Search for Invisibly Decays
of the Higgs Boson at the ILC Using key4HEP

Carsten Hensel, Second ECFA Workshop on e+e- Higgs/Electroweak/Top Factories
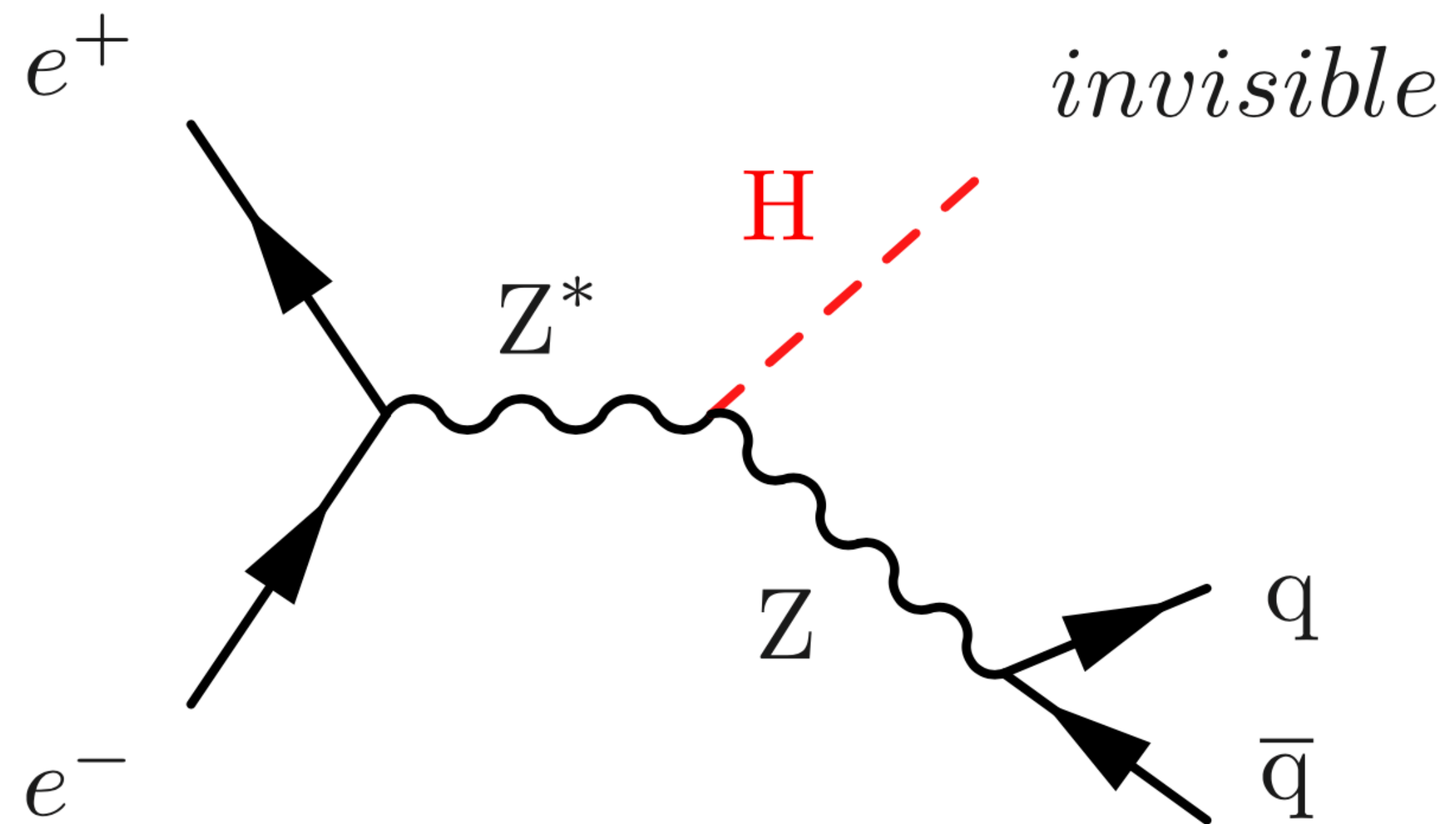
Outline

- Introduction

- key4HEP

- The analysis

- Status/Plans

Introduction

Higgs Boson: A Tool to Discover New Physics

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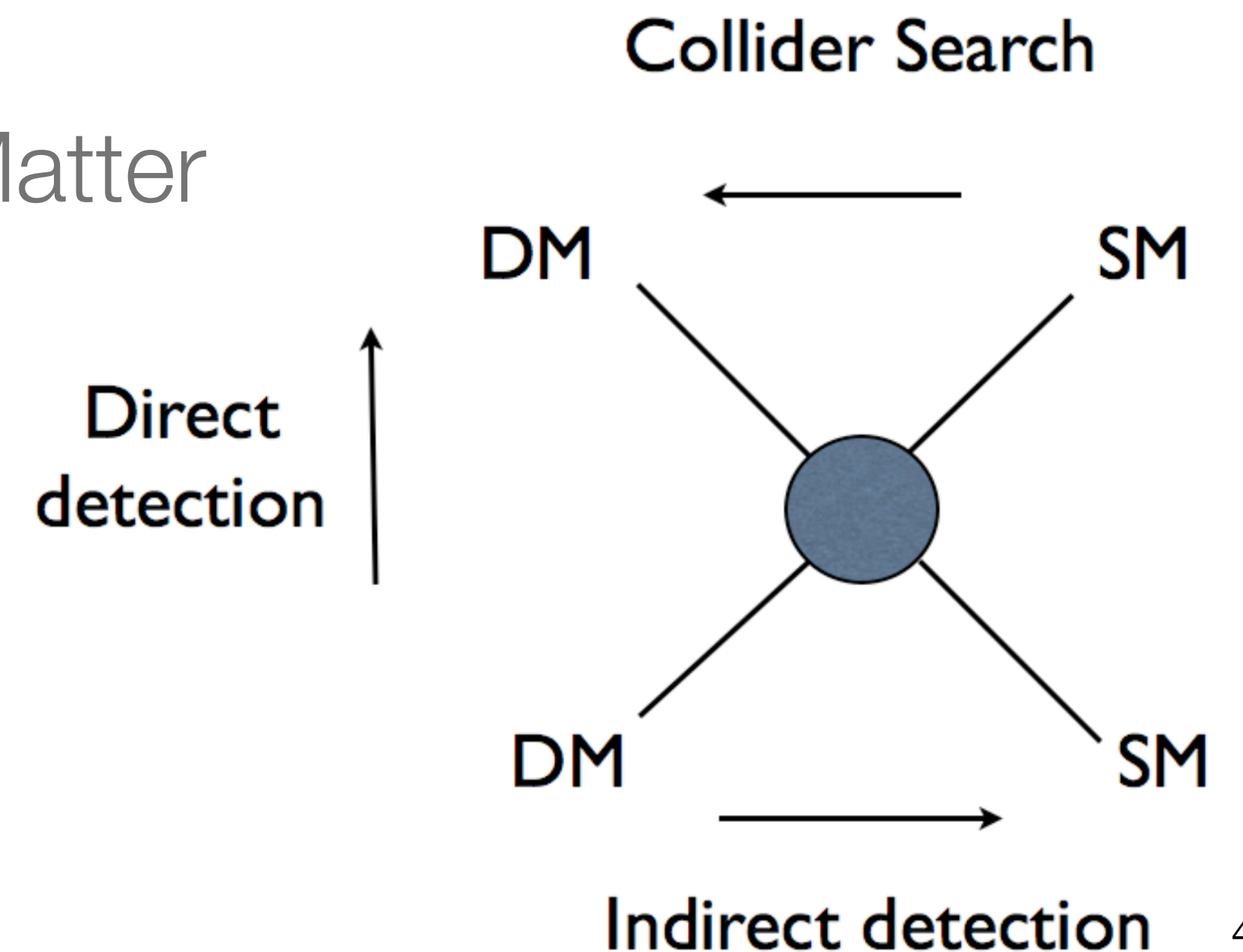
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- BR is small: $\sim 0.1\,\%$

- if size-able invisible Higgs decays found: sign for physics beyond SM

  - e.g. Higgs Portal Model connects SM and Dark Matter

$$SM \to H \to \chi\chi$$

  - and χ invisible

  - (DM candidate χ scalar, fermionic or vectorial)

