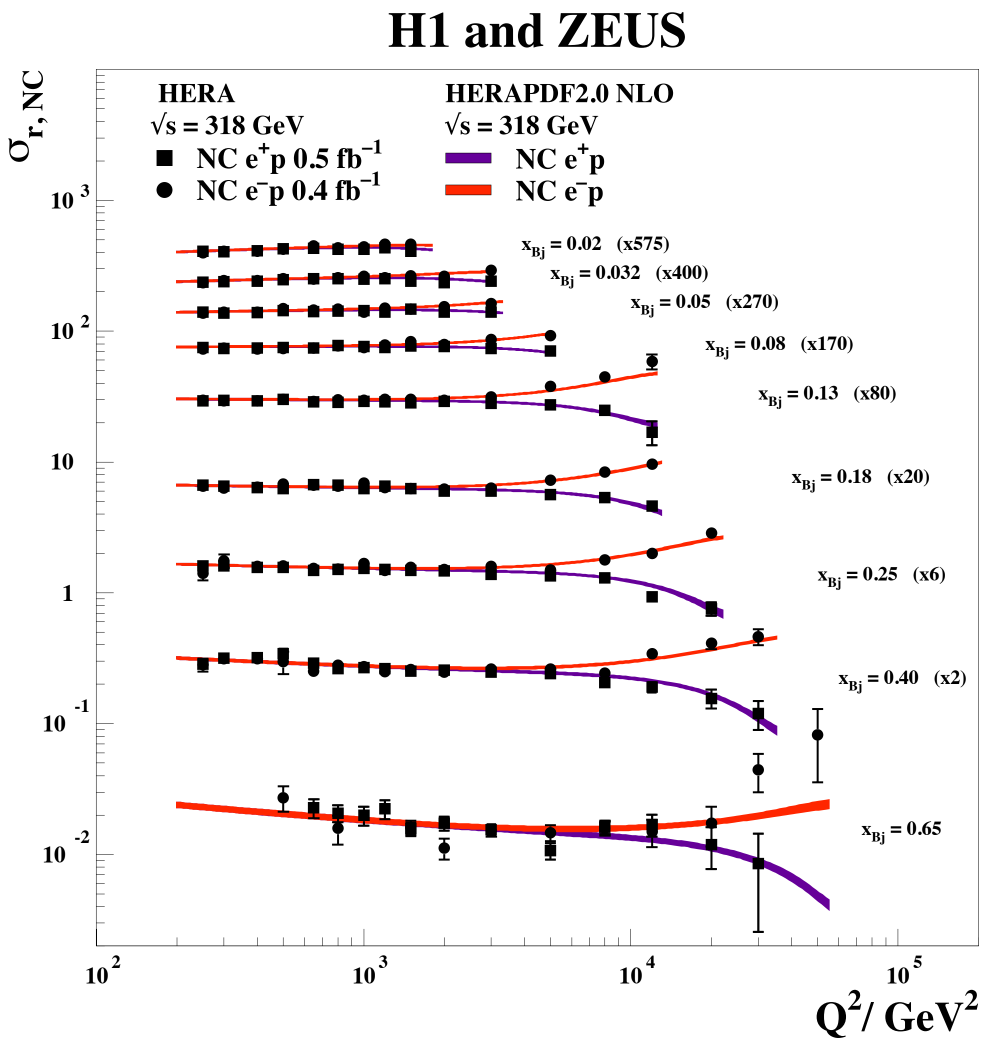
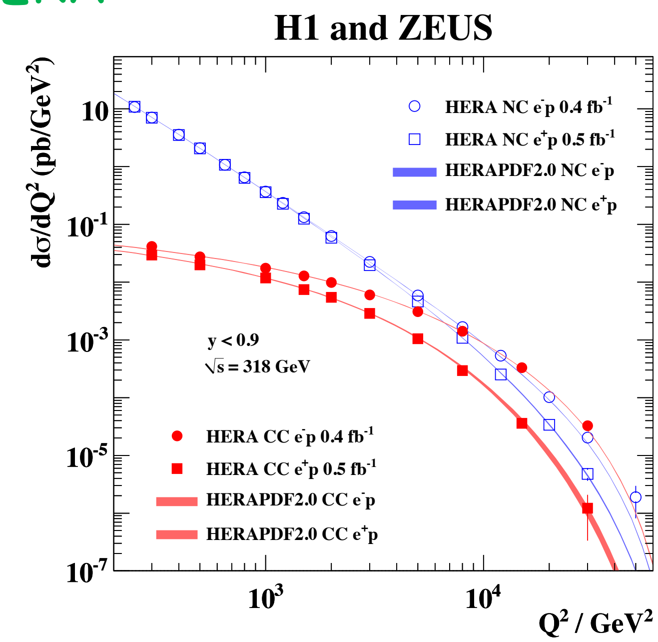
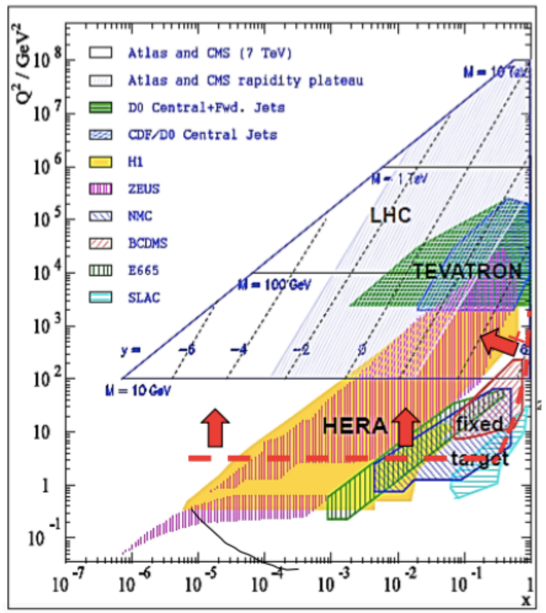
Legacy of HERA







from Paul Newman

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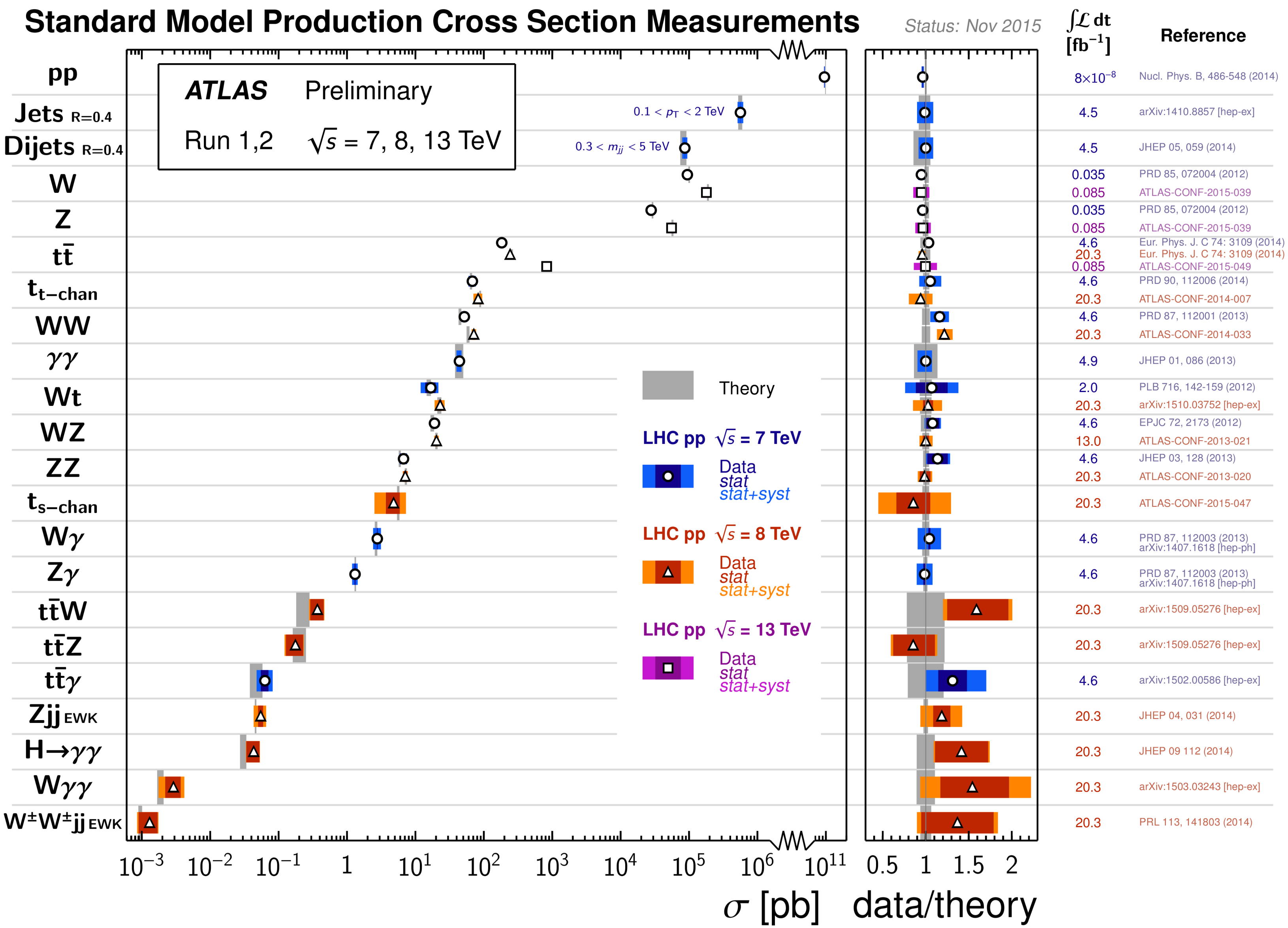
Legacy of LHC



