Conferência Nacional de CT&I

Futuros Aceleradores

Patricia Rebello Teles

15/04/2024

CBPF

CERN

FUTURE CIRCULAR COLLIDER

FCC hh ee he

CEPC

SppC

ILC

LHeC

SehC

HiLumi HL-LHC PROJECT

RENAFAE

FAPERJ Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro

International MUON Collider Collaboration

CLIC

Linha do tempo das descobertas das partículas fundamentais do Modelo Padrão

FERMIONS

e^- μ^- ν_e ν_μ u d s c τ^- b t ν_τ

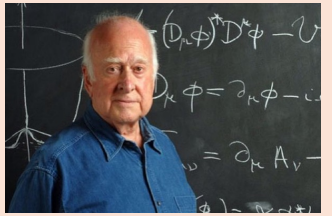
... 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 ...

Aceleradores

BOSONS

γ g $W^\pm, Z$

In memorian (2024)

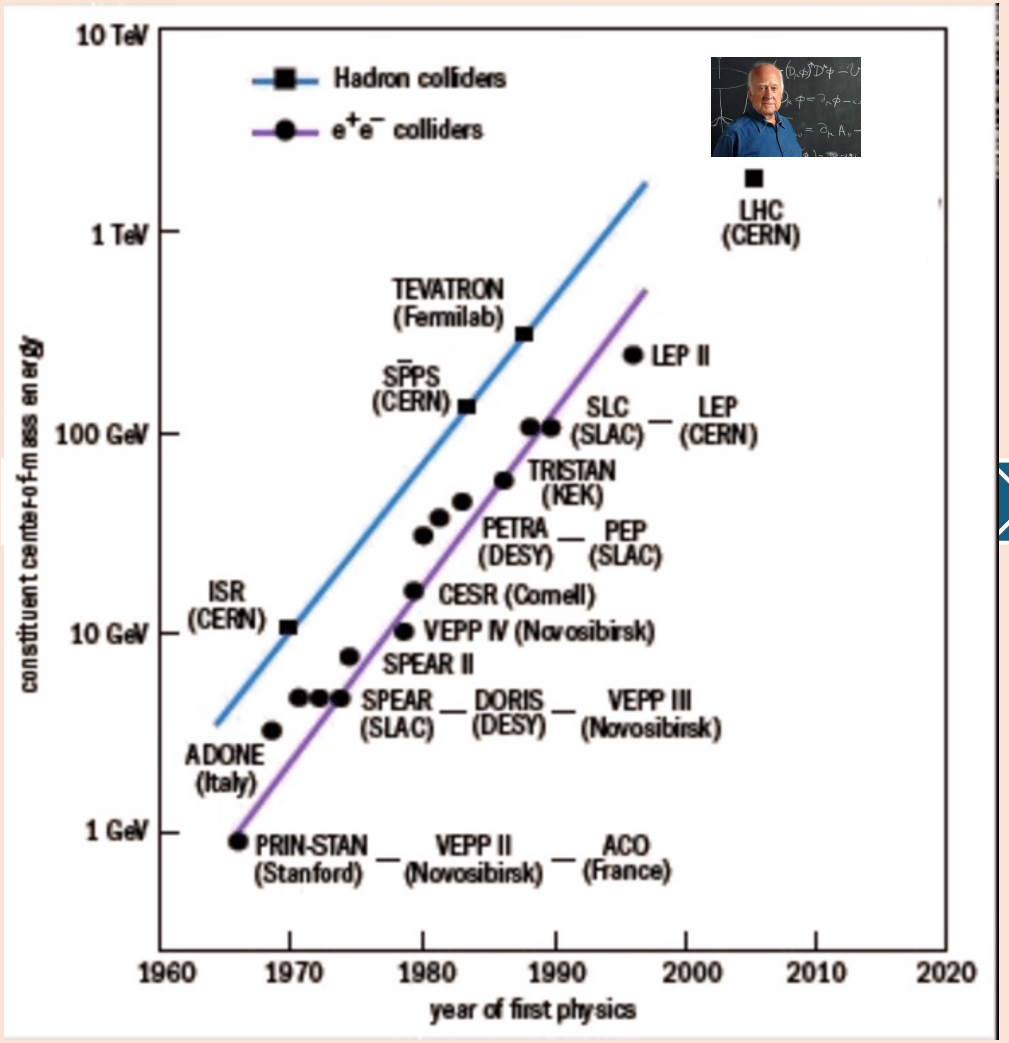


Continua sob intenso excrutínio experimental

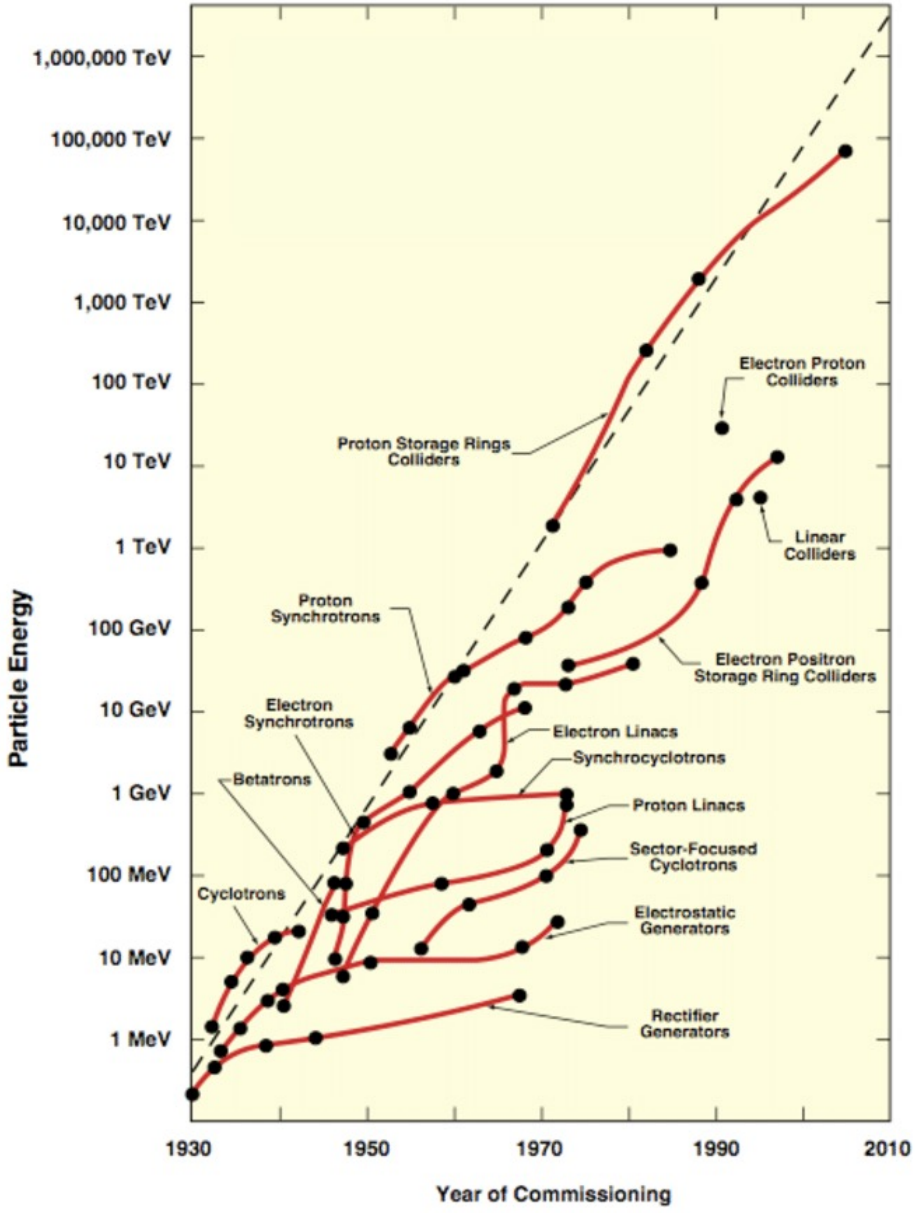
Linha do tempo das descobertas das partículas fundamentais do Modelo Padrão