Collider Search

DM ⟵ SM

Direct detection ↑

DM ⟶ SM

Indirect detection

LHC Results

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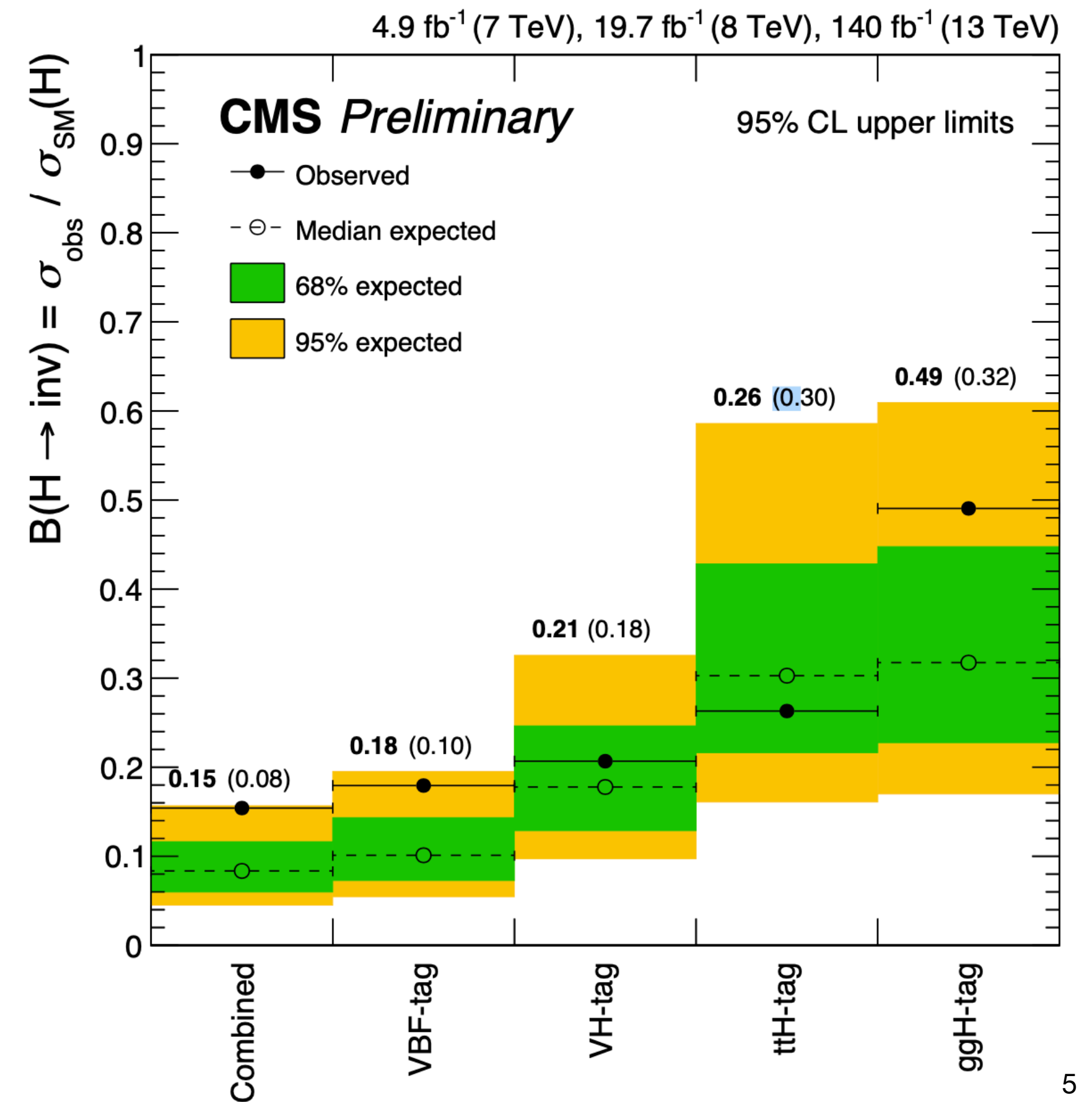
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- using missing E_T (and M_{qq})

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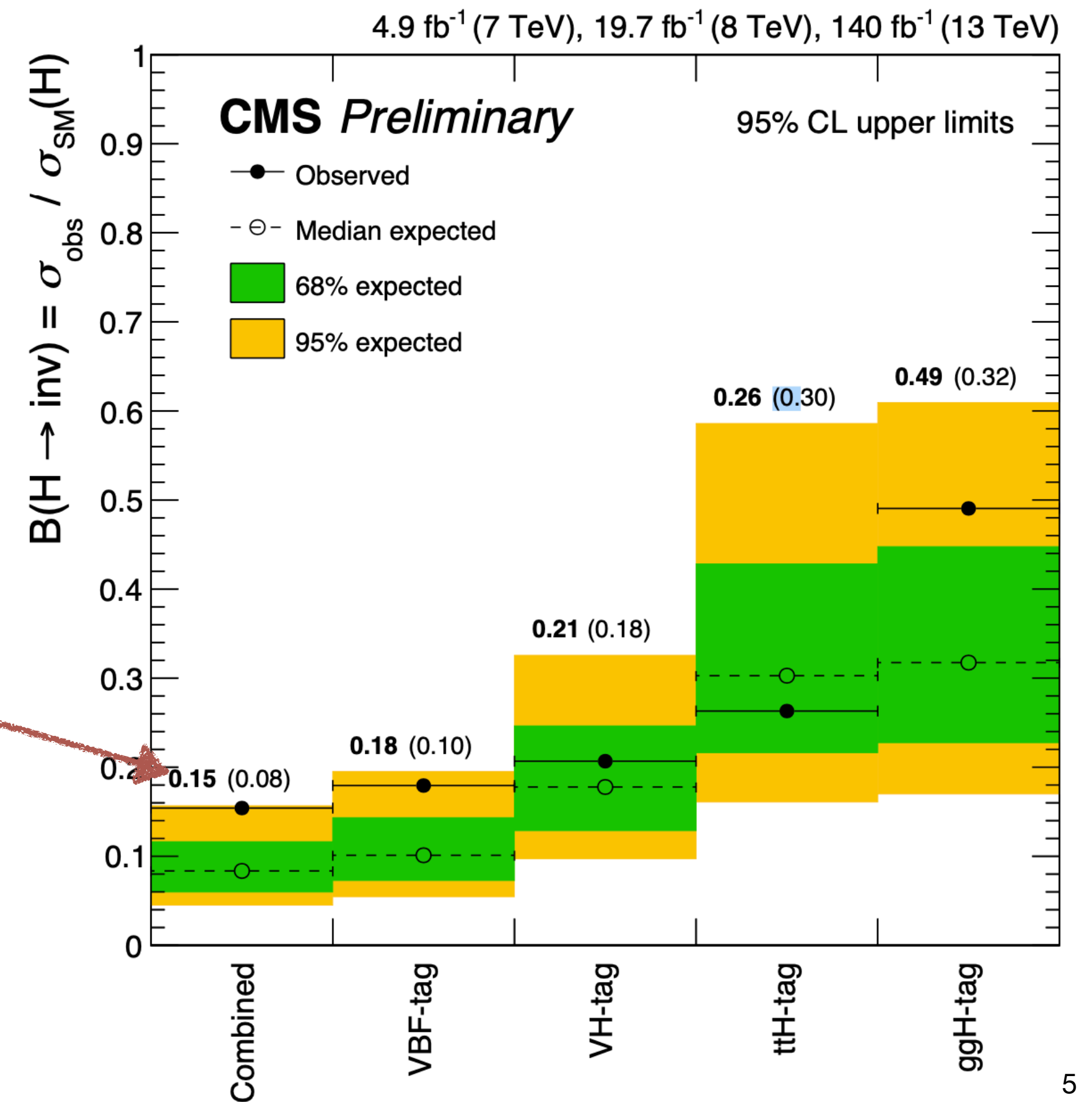- invisible Higgs decays were searched with $qq \rightarrow ZH$ and $qq \rightarrow qqH$ (VBF)
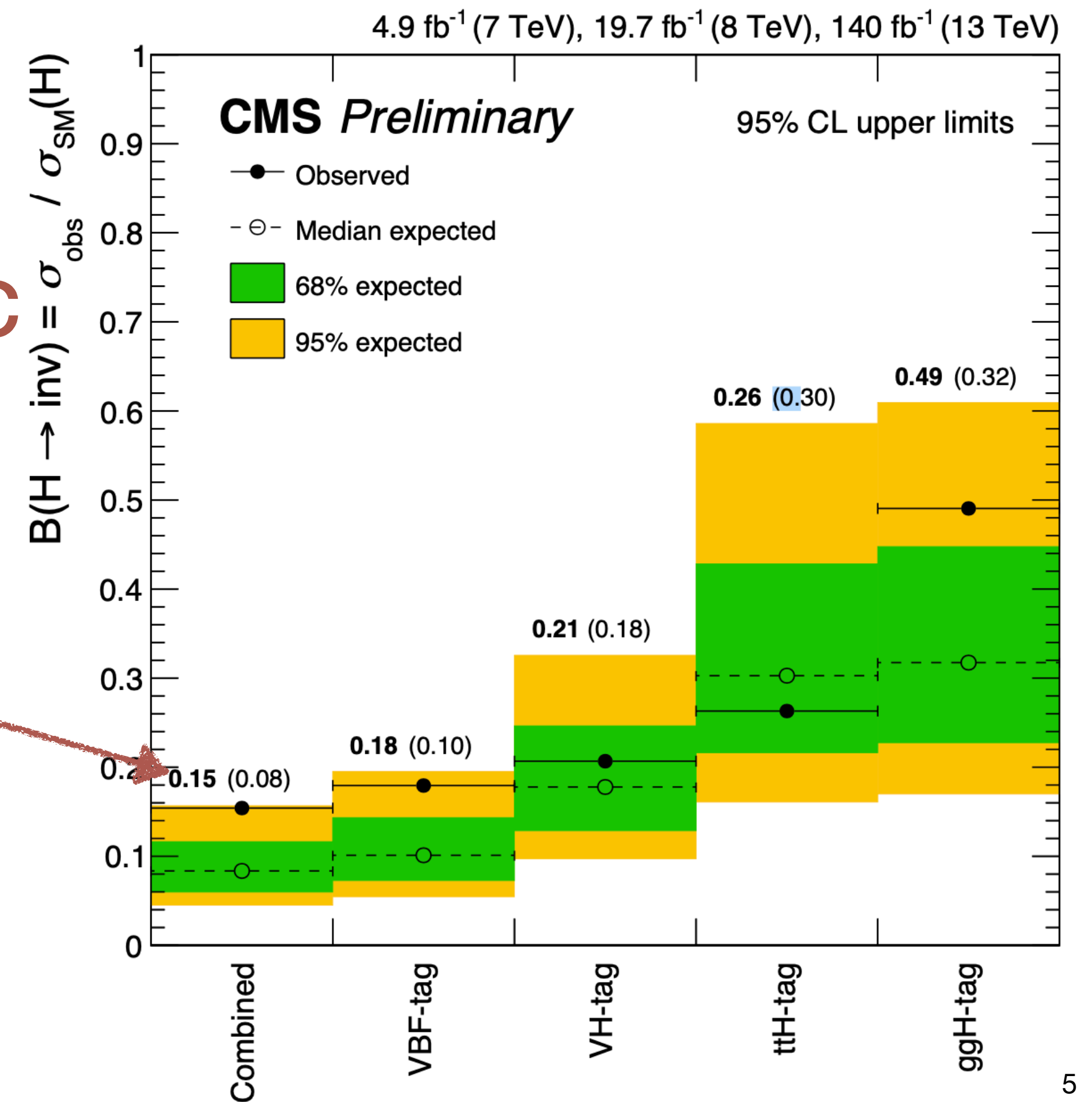
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Analysis	95% C.L. upper limit observed (expected)
Combination	$\mathcal{B}(H \rightarrow inv.) < 15\%$ (8%)