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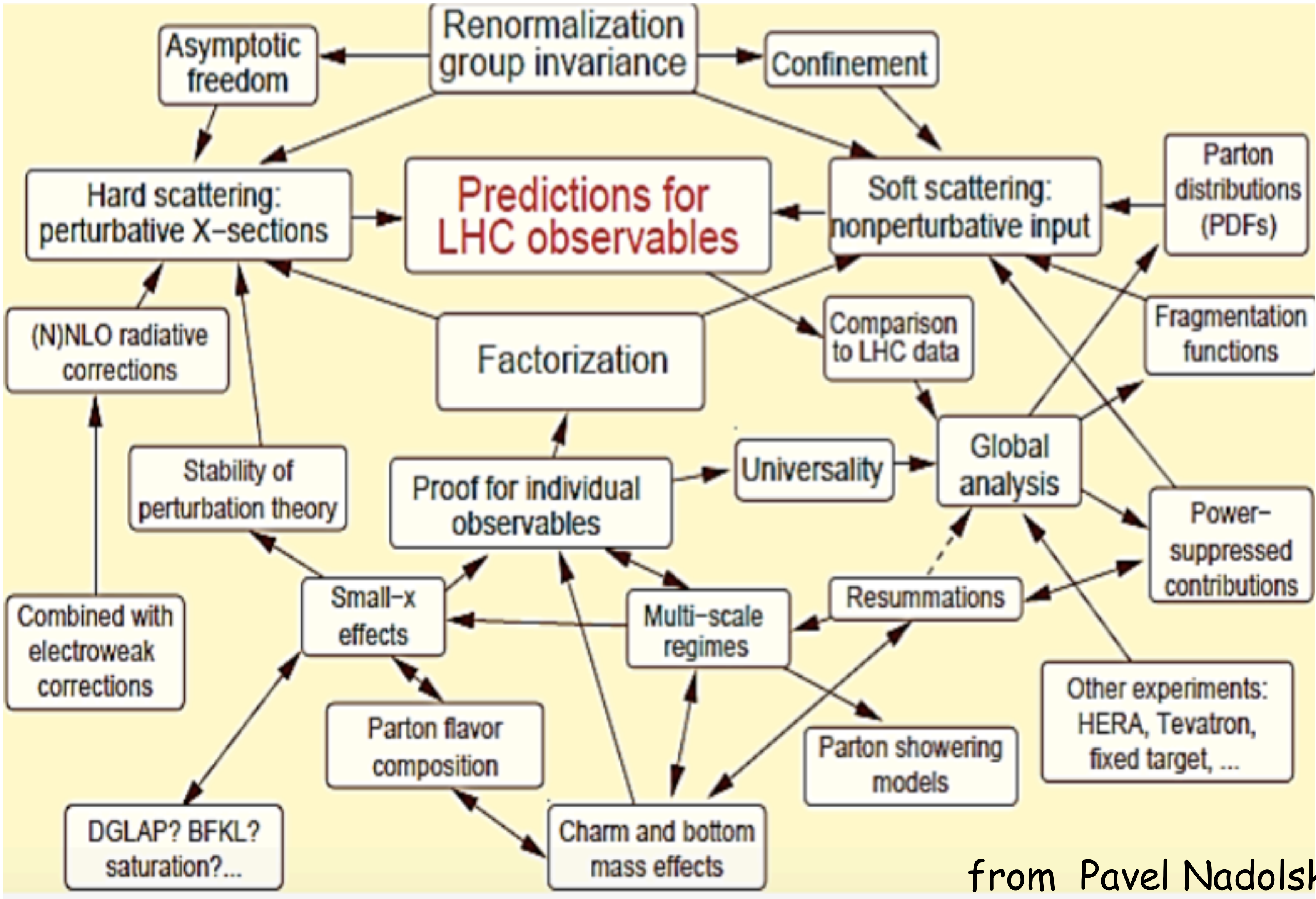
What it takes to get SM from LHC



from Pavel Nadolsky

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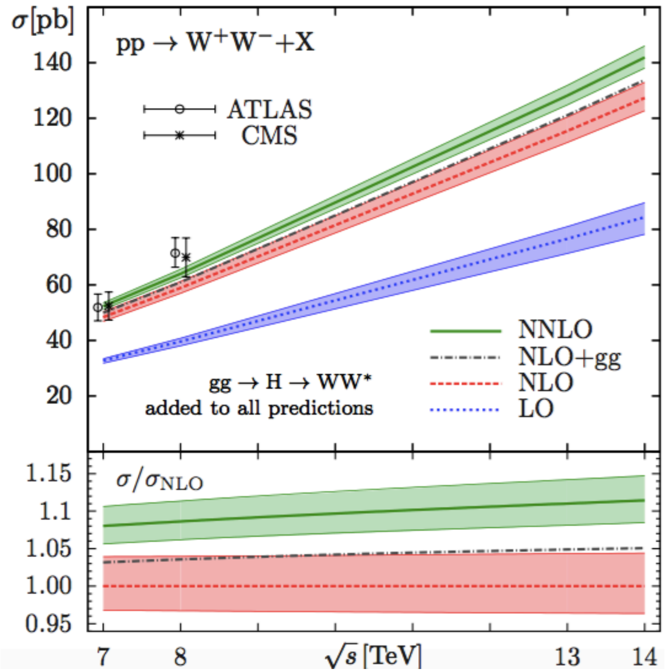
Theory4LHC from Thomas Gehrmann

Where do we stand?

- Witnessed an NLO revolution
- NLO and parton showers
- Substantial progress on NNLO calculations

Future Directions

- NLO+PS as new standard for event generation
- NNLO automation
- Beyond NNLO



Early LHC data - excess of W^+W^- over LO expectations

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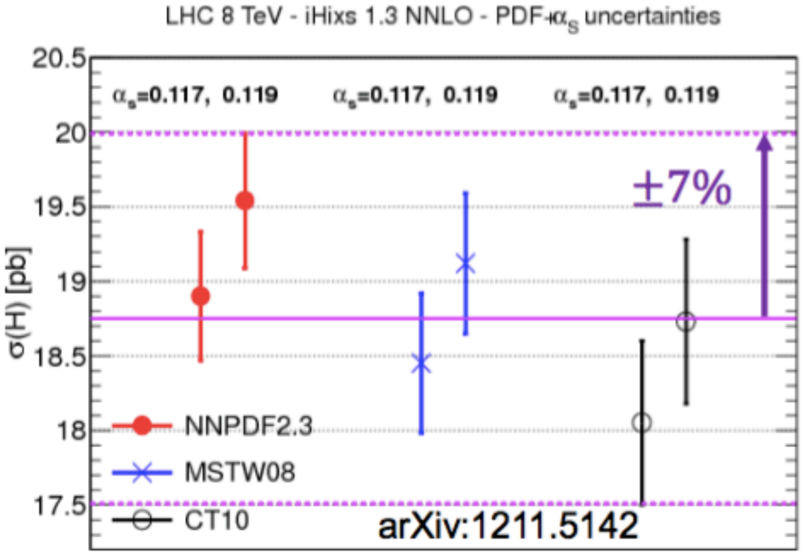
PDF uncertainties



	CT14	MMHT2014	NNPDF3.0
8 TeV	18.66 pb -2.2% +2.0%	18.65 pb -1.9% +1.4%	18.77 pb -1.8% +1.8%
13 TeV	42.68 pb -2.4% +2.0%	42.70 pb -1.8% +1.3%	42.97 pb -1.9% +1.9%

J.Huston, PDF4LHC, April 2015

Down from 7% to 3%

c) New (arXiv:1510.03865): using a combined PDFLHC15 set constructed from CT14, MMHT14, NNPDF3.0

- A statistical combination of 3 sets
- Reproduces the total uncertainty with only 30-100 error sets
- Eliminates redundant comparisons of 3 global sets
- can be used in many (not all) cases