FERMIONS

BOSONS



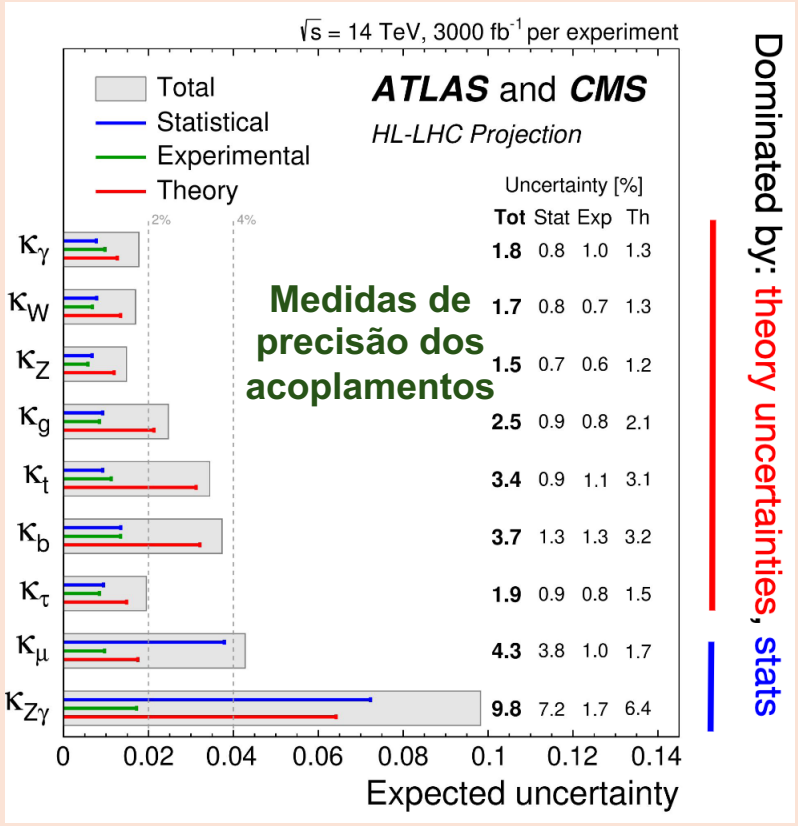
Livingston plots



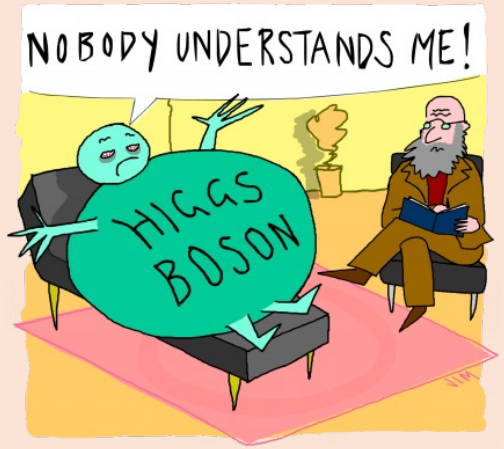
...

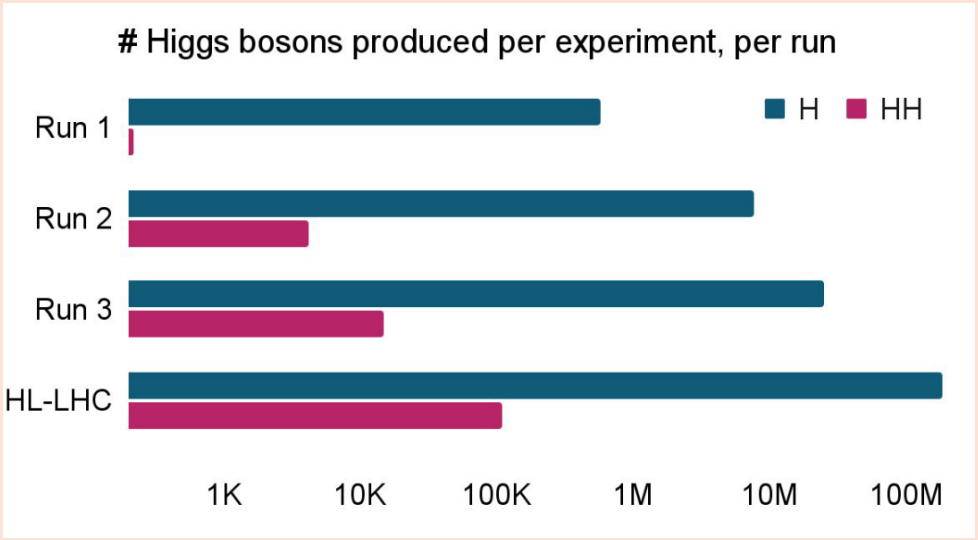
Investimento e Desenvolvimento de Tecnologia

Após 12 anos da observação do Higgs precisamos medir suas propriedades com precisão: massa, acoplamentos, auto-interação



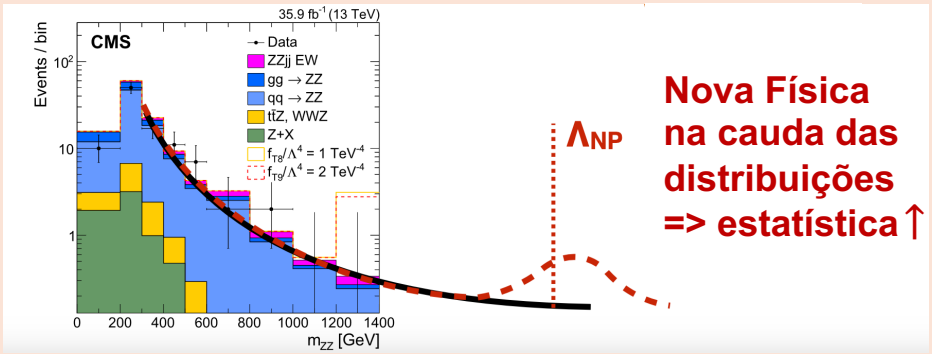
↑ $\sqrt{s}$ & L_{int} ⇒ ↑ Higgs produzidos