4.9 fb⁻¹ (7 TeV), 19.7 fb⁻¹ (8 TeV), 140 fb⁻¹ (13 TeV)

CMS *Preliminary*

95% CL upper limits

- ● Observed
- - ⊖ - Median expected
- 68% expected
- 95% expected

$B(H \rightarrow inv) = \sigma_{obs} / \sigma_{SM}(H)$

0.15 (0.08) — Combined
0.18 (0.10) — VBF-tag
0.21 (0.18) — VH-tag
0.26 (0.30) — ttH-tag
0.49 (0.32) — ggH-tag

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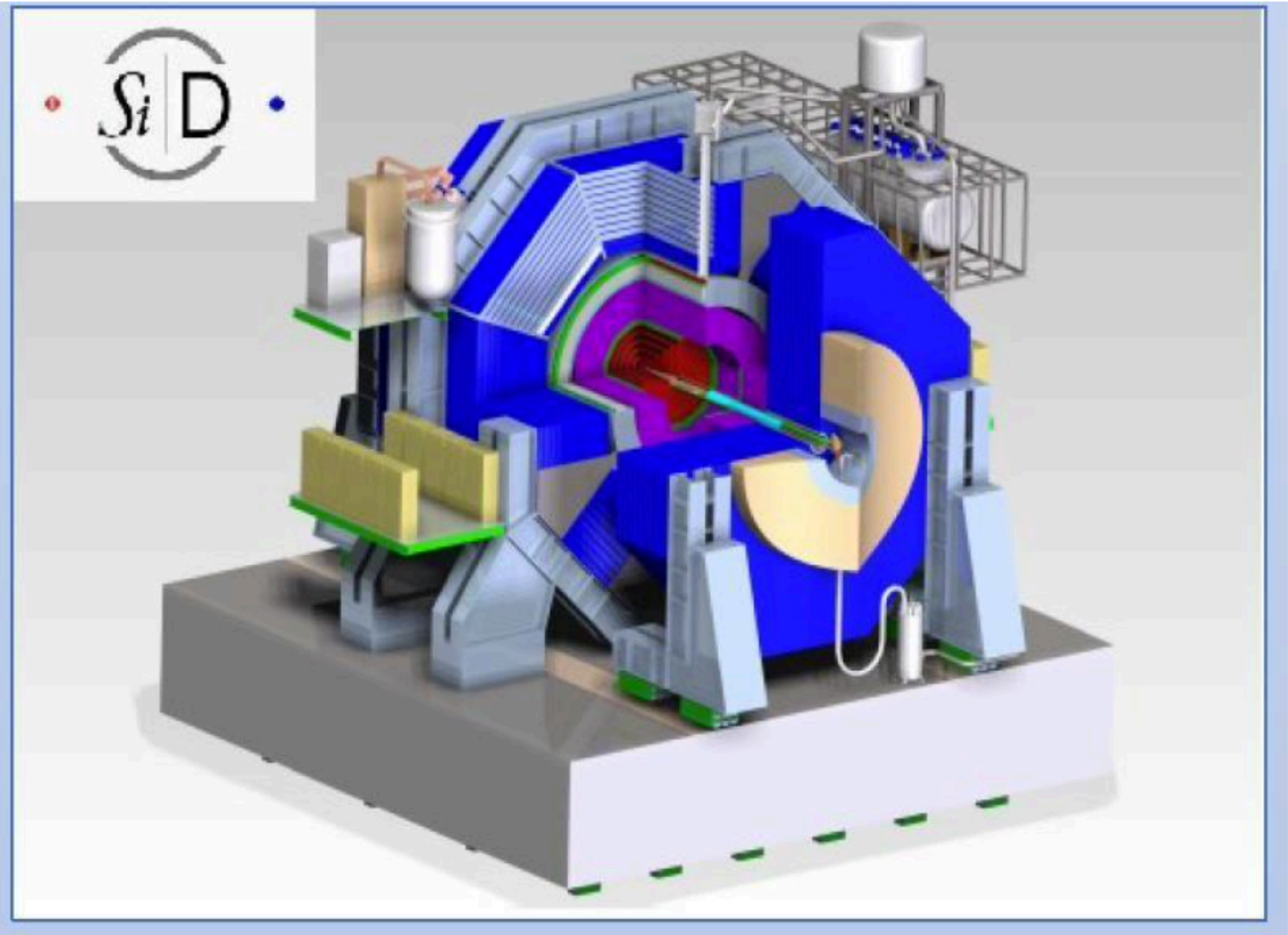
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- **very hard to achieve better than 10% at LHC**