from Pavel Nadolsky

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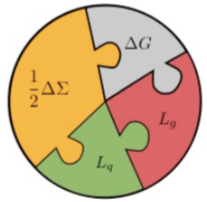
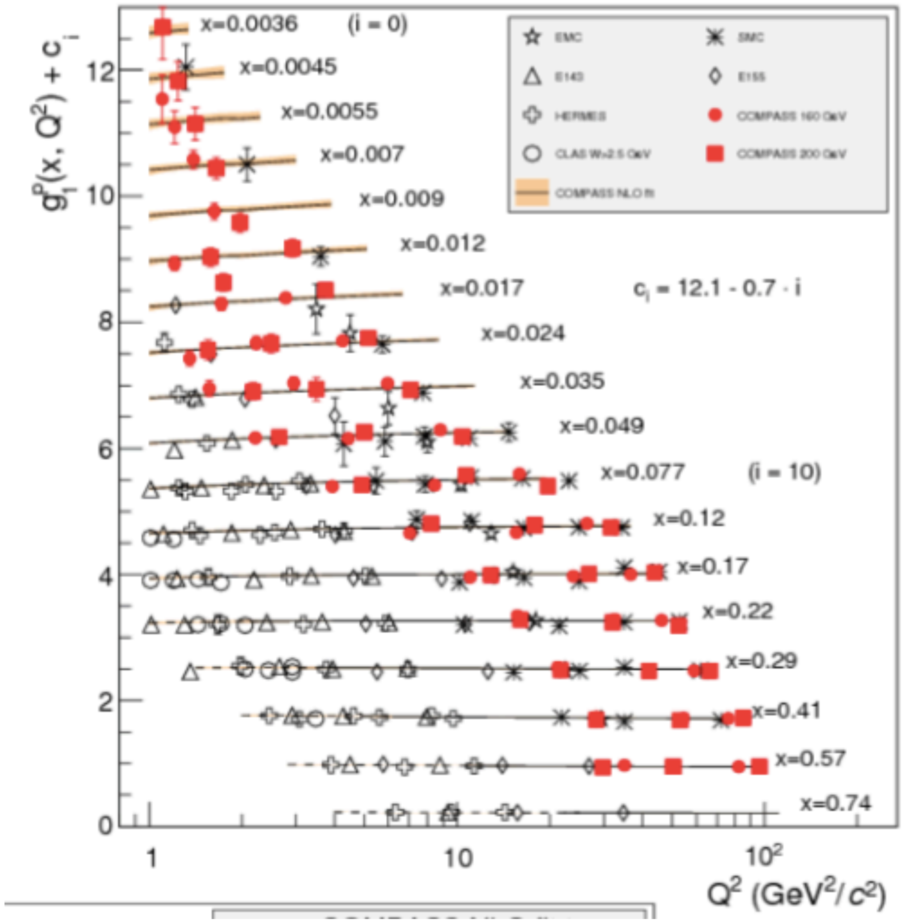
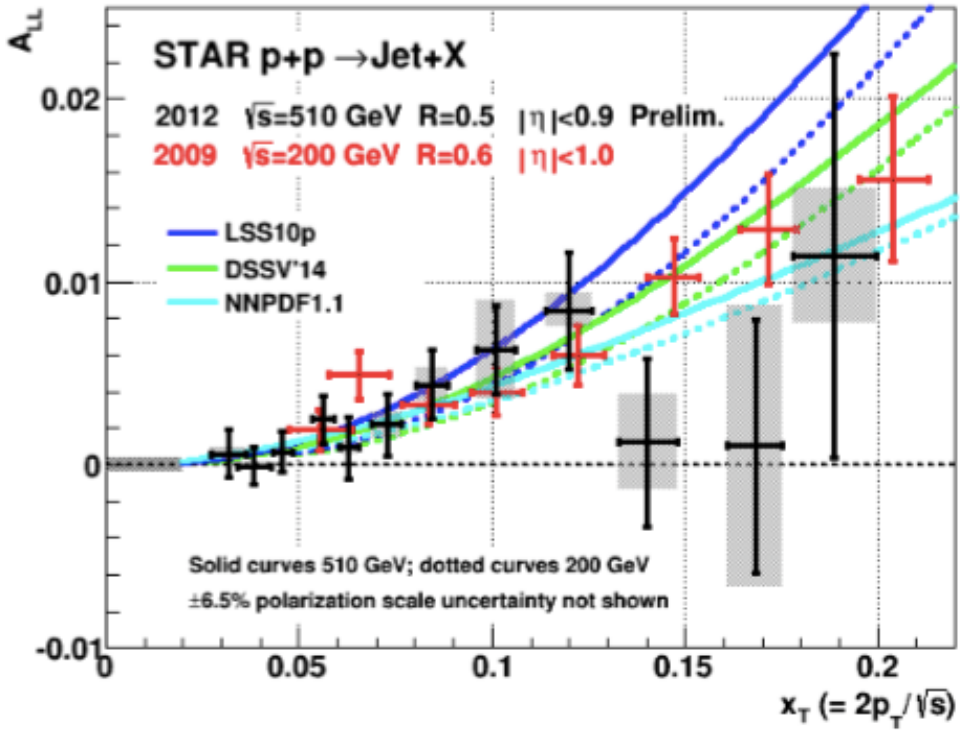
Spin







Progress towards understanding the 3-dim. picture of the nucleon from exclusive processes (from Ralf Seidel)

Glossary of future colliders

- Hadron machines

HE – LHC, pp 28 TeV
FCC – pp 100 TeV, 80 to 100 km tunnel, 16 to 20 T magnets
SppC – pp 50 to 100 TeV, 50 km tunnel…. (China)
SSC – pp 100 to 300 TeV, 270 km tunnel, 5 T to 15 T magnets

- Electron-positron machines

ILC –linear collider, 500 GeV baseline (expandable to 1 TeV)
CLIC – linear collider, 380 GeV to 3 TeV
FCC ee – circular collider, 240 to 350 GeV
CEPC – circular collider, 240 GeV
SSC – resurrected 87 km tunnel for circular Higgs factory

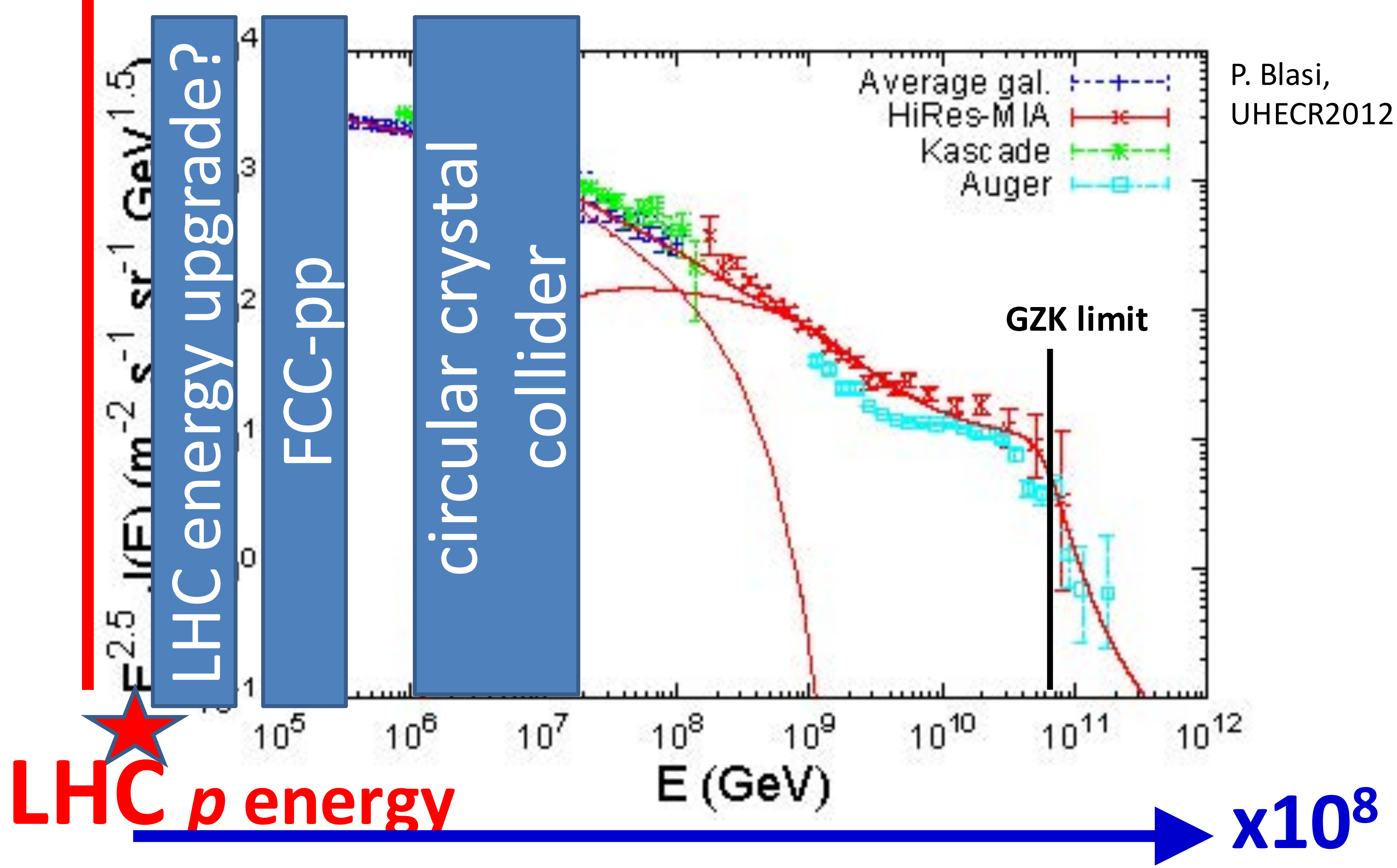
- Muon collider – Higgs factory and energy frontier

Circular collider – 120 GeV (expandable to 5 TeV), 300 m long

- γγ colliders, ep colliders (derivatives of ee and pp colliders)
- Plasma wake field accelerators (laser or beam driven)

10^{45} m^{-2}s^{-1}sr^{-1}GeV$^{1.5}$!