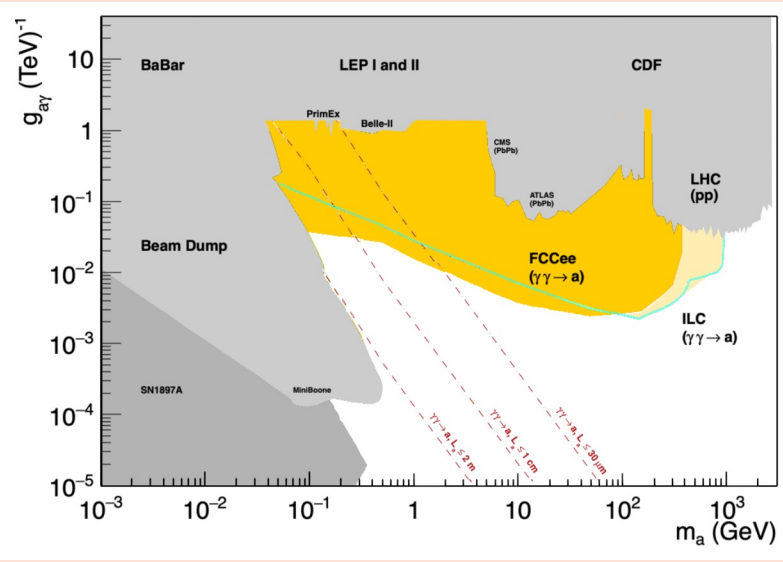
MP teoria efetiva => nova física esperada (↑ $\sqrt{s}$ => ↑ M_X e ↑ L_{int} => ↓ acop.); no NP escalas 1 - 3 TeV

Incertezas sistemáticas (medidas de precisão) => ↑ estatística



Nova Física na cauda das distribuições => estatística ↑

<u>Questões em aberto</u>: DM, hierarquia das massas e GUT, massa dos neutrinos, assimetria matéria–antimatéria (estudo violação CP – B factories, …),

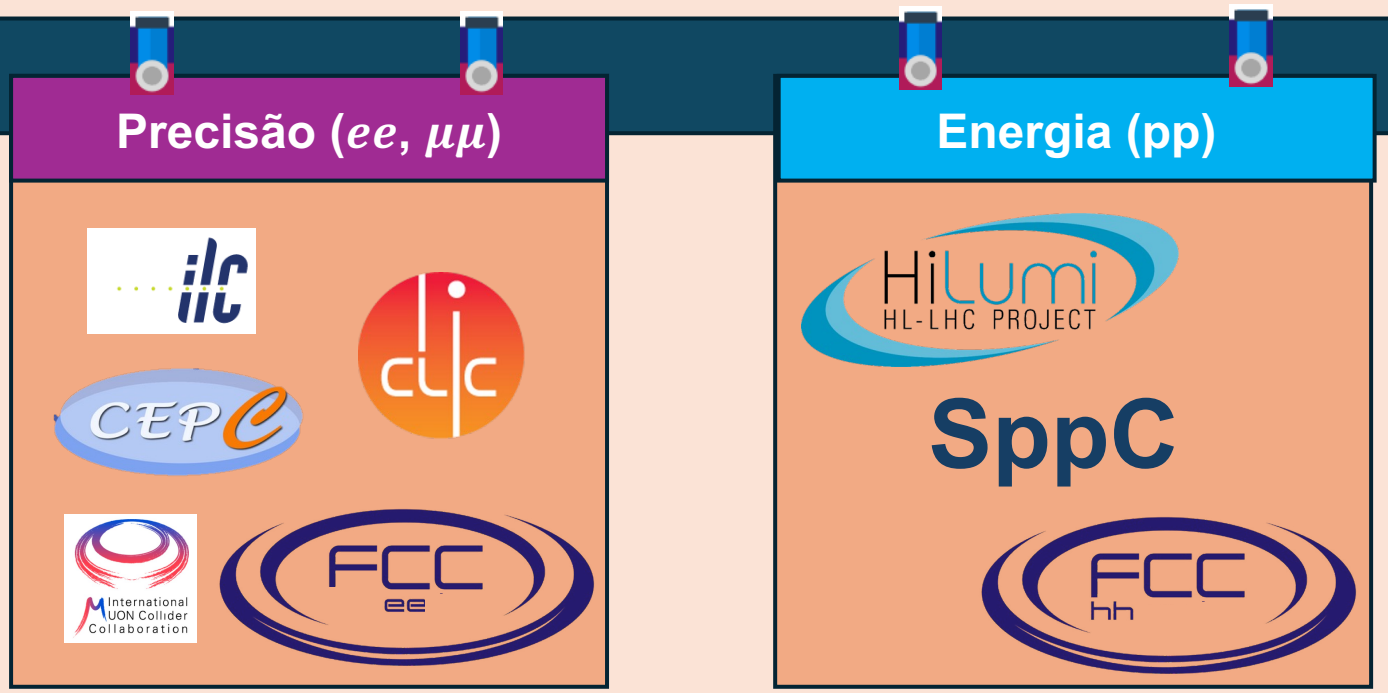


P.R. Teles et al. PRD 109 (2024) 5 . **Incluído no FCC MidTerm Report.**

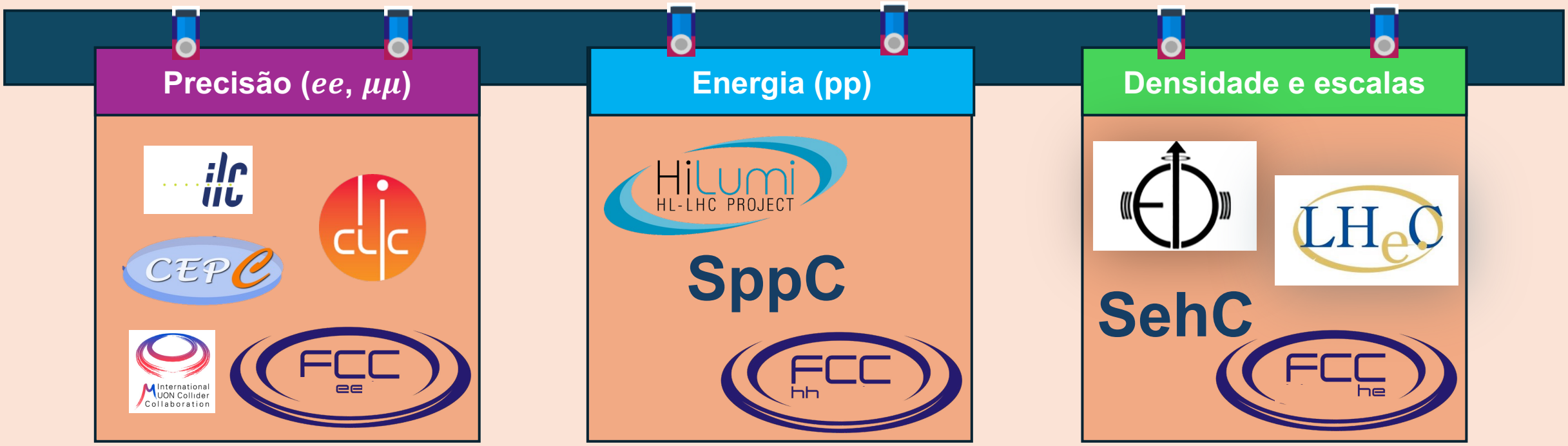
O que esperar dos futuros aceleradores?