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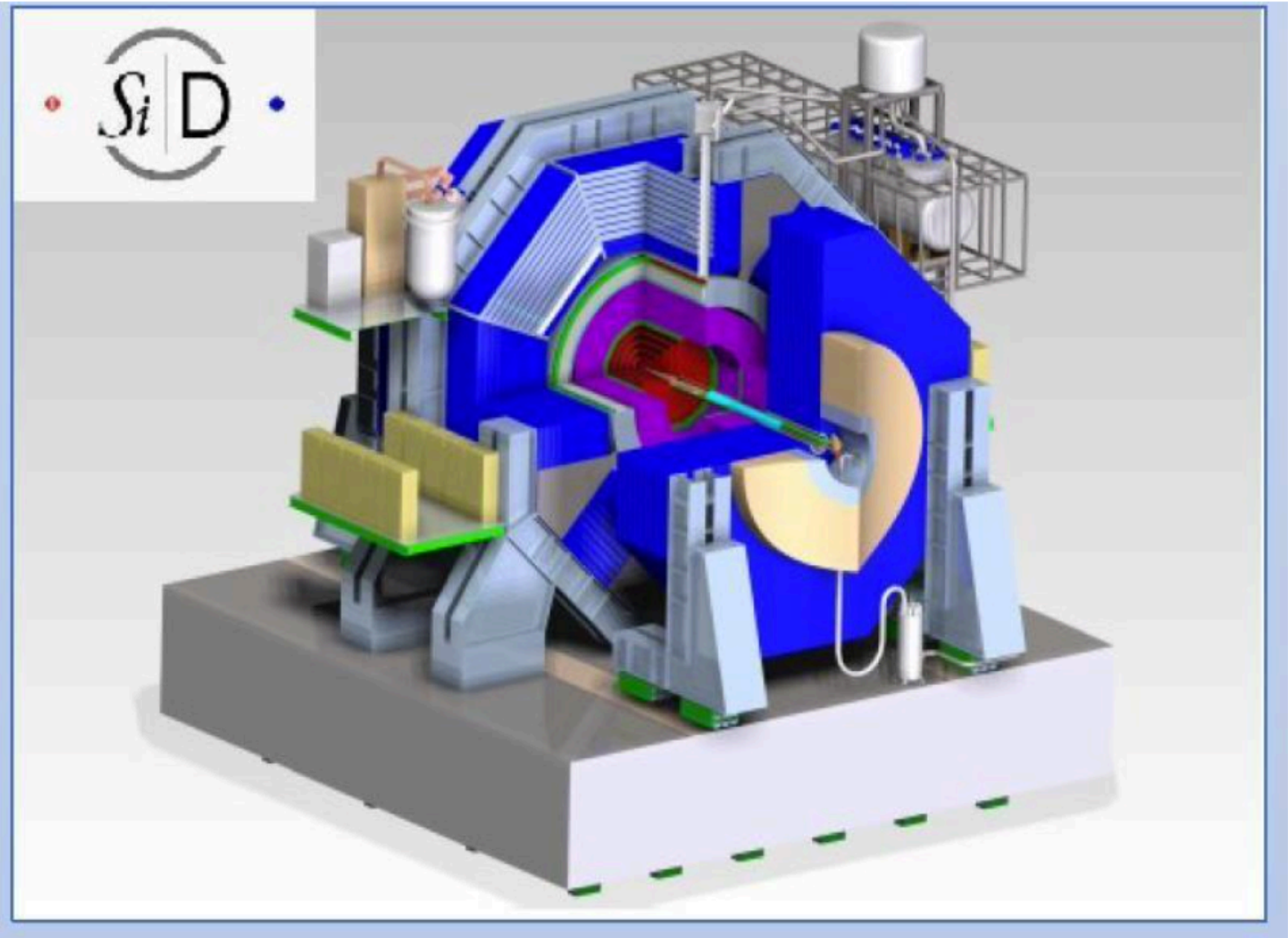**0.49** (0.32) ggH-tag
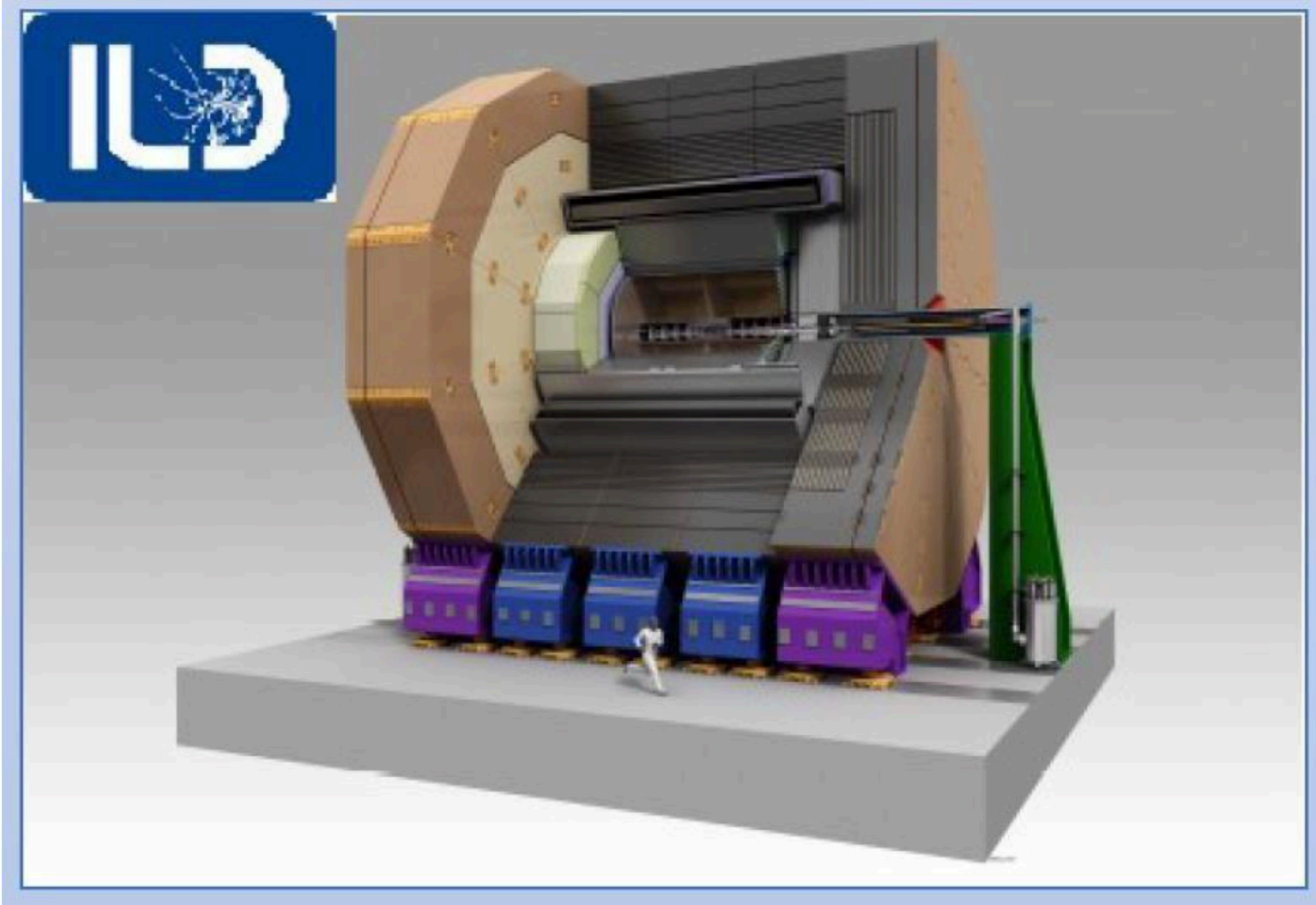
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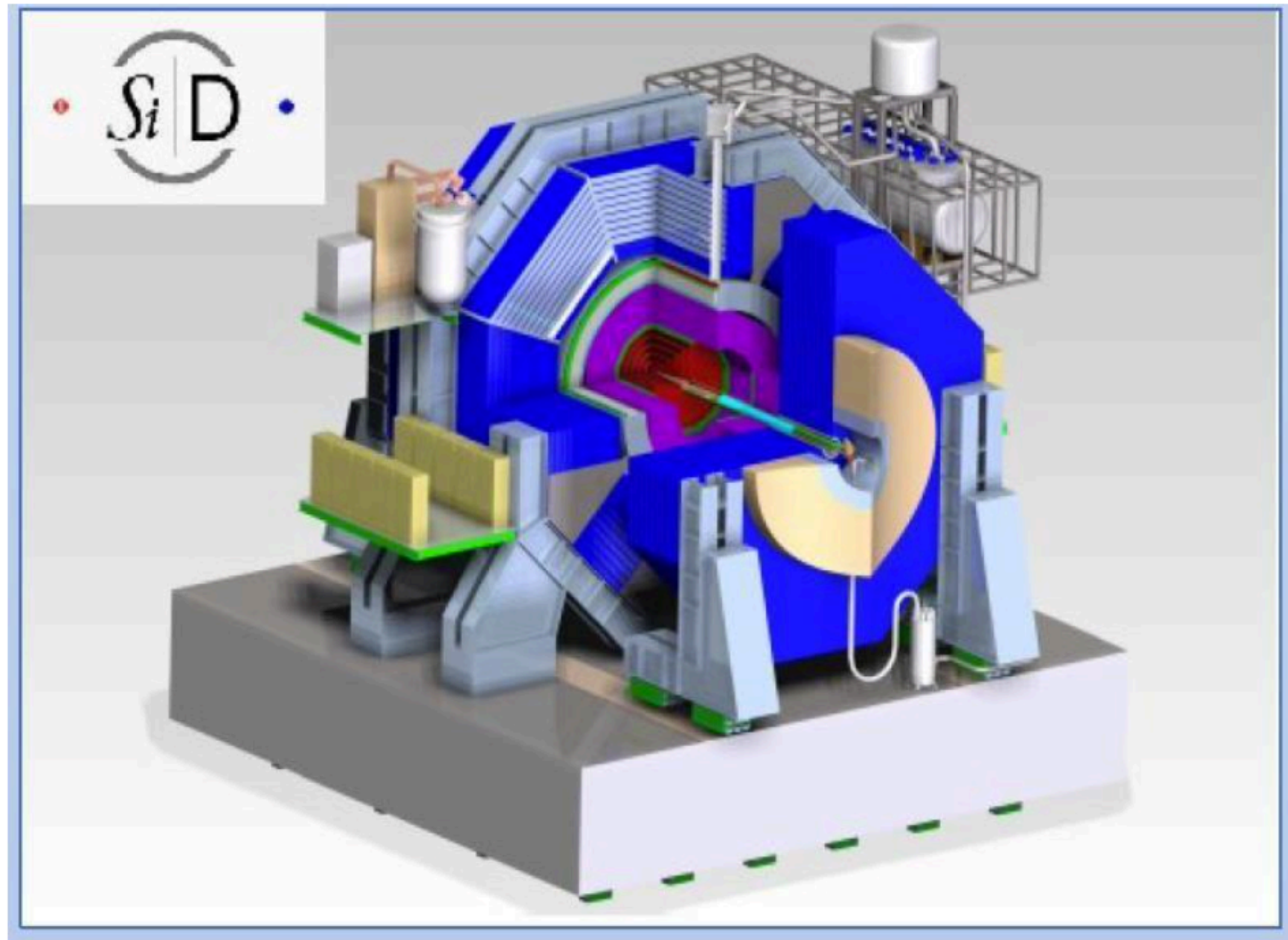# Upper Limits/Sensitivity ILC