cosmic-ray energy spectrum



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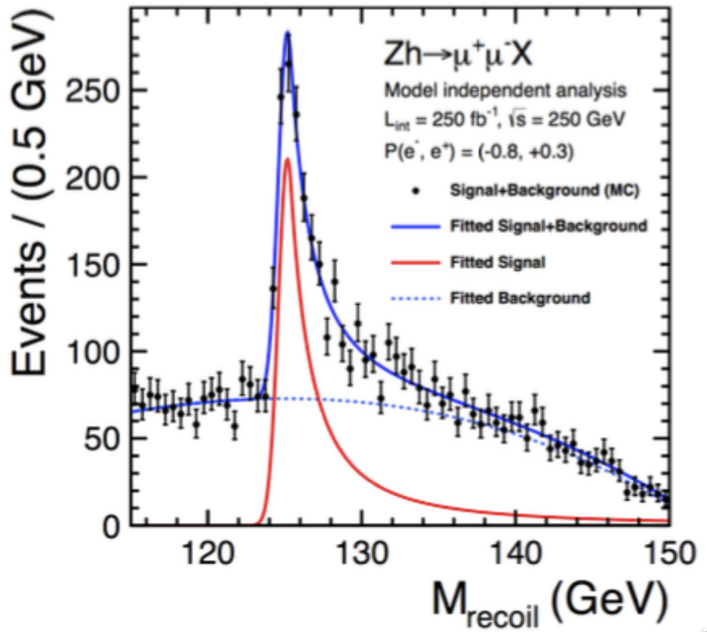
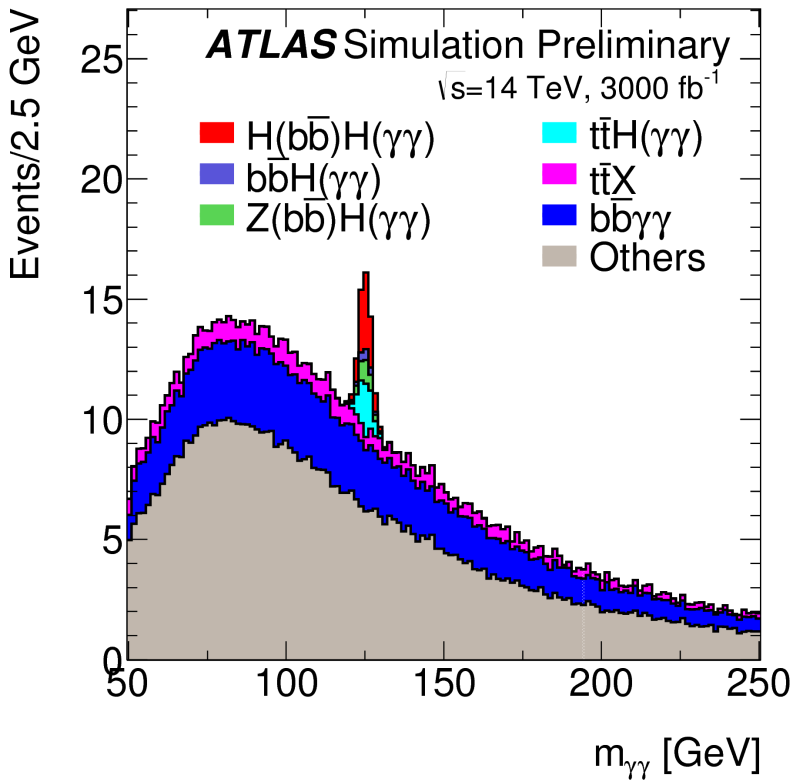
Choice of experiments for precision Higgs physics

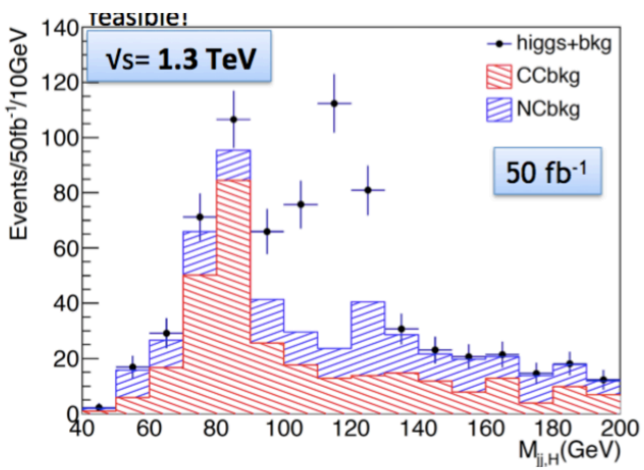
ILC



HL-LHC



LHeC



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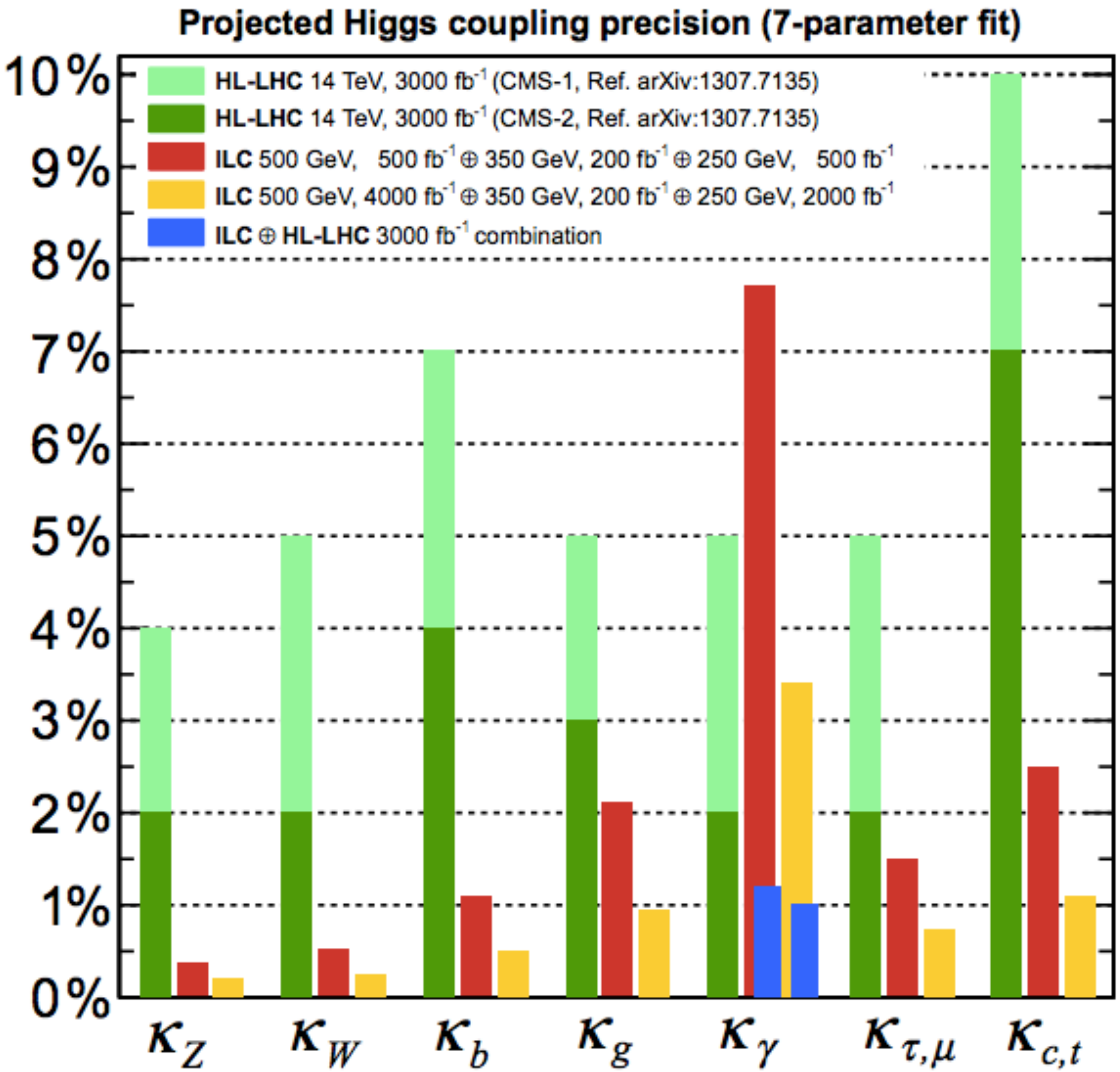