Precisão (ee, $\mu\mu$)

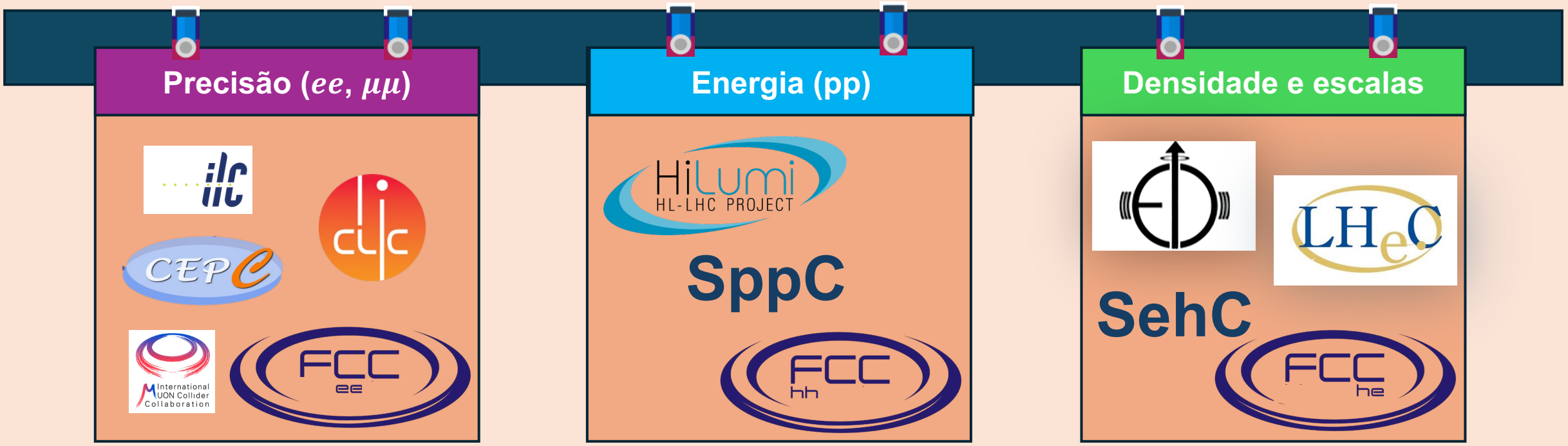
O que esperar dos futuros aceleradores?



O que esperar dos futuros aceleradores?

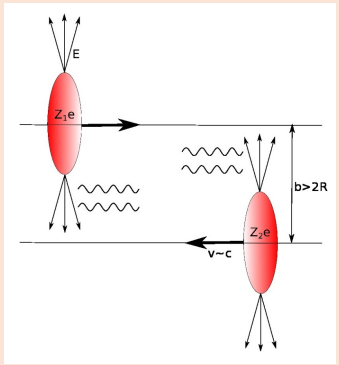


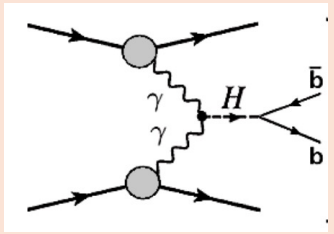
O que esperar dos futuros aceleradores?



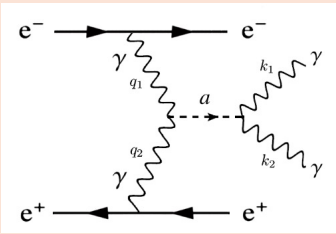
Colisores de fótons de alta energia

- **Relevante para vários canais de nova física** (ALPs, SUSY, EFT)
- **Processos EW raros são beneficiados pelas altas taxas de luminosidade integrada**





P. R. Teles et al. Phys.Rev.D 101 (2020) 3, 033009



PRD 109 (2024) 5 . **Incluído no FCC MidTerm Report**

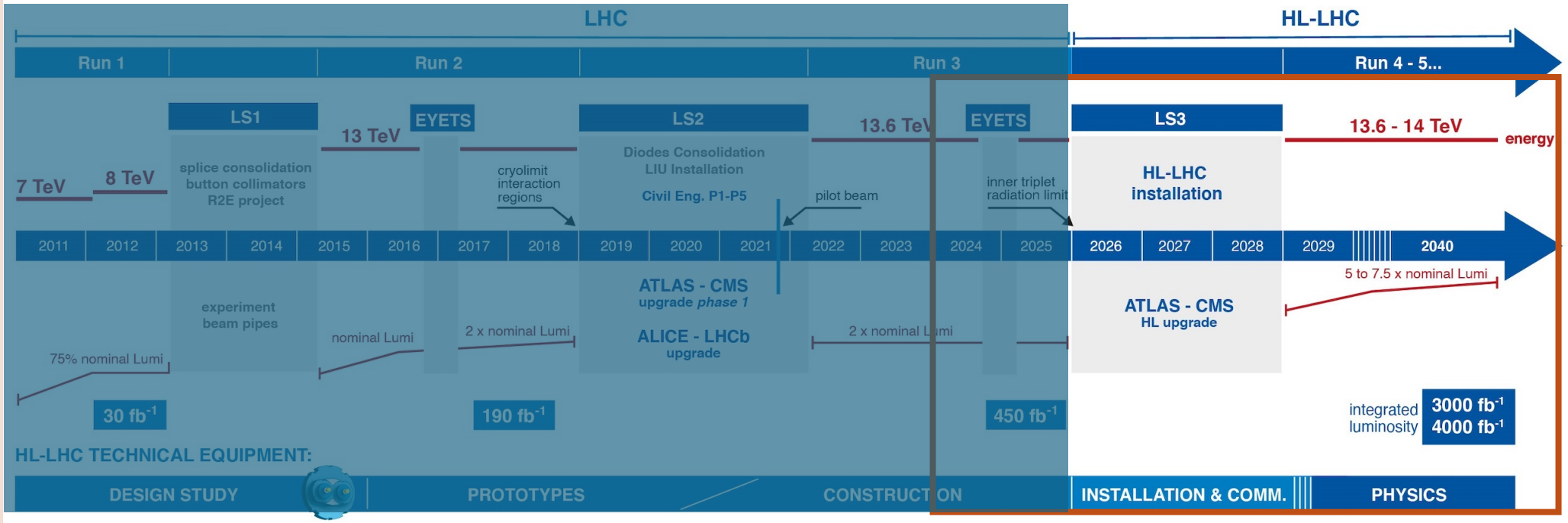
https://voisins.web.cern.ch/en/high-luminosity-lhc-hl-lhc

Em abril iniciamos colisões pp com feixes estáveis de $\sqrt{s} = 6.8$ TeV

Agenda colisões LHC 2024:

- **pp : meados Outubro**
- **ppref + HI: fim Outubro – Novembro**
- **Parada de Fim de Ano (YETS): inicia em 25/11**

LHC / HL-LHC Plan



https://voisins.web.cern.ch/en/high-luminosity-lhc-hl-lhc

HL-LHC CIVIL ENGINEERING:

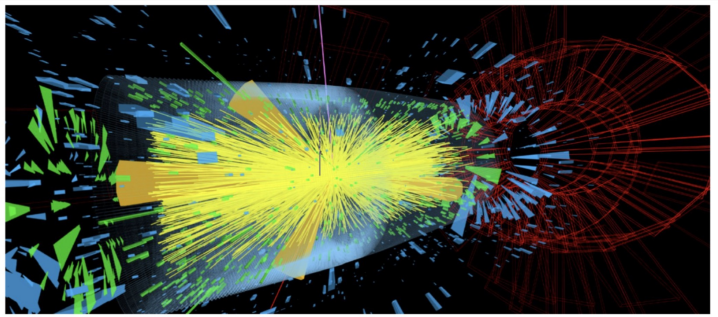
DEFINITION	EXCAVATION	BUILDINGS

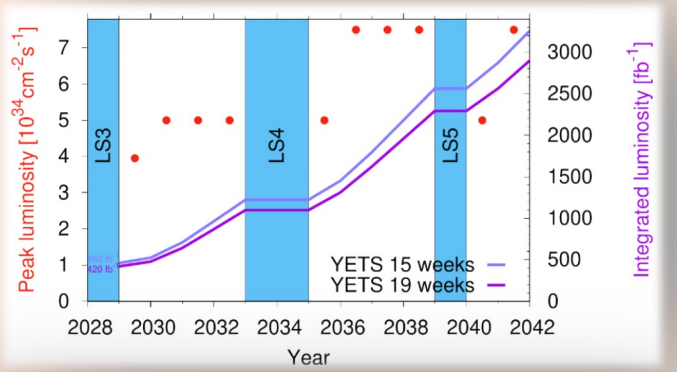
- **Início LS3 : ~ meados Nov/2025**
- **Duração ~3 anos**