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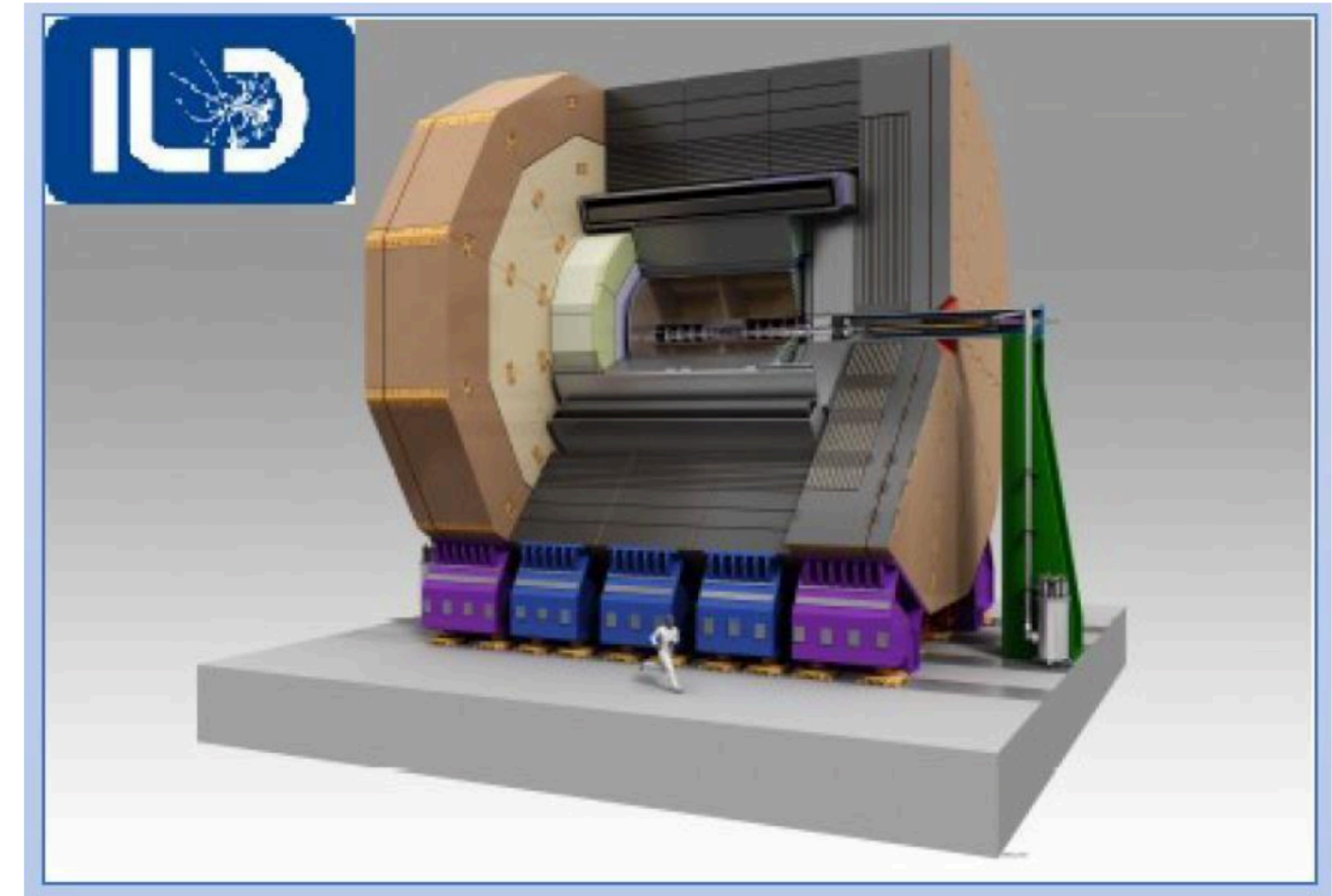
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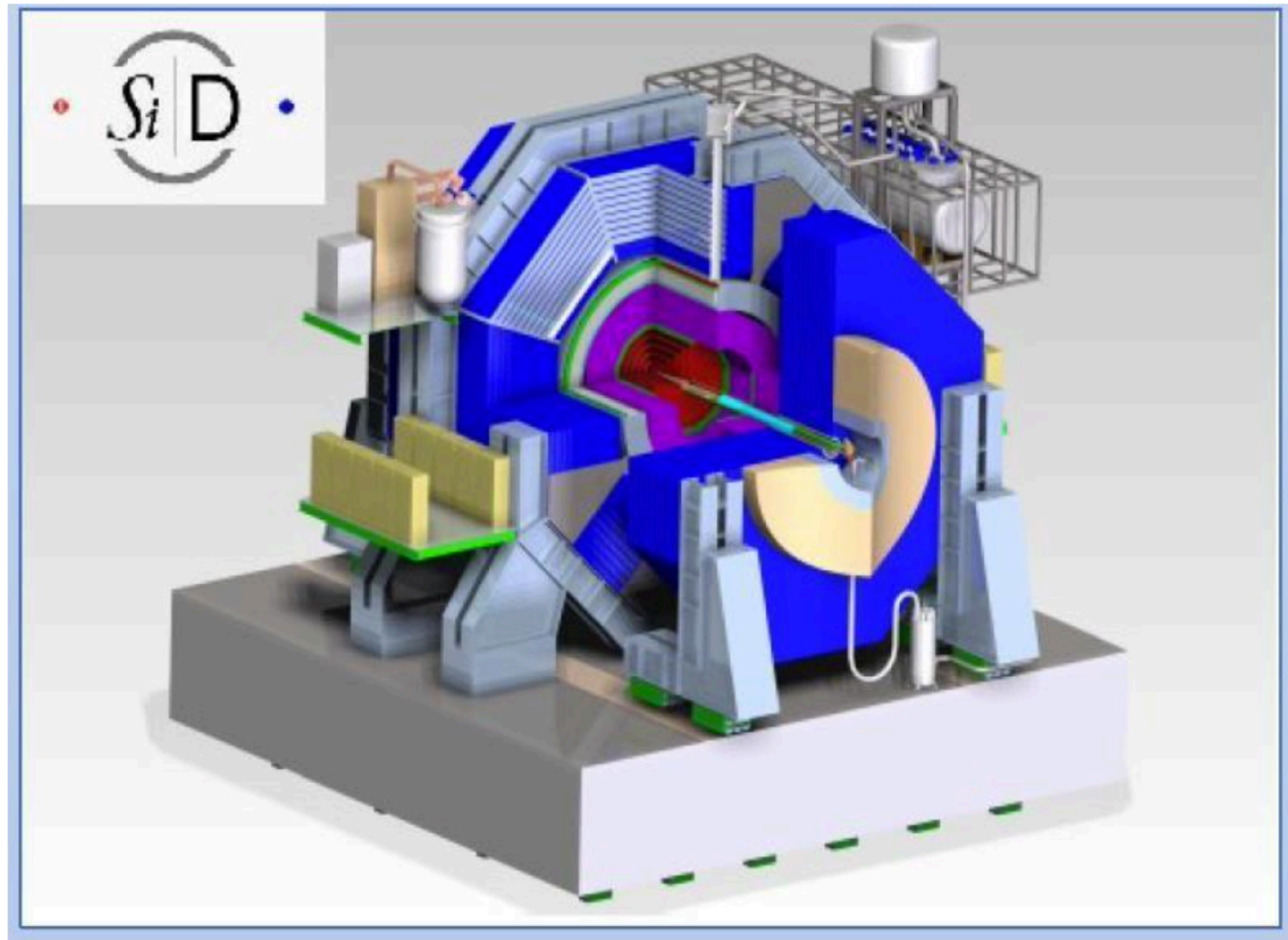
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