ILC below 1%, except $\gamma\gamma$
LHC 2% to 3% except *bb cc tt*

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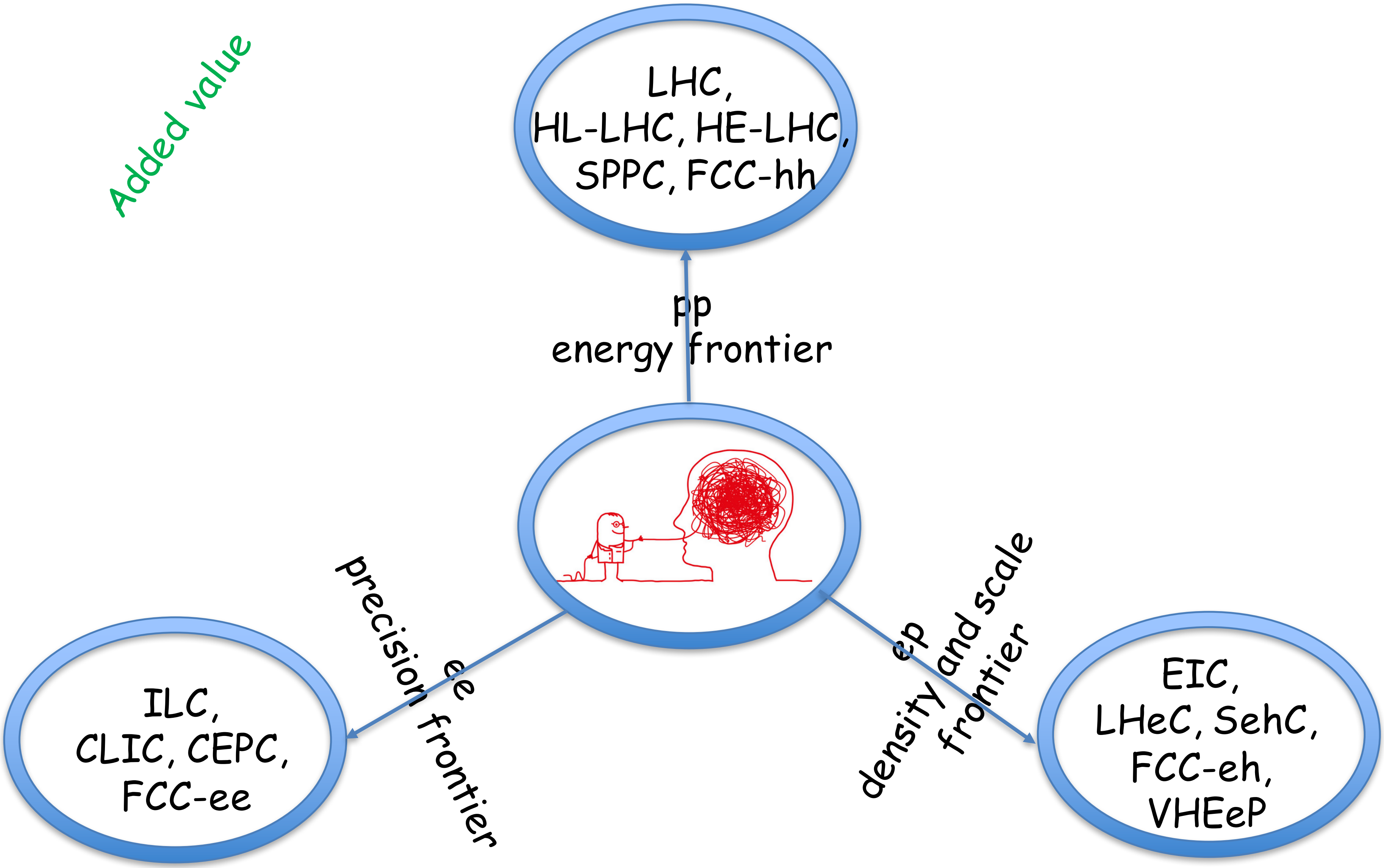

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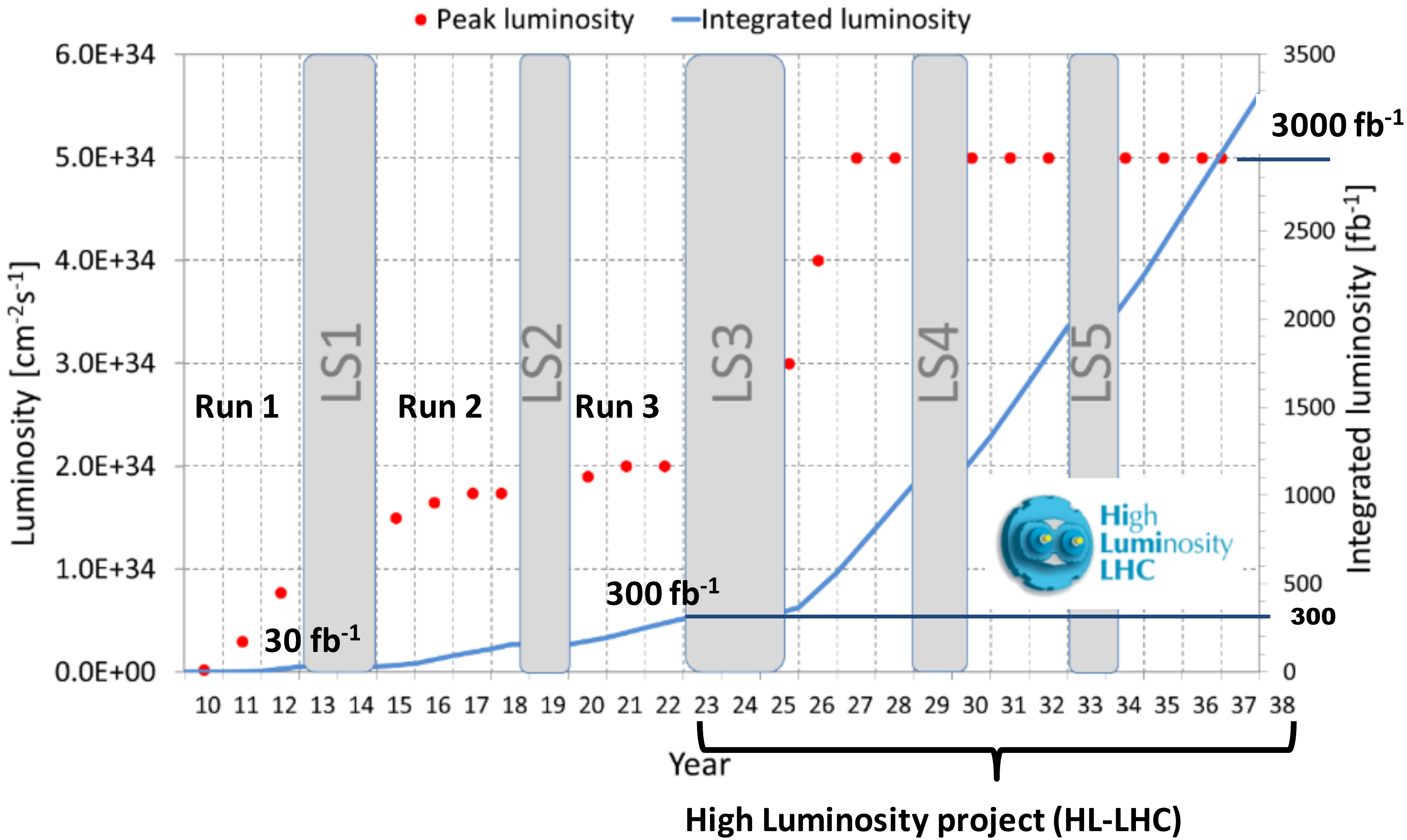
Choice driven by cost, consensus and … globalization

NATURE|COMMENT - Particle physics: Together to the next frontier
Nigel Lockyer

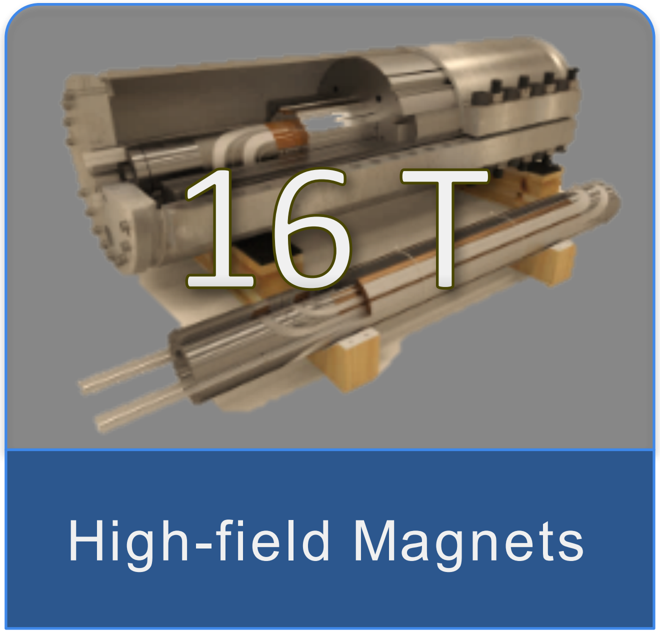
SCOTT GARRETT

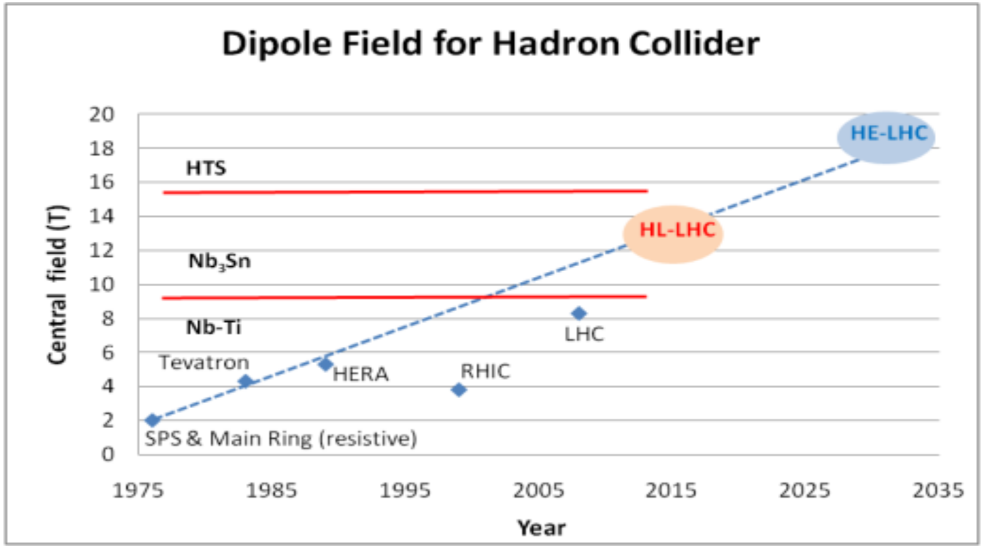
LHC roadmap: **Goal of 3’000 fb^{-1}** by mid 2030ies