HL-LHC é desafiador

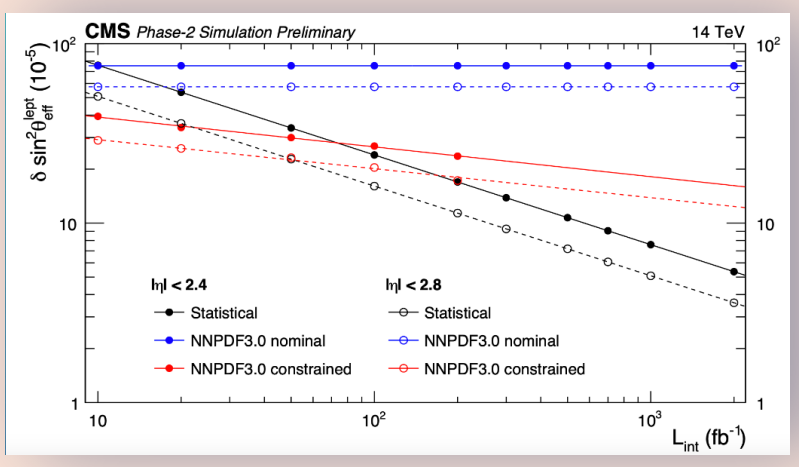
HL-LHC operação 2029 - 2041

- Lumi. Int. > 3 ab^{-1} em 10 anos
- 200 interações por colisão pp (**alto PU**)
- Ambiente de **alta radiação**
- **Upgrade de todos os detetores do LHC**.
  - Implementação durante LS3.





Medidas de precisão da massa do W mass do sin^2 θ dependem de aprimoramento nas PDFs

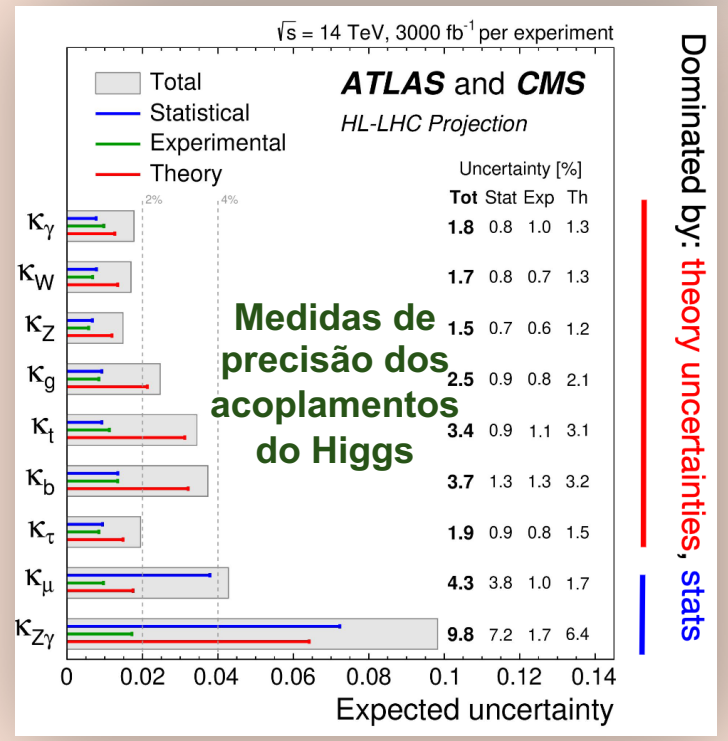


CBPF

- Supermódulo do **EB** do **ECAL:** nova eletrônica de leitura em teste na linha de feixe H4 do CERN.
- **Calibração do ECAL** => desafio na Fase II
- Tampas do ECAL => novo **HGCAL**

CMS ECAL upgrade for precision timing and energy measurements at the High Luminosity LHC