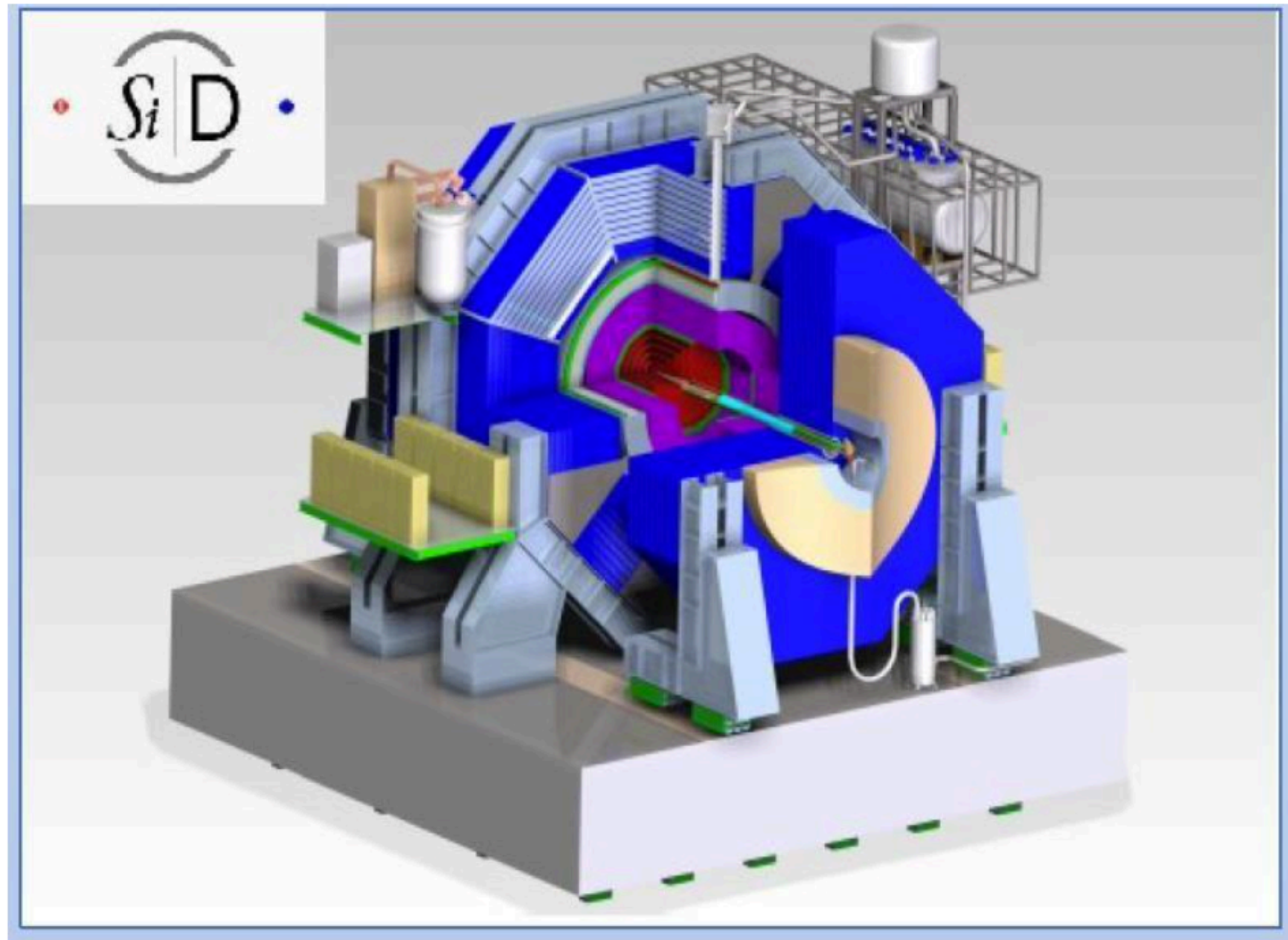$\mu\mu$ 0.27%   combined 0.16
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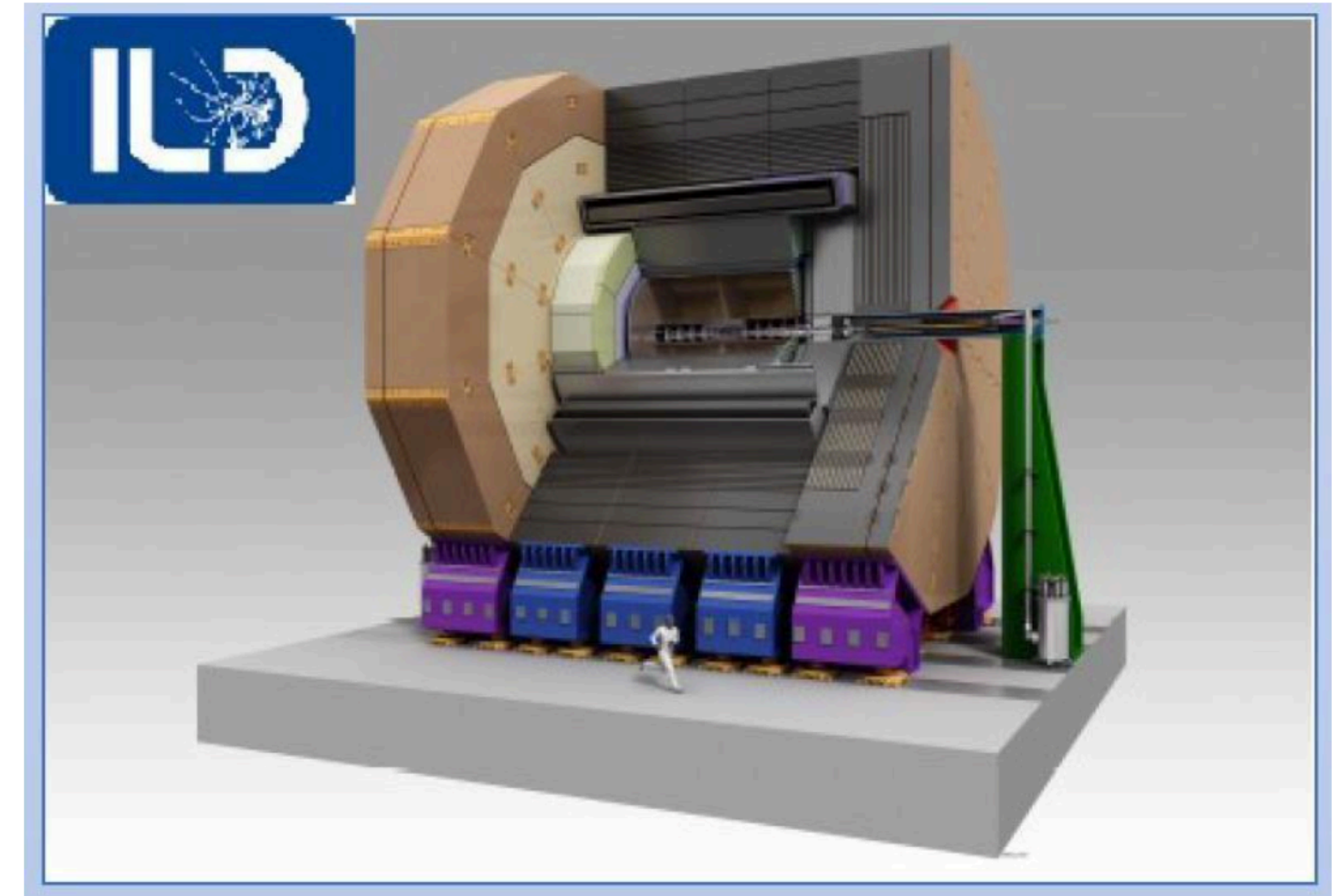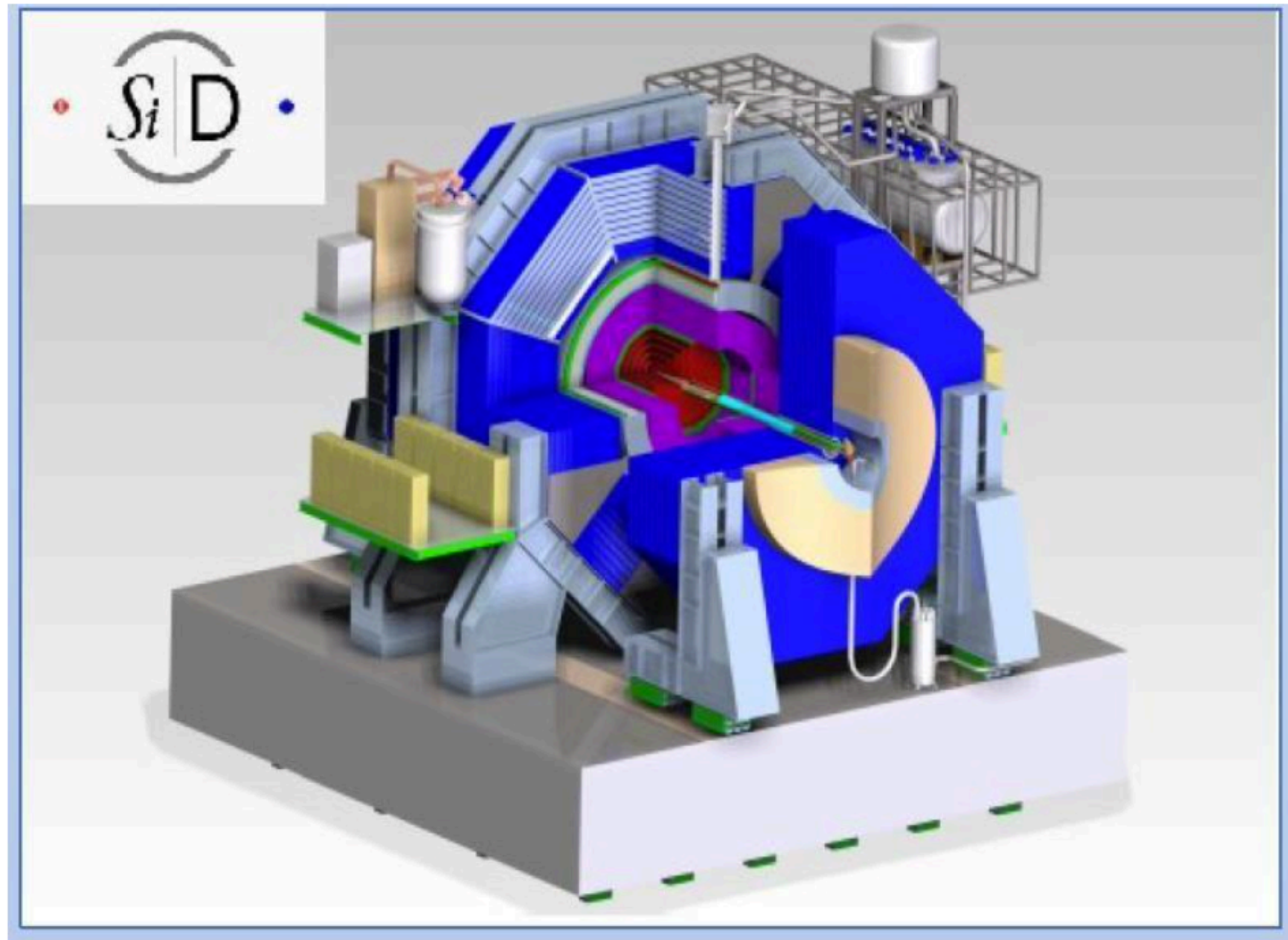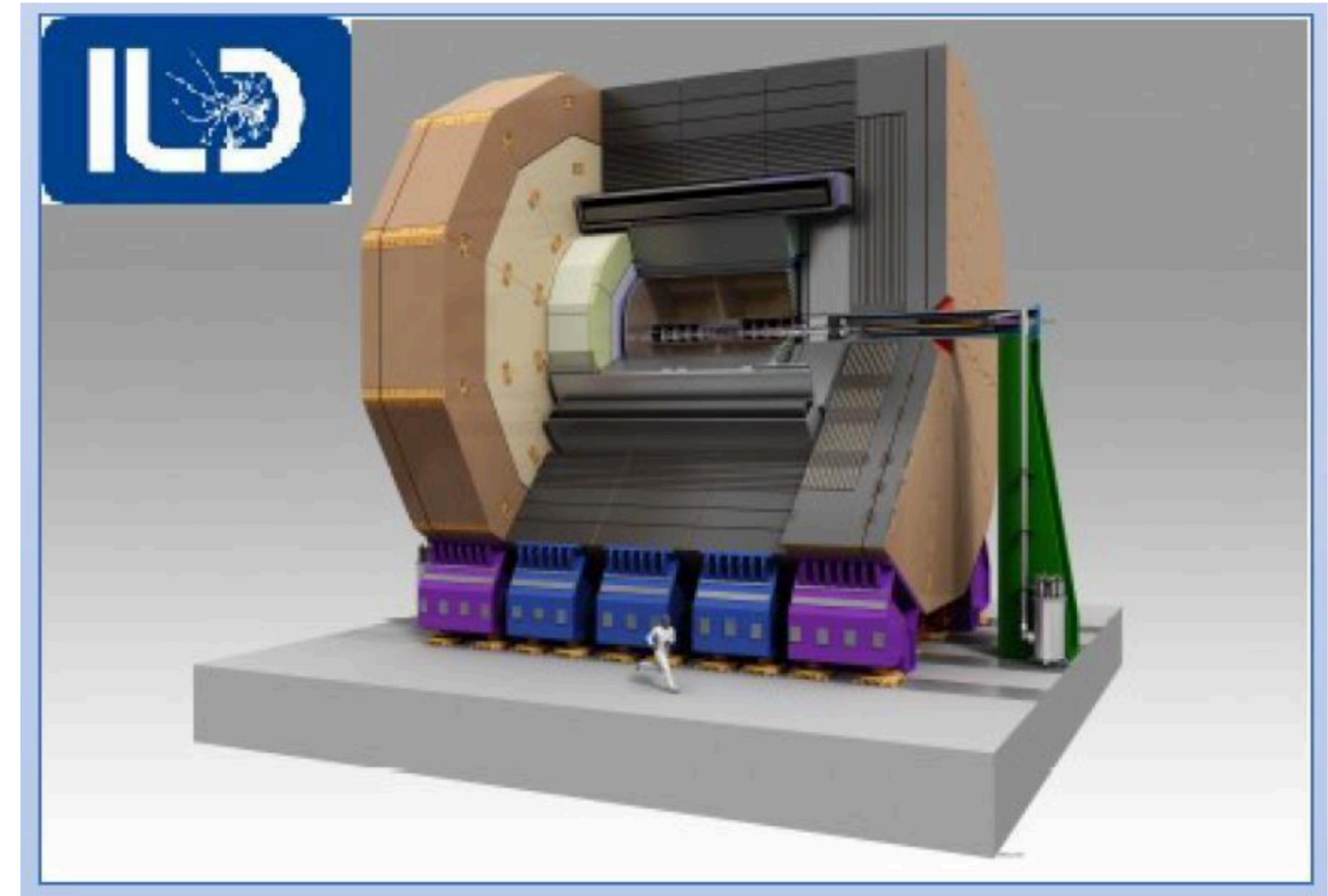(2002.12048)