LHC timeline

Magnets: Key Enabler





HE-LHC a distinct possibility

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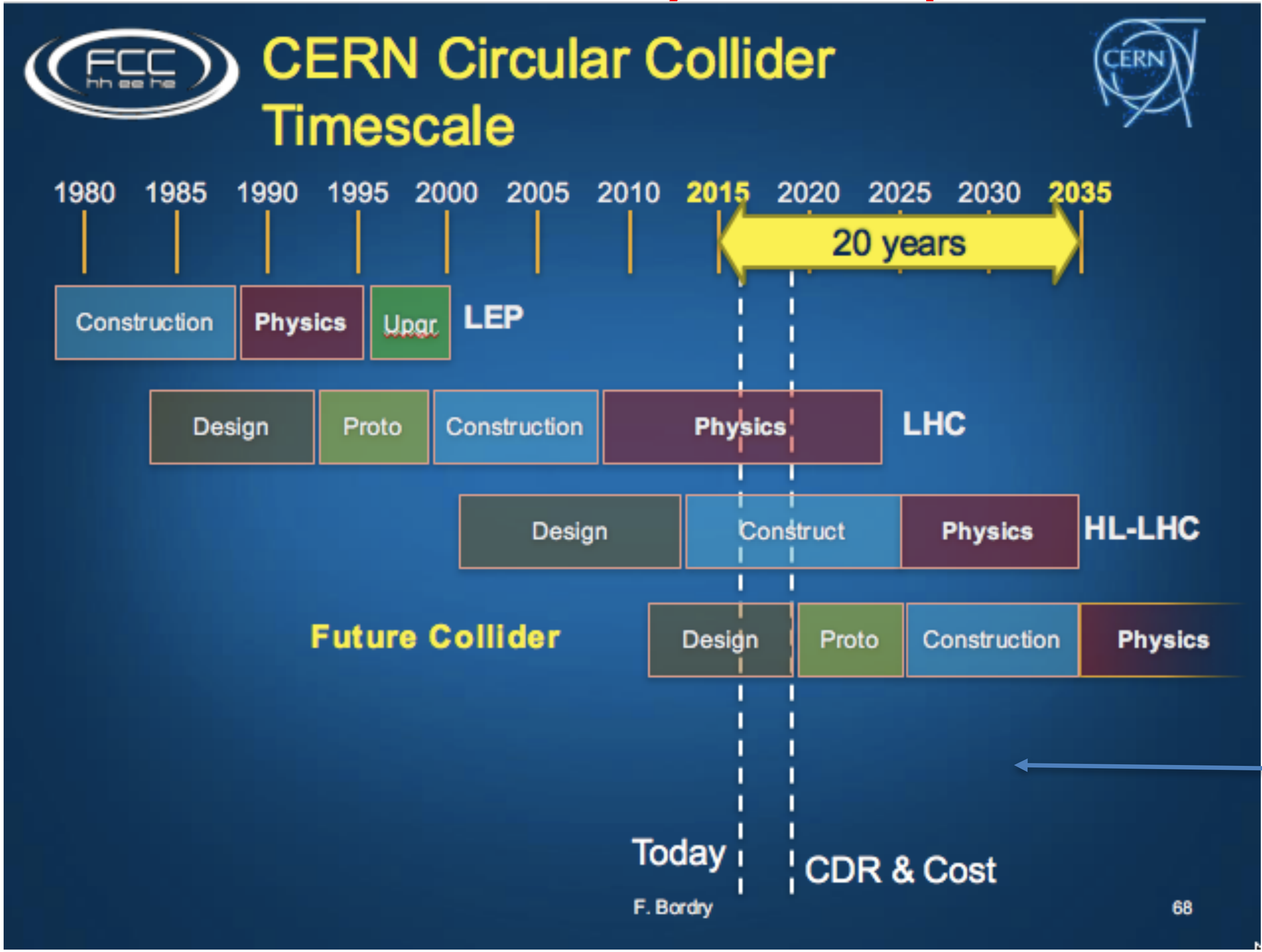

ILC Physics ???

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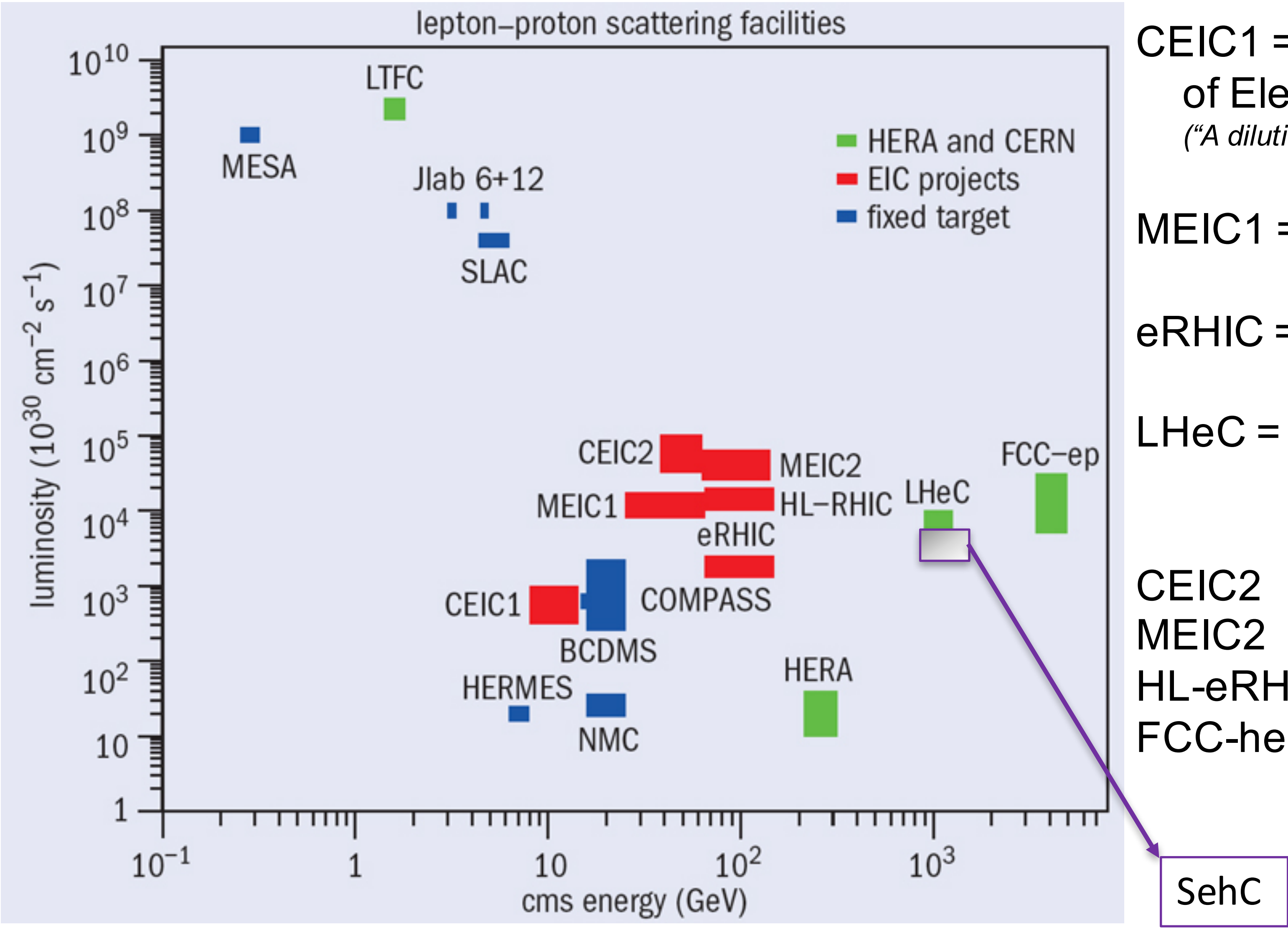


CEIC1 = Chinese version of Electron-Ion Collider
("A dilution-free mini-COMPASS")