https://iopscience.iop.org/article/10.1088/1742-6596/2374/1/012072/pdf



CBPF contribuição ativa no upgrade do ECAL

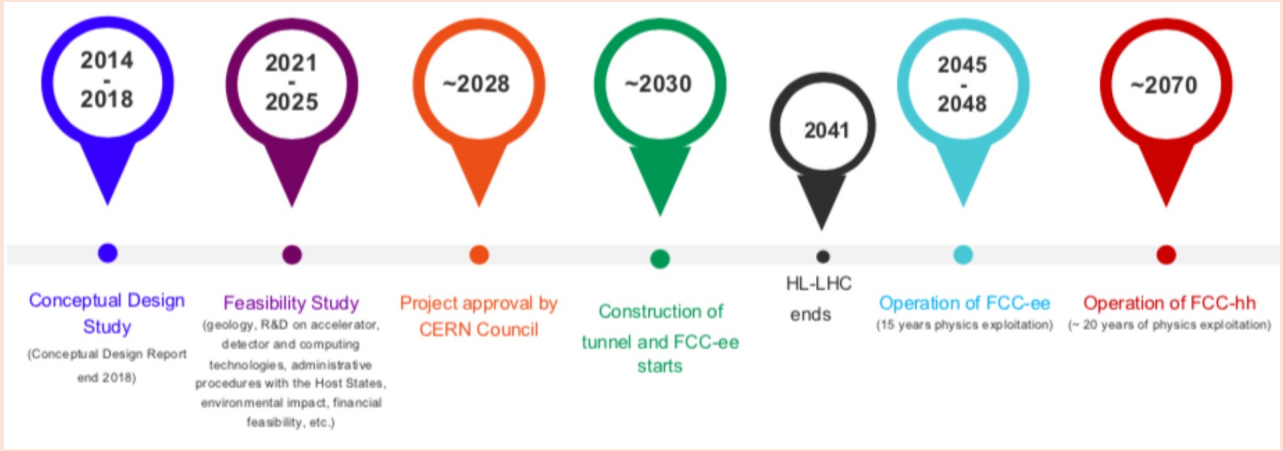
M&O B e HI+ECAL@CBPF

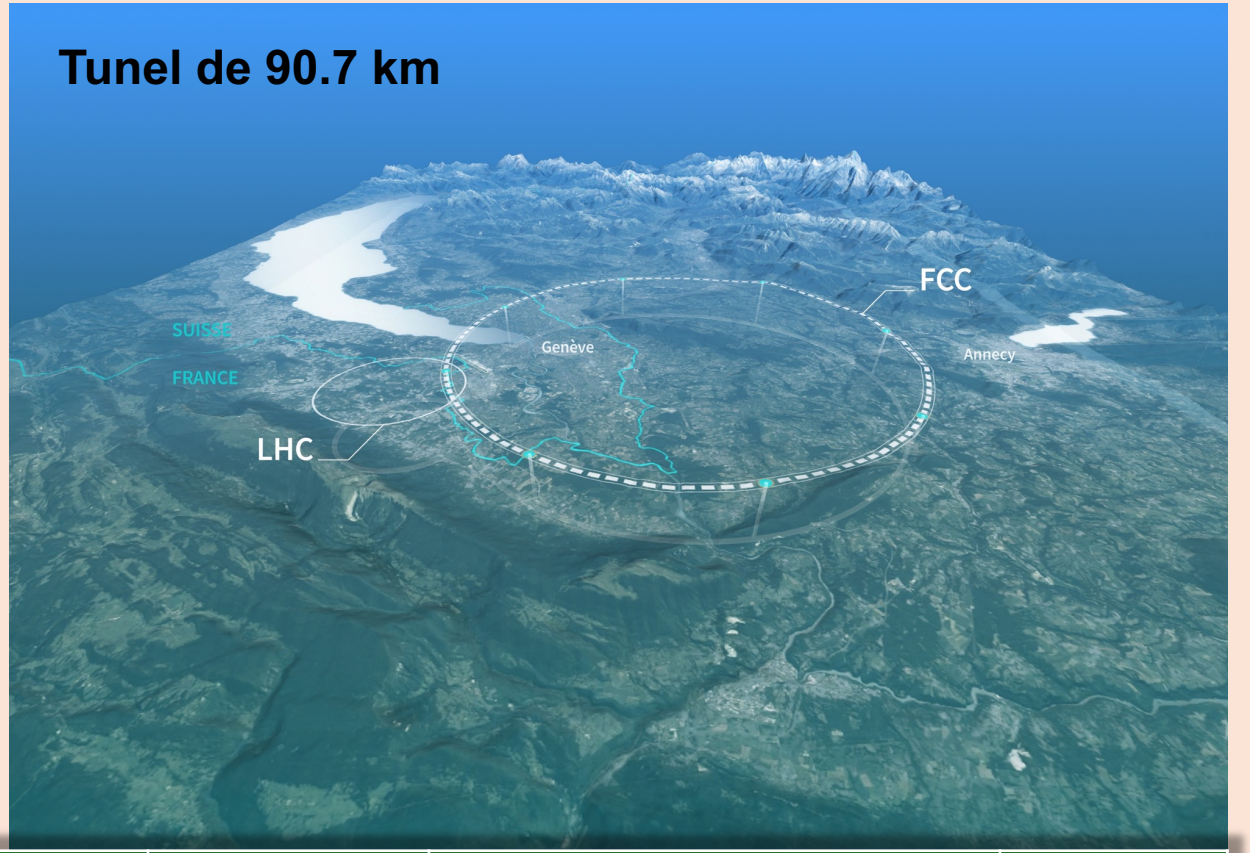
FAPERJ

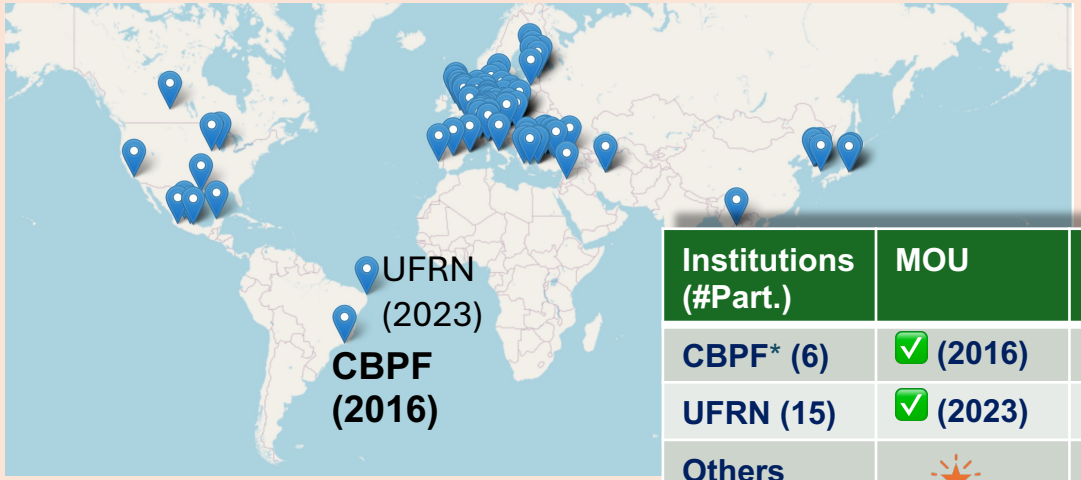
RENAFAE

European Strategy Update (2018-2020)
Snowmass Community Planning Exercise (2020-2022)

Futuro Colisor Circular







Institutions (#Part.)	MOU	Funding Agencies	Papers Presentations	Student Engagement	Other Exp. (colliders)
CBPF* (6)	✅ (2016)	✅ (HI+ECAL@CBPF)	✅	✅ (UG + PhD + PostDoc)	✅ LHC
UFRN (15)	✅ (2023)	✅	✅	✅ (UG + MSc + PhD + PostDoc)	☑ ?
Others	✳	✅	✅	✅ (UG + MSc + PhD + PostDoc)	✅ LHC

Others: UFPel (10), UFRGS (2), UERJ (6) and USP (2) – Brazil*

FCC-ee: Your Questions Answered link

2020 Update of the European Strategy for Particle Physics link

***Latin American Strategy Forum for Research Infrastructure (LAS4RI)**

Apresentação Forum dos Contatos Nacionais no FCC Workshop em Annecy Jan 2024 (America Latina)

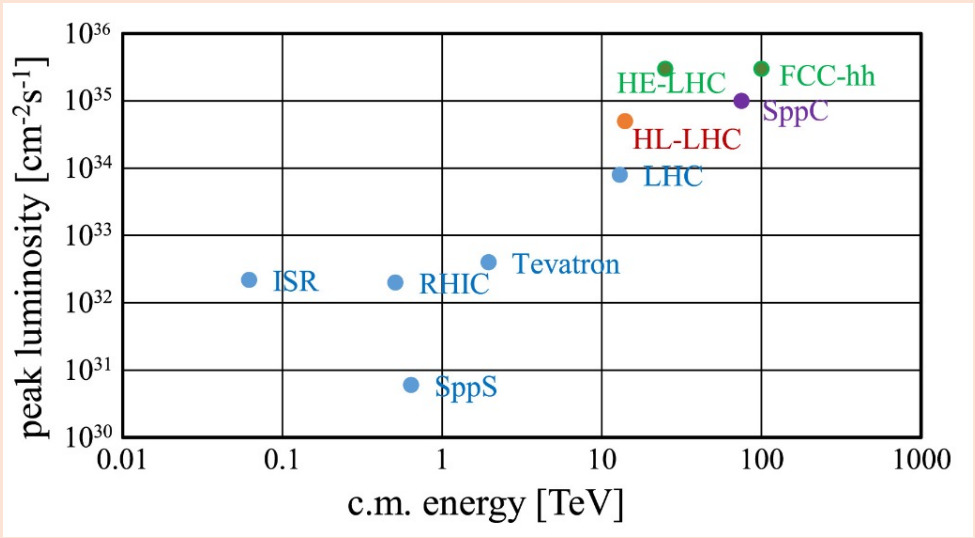
Brazilian Participation in the Next-Generation Collider Experiments link. Atualização em andamento (G. Silveira 11/04/2024)