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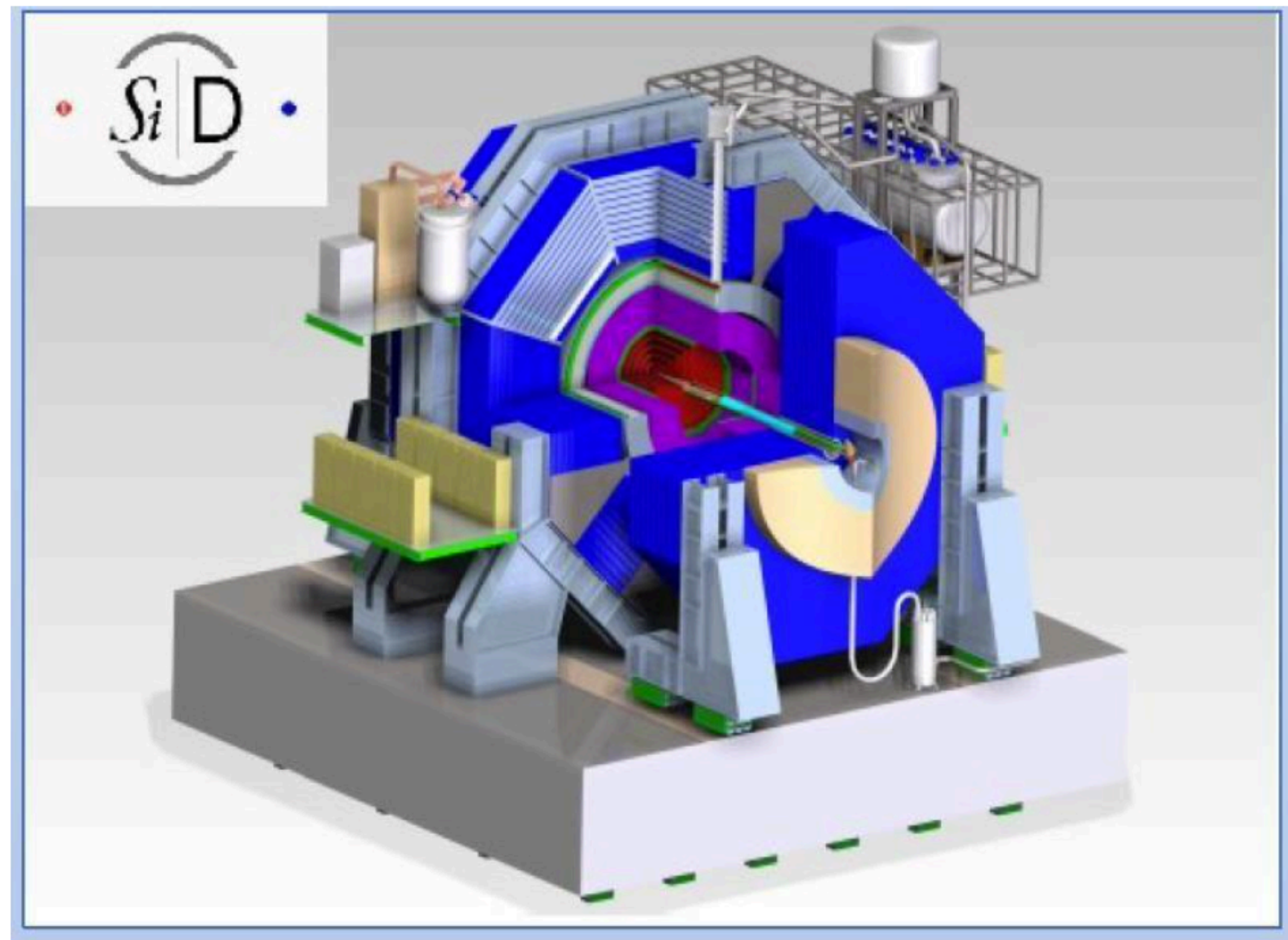ee 0.33%
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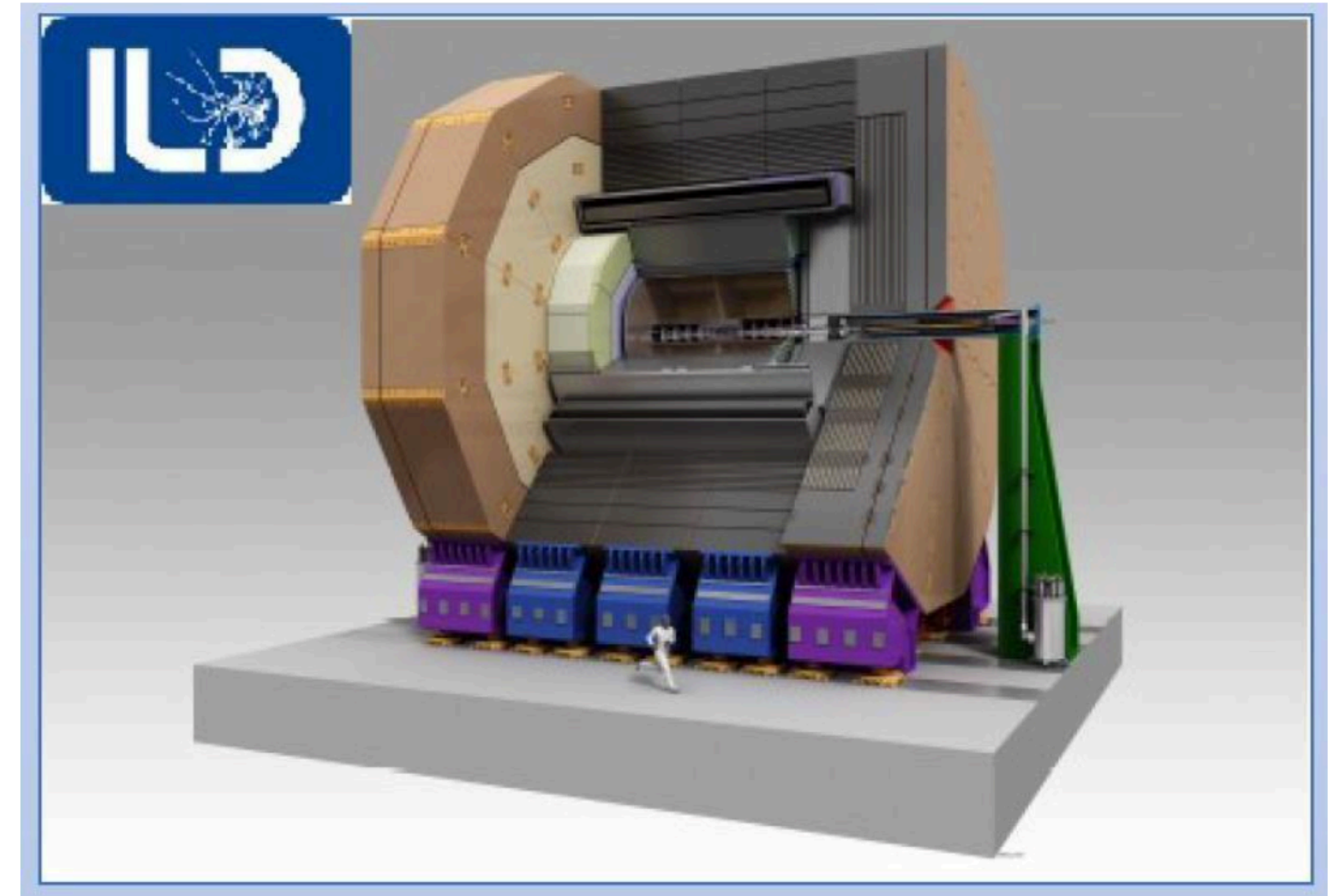
approaching SM limit