MEIC1 = EIC@Jlab

eRHIC = EIC@BNL

LHeC = ep/eA collider @ CERN

CEIC2
MEIC2
HL-eRHIC
FCC-he

Electron Ion Colliders

Past

Possible Future

Europe — US (EIC) — China (CEIC) — Europe

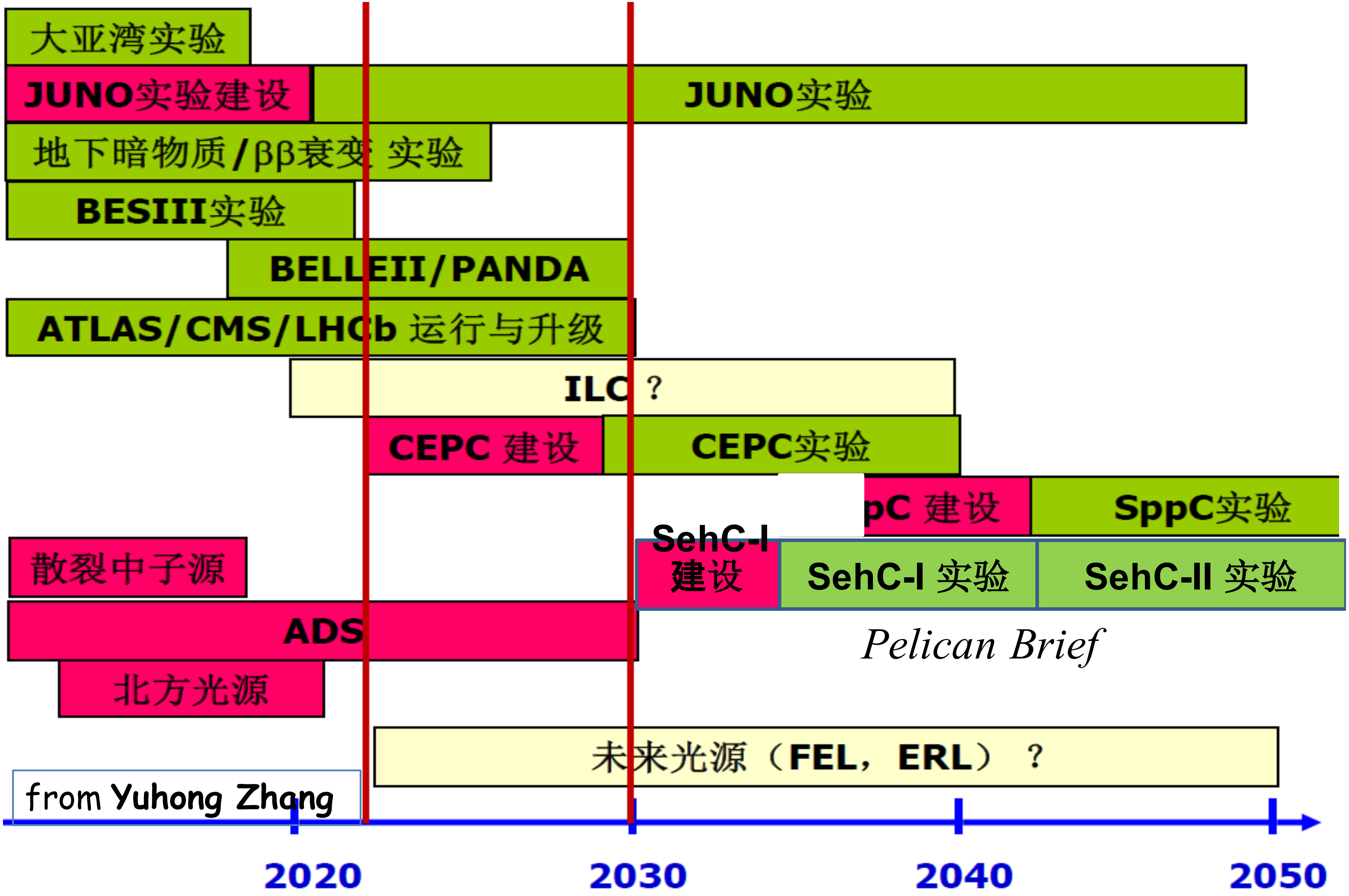
	HERA@DESY	LHeC@CERN	eRHIC@BNL	MEIC@JLab	HIAF@CAS	ENC@GSI
E_{CM} (GeV)	320	800-1300	70-150	12-70 → 140	12 → 65	14
proton x_{min}	1×10^{-5}	5×10^{-7}	4×10^{-5}	5×10^{-5}	$7 \times 10^{-3} \rightarrow 3 \times 10^{-4}$	5×10^{-3}
ion	p	p to Pb	p to U	p to Pb	p to U	p to ~^{40}Ca
polarization	-	-	p, ^{3}He	p, d, ^{3}He (^{6}Li)	p, d, ^{3}He	p,d
L [$cm^{-2} s^{-1}$]	2×10^{31}	$10^{33\text{-}34}$	$10^{33} \rightarrow 10^{34}$	$10^{34\text{-}35}$	$10^{32\text{-}33} \rightarrow 10^{35}$	10^{32}
IP	2	1	2+	2+	1	1
Year	1992-2007	2025	2025	Post-12 GeV	2019 → 2030	upgrade to FAIR
		Followed by FCC-he?		Figure-8	Figure-8	Dormant

High-Energy Physics

Hadron Physics

Note: x_{min} ~ x @ Q^2 = 1 GeV^2

Timeline and Envision of *SehC* Staging



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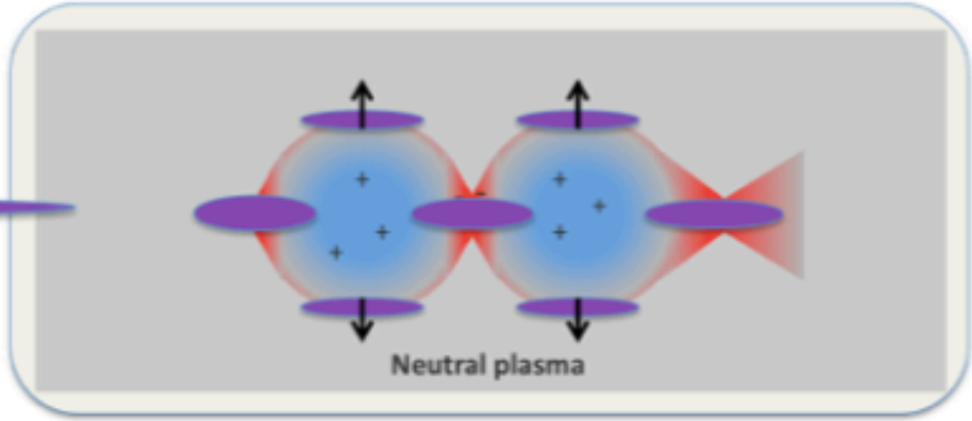
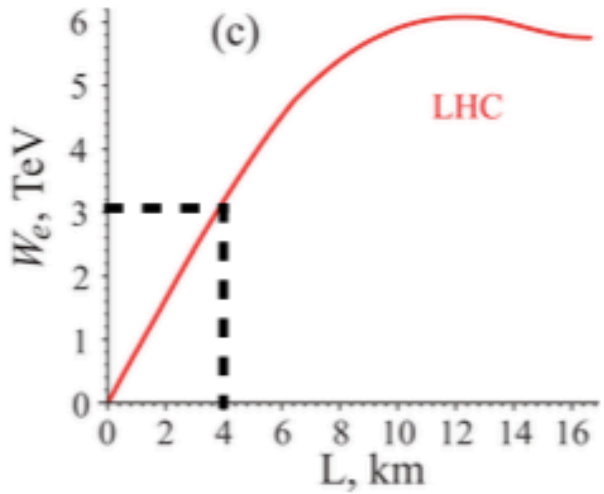
VHEep project by Matthew Wing

Plasma wakefield accelerator (AWAKE scheme)



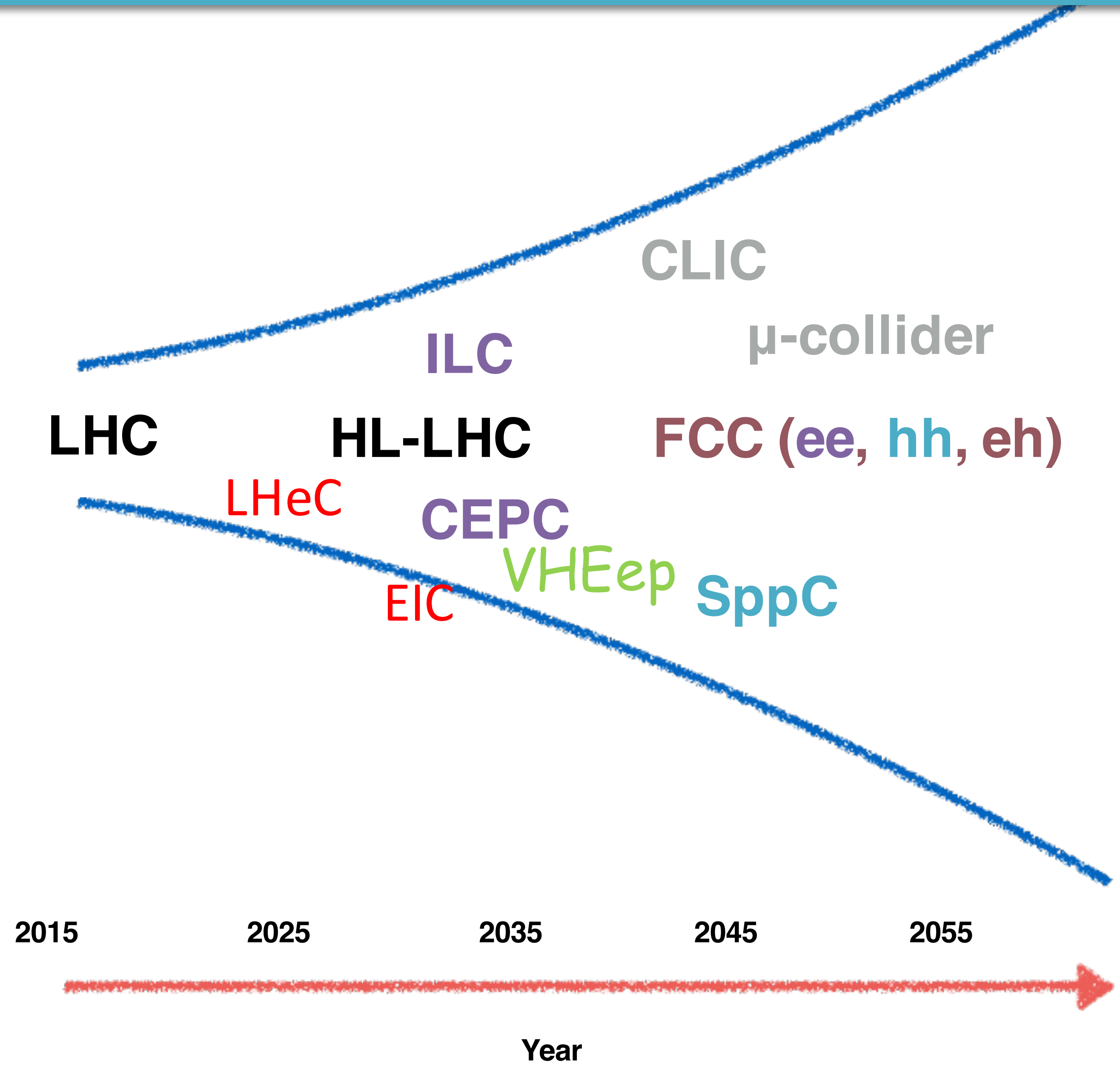
Self-modulated driver beam

- Long beam modulated into micro-bunches which constructively reinforce to give large wakefields.
- Self-modulation instability allows **current beams to be used**, as in AWAKE experiment at CERN.
- With high accelerating gradients, can have
  - Shorter colliders for same energy
  - Higher energy
- Using the LHC beam can accelerate electrons up to *6 TeV* over a reasonable distance.
- We choose $E_e = 3$ *TeV* as a baseline for a new collider with $E_P = 7$ *TeV* ⇒ $\sqrt{s}$ **= 9 *TeV***.
  - Centre of mass energy ×30 higher than HERA.