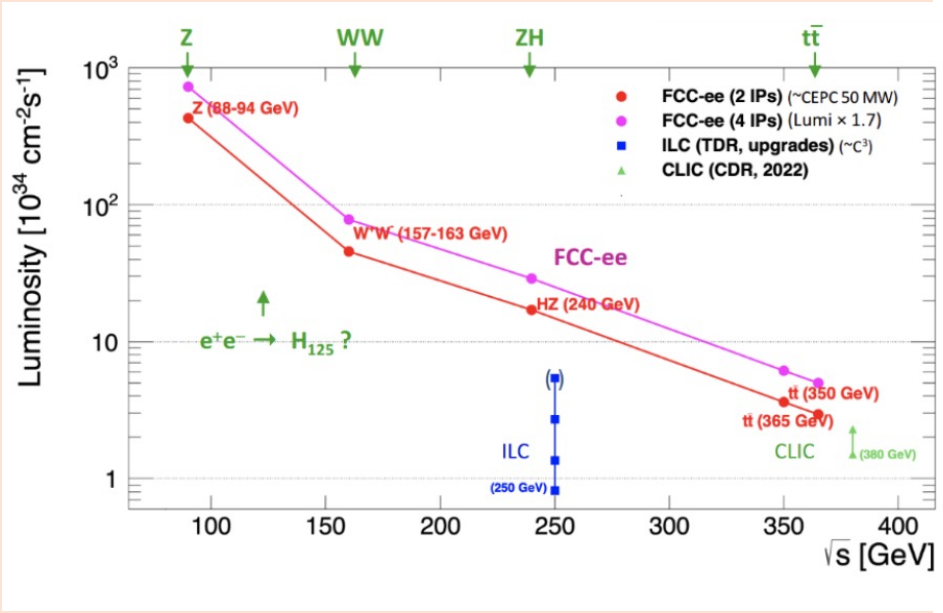
Sobre o Futuro Colisor Circular

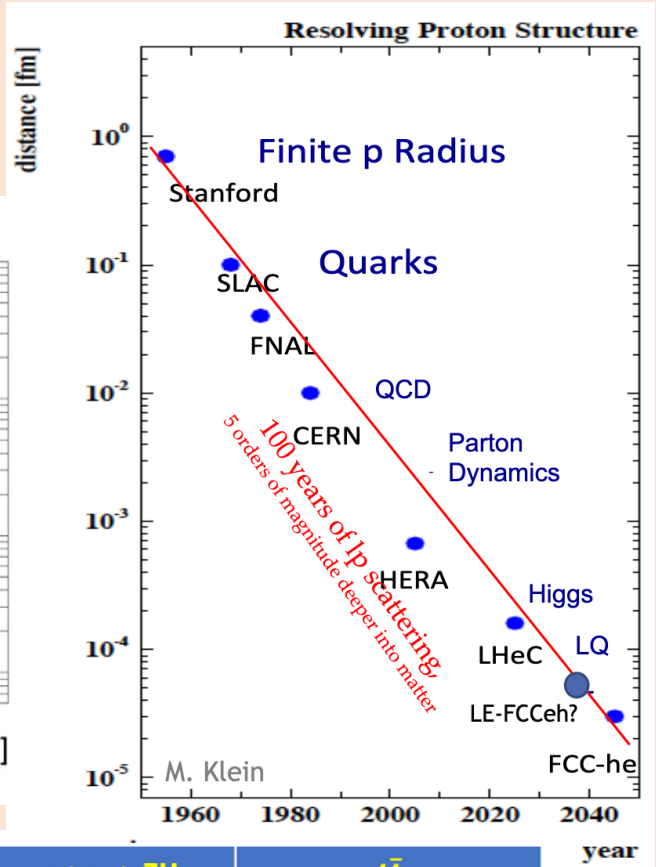
Dois estágios:

• Estágio 1: **FCC-ee** (Z, W, H ,Q) com medidas ultraprecisas do setor eletrofraco, Higgs e cia.; fábrica de Higgs e top em alta luminosidade.

• Estágio 2: **FCC-hh** (~100 TeV) continuação atingido **fronteira de energia**, tb com opções AA e ep/A options (**FCC-eh**)







Working Point FCC-ee	Z (early/later)	WW (early/later)	e+e- -> ZH Never done	$t\bar{t}$ (early/later) Never done
$\sqrt{s}$ (GeV)	88 / 94	157/163	240	340 / 365
Lumi/IP ($10^{-34}\ cm^{-2}\ s^{-1}$)	70 / 140	10/20	5	0.75 / 1.20
Lumi/Year (ab^{-1})	34 / 68	4.8/9.6	2.4	0.36 / 0.58
Run time (year)	2 / 2	2/0	3	1 /4
Yields	6×10^{12} Z	2.4×10^{8} WW	$\mathbf{1.45 \times 10^{8}\ ZH}$ + $45k\ WW \to H$	$\mathbf{1.9 \times 10^{6}\ t\bar{t}}$ + 330k ZH +$80k\ WW \to H$

Luminosities for the Mid-Term Report June 2023

4 IPs; 185 days of physics/year; 75% eff.

Brazilian Center for Physics Research – CBPF Rio de Janeiro - Brazil

Gilvan Alves (senior researcher) &

Patricia Rebello Teles (postdoc)

(CMS Collaboration – LHC)

CBPF

FCC MOU desde 2016

Apresentação Forum dos Contatos Nacionais no FCC Workshop em Annecy Jan 2024

- FCC-ee/eh/hh as $\gamma\gamma$ colliders* (David d'Enterria - CERN): Higgs, ALPs, Gravitons, aQGCs; FCC Reports

- **Project HI+ECAL@CBPF** (FAPERJ - 2022)
  - 1 postdoc + 1 PhD + 2 undergraduate
  - Detector simulation in GEANT: ECAL studies
  - FCC-hh: UltraPeripheral Collisions

CNPq Conselho Nacional de Desenvolvimento Científico e Tecnológico

CAPES

FAPERJ Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro

Publications

- Prospects for $\gamma\gamma \to \mathrm{H}$ and $\gamma\gamma \to \mathrm{W^+W^-}$ measurements at FCC-ee. PHOTON'15, e-Print: 1510.08141 [hep-ph]
- Measurements of $\gamma\gamma \to \mathrm{H}$ and $\gamma\gamma \to \mathrm{W^+W^-}$ in $\mathrm{e^+e^-}$ collisions at the Future Circular Collider, EDS BLOIS 2017, e-Print: 1712.07023 [hep-ph]
- Prospects for $\gamma\gamma \to \mathrm{H}$ observation in ultraperipheral ion collisions at the Future Circular Collider, PHOTON'17, e-Print: 1712.10104 [hep-ph]
- Two-photon fusion Higgs production in collisions with proton and ion beams at LHC, HE-LHC and FCC, PHOTON'19, Frascati Phys.Ser. 69 (2019) 156-163
- Higgs boson production in photon-photon interactions with proton, light-ion, and heavy-ion beams at current and future colliders, Phys.Rev.D 101 (2020) 3, 033009
- New Physics Searches at Future Colliders (from HL-LHC to FCC), talk in the Spring Meeting of Brazilian Physics Society (2023)
- Searches for axion-like particles via $\gamma\gamma$ fusion at future e^+e^- colliders. PRD 109 (2024) 5 . **Incluído no FCC MidTerm Report**.
- Contributed to the FCC Reports FCC-ee, FCC-hh, Physics Opportunities, FCC HE-LHC
- Other works in progress: phenomenology and detector simulation

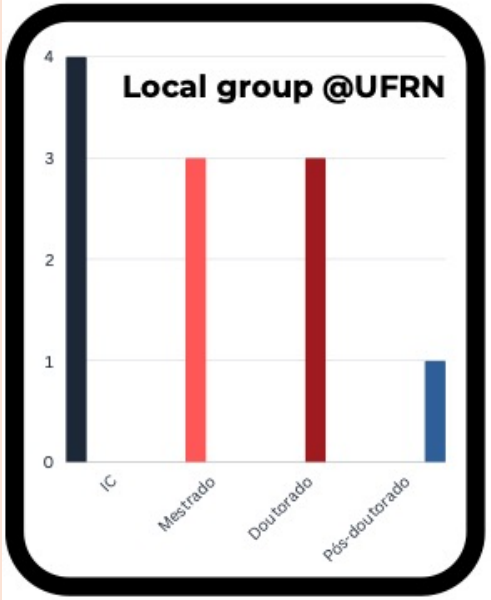
UFRN - working Group -International Inst. of Physics, Brazil

Farinaldo Queiroz, Victor Gonçalves, Luciano Abreu, Sandro Fonseca

FCC MOU desde 2023

PED goals

New Physics at FCC:
dark matter
Z' models
Seesaw



Publications

[1] Vector-Like Fermions and Inert Scalar Solutions to the Muon g-2 Anomaly and collider probes at the HL-LHC and FCC-hh, arxiv:2312.03851

[2] On the role of LHC and HL-LHC in constraining flavor changing neutral currents, PLB 2024, arxiv: 2304.00041

[3] Flavor changing interactions confronted with meson mixing and hadron colliders, PRD 2023, arxiv: 2208.08462

[4] Search for leptophilic dark matter at the LHeC, J.Phys.G 50 2023 , arxiv: 2207.01656

[5] Constraining 3-3-1 models at the LHC and future hadron colliders, PRD 2023 , arxiv: 2203.02520

Schools/Workshops

School on Collider Physics and Madgraph, February 2024

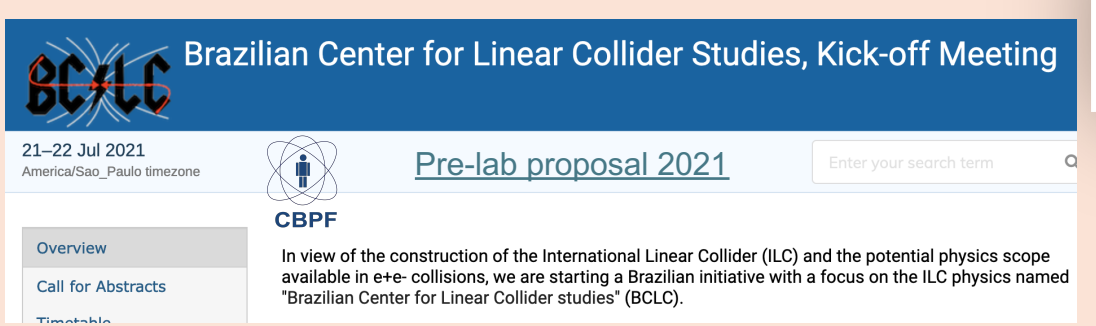
School on Collider Physics Topologies, June 20024

Workshop on Collider Physics, September 2024

SIMONS FOUNDATION CNPq

Apresentação Forum dos Contatos Nacionais no FCC Workshop em Annecy Jan 2024

Outros aceleradores



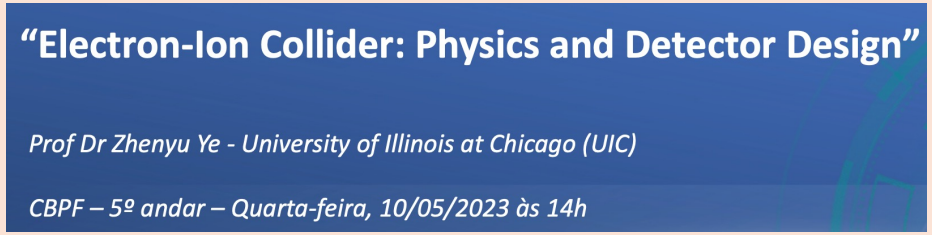
Department of Energy

U.S. Department of Energy Selects Brookhaven National Laboratory to Host Major New Nuclear Physics Facility

JANUARY 9, 2020

The Electron Ion Collider (EIC), to be designed and constructed over ten years at an estimated cost between $1.6 and $2.6 billion, will smash electrons into protons and heavier atomic nuclei in an effort to penetrate the mysteries of the "strong force" that binds the atomic nucleus together.

https://www.energy.gov/articles/us-department-energy-selects-brookhaven-national-laboratory-host-major-new-nuclear-physics



CBPF

FAPERJ
Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro

HI+ECAL@CBPF

Acceleration of electrons in the plasma wakefield of a proton bunch

E. Adli, A. Ahuja, O. Apsimon, R. Apsimon, A.-M. Bachmann, D. Barrientos, F. Batsch, J. Bauche, V. K. Berglyd Olsen, M. Bernardini, T. Bohl, C. Bracco, F. Braunmüller, G. Burt, B. Buttenschön, A. Caldwell, M. Cascella, J. Chappell, E. Chevallay, M. Chung, D. Cooke, H. Damerau, L. Deacon, L. H. Deubner, ... G. Xia + Show authors

Nature **561**, 363–367 (2018) | Cite this article

CERN release, 27th of July 2023

AWAKE introduces a stronger wave to accelerate particles

Plasma accelerator AWAKE has tested scalability and is all set to begin its second phase of data taking with an upgraded plasma source

- **Pesquisas para Aceleradores Compactos**:
  - pesquisas de aceleradores de "wakefield" de plasma (AWAKE), aceleradores à laser (Laboratório de Lasers de Pulsos Ultracurtos de Alta Intensidade do IPEN – tese PhD e LCLS - Linac Coherent Light Source nos EUA)
  - mais acessíveis, abrindo **novos caminhos na física de partículas e em outras áreas** como a medicina (terapias de câncer com prótons e íons pesados) => impacto social e ambiental

Conclusões e Perspectivas

- O Modelo Padrão é uma conquista monumental da física de partículas:
  - Resistente ao excrutínio experimental, mas não é a palavra final na física de partículas.
  - Questões fundamentais persistem: natureza da DM, prevalência de matéria sobre antimatéria, a complexa física de neutrinos, dentre outras aguardam esclarecimentos.
- O futuro da HEP é empolgante:
  - Projetos ambiciosos de aceleradores como o HL-LHC (CERN – 2029), o FCC-ee/eh/hh (CERN – 2041 – ~fim do séc XXI), o CLIC (CERN - 2035) e o EIC (EUA - ~2030) alcançando energias e luminosidades sem precedentes.
  - Participação ativa do Brasil em várias colaborações.
  - Alta demanda de estudantes, pesquisadores e financiamentos de pesquisa.
  - O uso de plasma e laser pode revolucionar a forma como aceleramos partículas.
- O Brasil, como membro associado do CERN na vanguarda desses avanços científicos:
  - Posição estratégica, portas abertas para estudantes e pesquisadores brasileiros participarem de descobertas científicas de ponta,
  - Oportunidades para empresas de tecnologia nacionais: desenvolvimento de novas tecnologia
  - Brasil como um jogador chave na ciência global.

BACKUP

Comparando as luminosidades e energias entre as diversas propostas