A. Caldwell & K. Lotov, Phys. Plasmas **18** (2011) 103101

Colliders of the 21st Century



KLUTE

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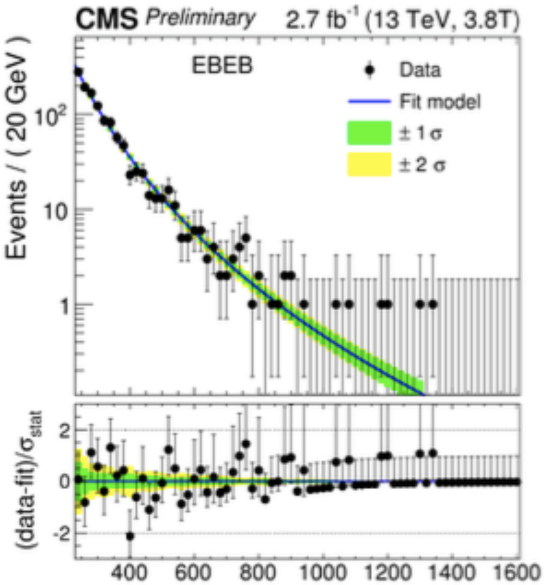
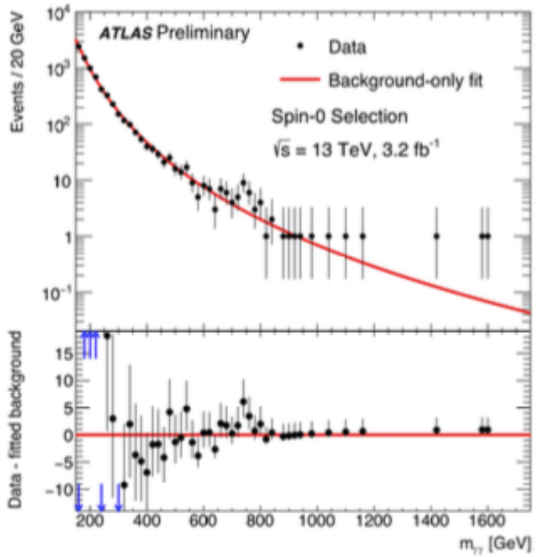
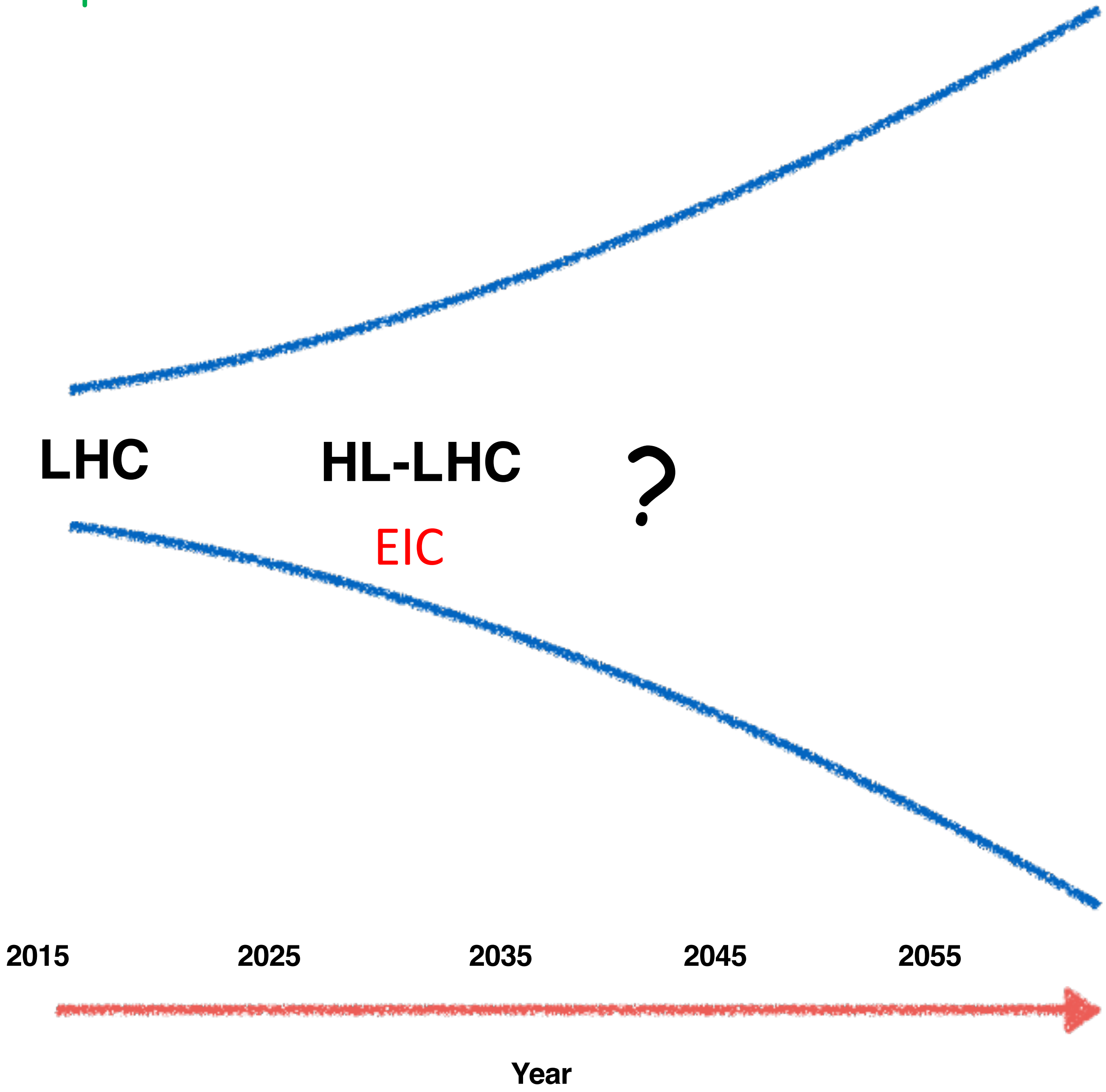
Markus's map if 750 GeV feature confirmed







European Strategy – next update ≥ 2019

- 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. (HL-LHC)

- CERN should undertake design studies for accelerator projects in a global context, with emphasis on proton-proton and electron- positron high-energy frontier machines. These design studies should be coupled to a vigorous accelerator R&D programme (CLIC, FCC hh,ee,ep … AWAKE)

- There is a strong scientific case for an electron-positron collider… The Technical Design Report of the International Linear Collider (ILC) has been completed, with large European participation... Europe looks forward to a proposal from Japan to discuss a possible participation. (Waiting for Japanese Gov. decision)

- 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. (LBNF in FNAL – DUNE in S. Dakota)

Particle Physics Perspective

ep in CERN agenda

International Advisory Committee + Mandate

Guido Altarelli (Rome)
Sergio Bertolucci (CERN)
Nichola Bianchi (Frascati)
Frederick Bordry (CERN)
Stan Brodsky (SLAC)
Hesheng Chen (IHEP Beijing)
Andrew Hutton (Jefferson Lab)
Young-Kee Kim (Chicago)
Victor A Matveev (JINR Dubna)
Shin-Ichi Kurokawa (Tsukuba)
Leandro Nisati (Rome)
Leonid Rivkin (Lausanne)
Herwig Schopper (CERN) – **Chair**
Jurgen Schukraft (CERN)
Achille Stocchi (LAL Orsay)
John Womersley (STFC)

IAC Composition June 2014, plus
Oliver Brüning Max Klein ex officio

Max Klein ICFA Beijing 10/2014

The IAC was invited in 12/13 by the DG with the following

Mandate 2014-2017

Advice to the LHeC Coordination Group and the CERN directorate by following the development of options of an ep/eA collider at the LHC and at FCC, especially with:

Provision of scientific and technical direction for the physics potential of the ep/eA collider, both at LHC and at FCC, as a function of the machine parameters and of a realistic detector design, as well as for the design and possible approval of an ERL test facility at CERN.

Assistance in building the international case for the accelerator and detector developments as well as guidance to the resource, infrastructure and science policy aspects of the ep/eA collider.

Summary

The below represents my private view on the future of DIS

Given

- the number and size of projects, the existing commitements and the global nature of decision making,

- the timeline of the various projects,

- the unique potential of DIS in exploring the structure of the proton (large x) and QCD dynamics at high density (low x),

- given the "interdisciplinary nature" of ep/eA scattering (between particle physics and nuclear physics = hadronic physics)

EIC looks like the most realistic project for the "near" future