key4HEP

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- software stack that connects and extends individual packages towards a complete data processing framework for detector studies

  - fast/full simulation

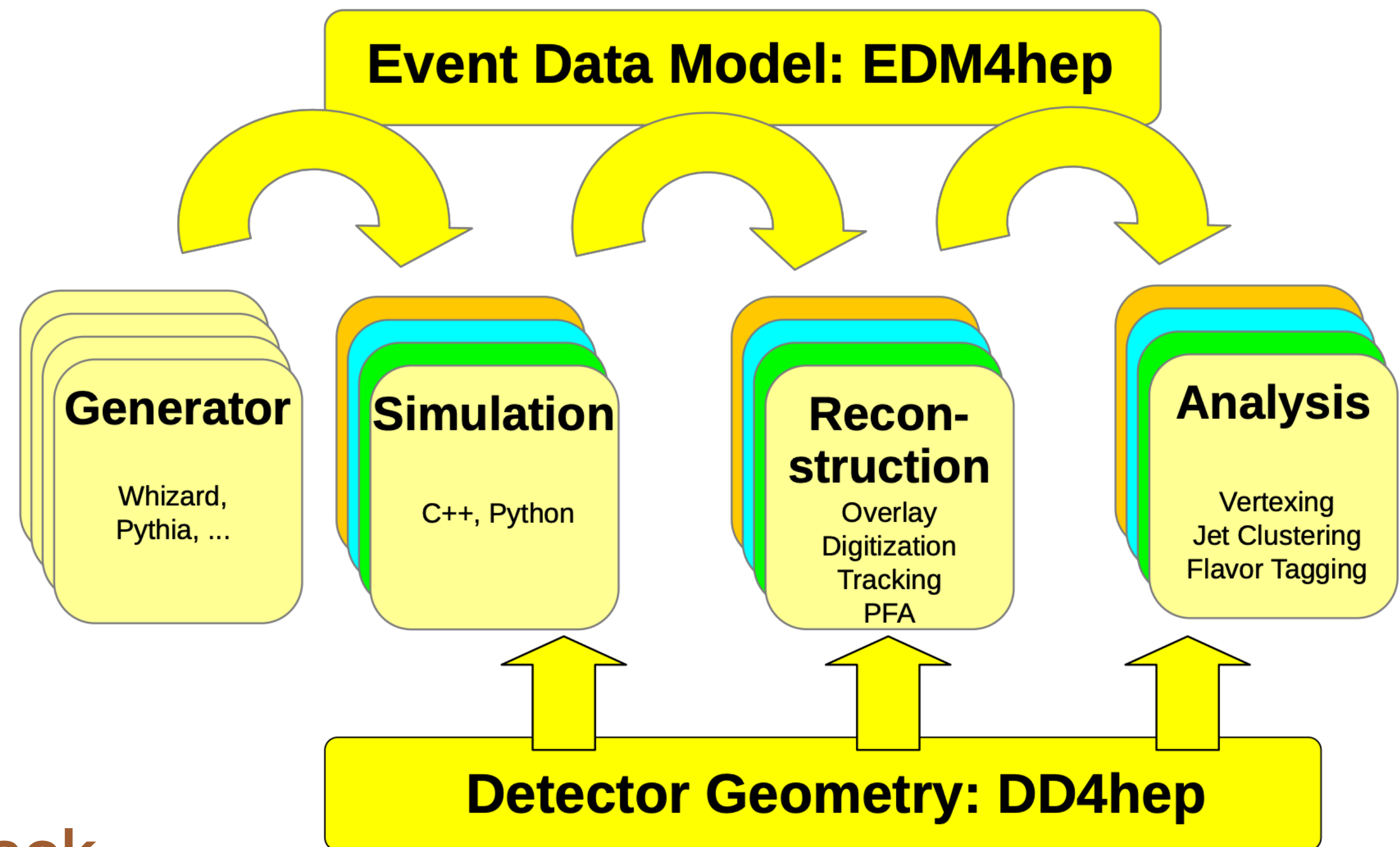 - reconstruction

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  - fast/full simulation

  - reconstruction

  - analysis

- Ingredients

  - Event data model: **EDM4hep**

  - Geometry information: **DD4hep**

  - Framework: **Gaudi**

  - Packaging and deployment: **Spack**

The Analysis

Analysis Structure

- forced two-jet reconstruction/two leptons required

- isolated lepton veto/jet veto

- Z mass reconstruction from di-jet/di-lepton

- ISR corrected recoil mass selection

- toy MC to set upper limit

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k4MarlinWrapper runs **Marlin** processors as **Gaudi** algorithms.

iLCSoft   key4HEP

	Marlin	Gaudi
language	C++	C++
working unit	Processor	Algorithm
configuration language	XML	Python
set up function	init	initialize
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- **LeptonPairing** (Marlin wrapper)

  - select Z pair candidate

  - brems/FSR recovery

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More Analysis Details: Major Backgrounds

- $e^+e^- \to ZZ \to Z\nu\nu$

- $e^+e^- \to WW \to W\ell\nu$

- $e^+e^- \to Z\nu_e\nu_e$

- $e^+e^- \to We\nu_e$
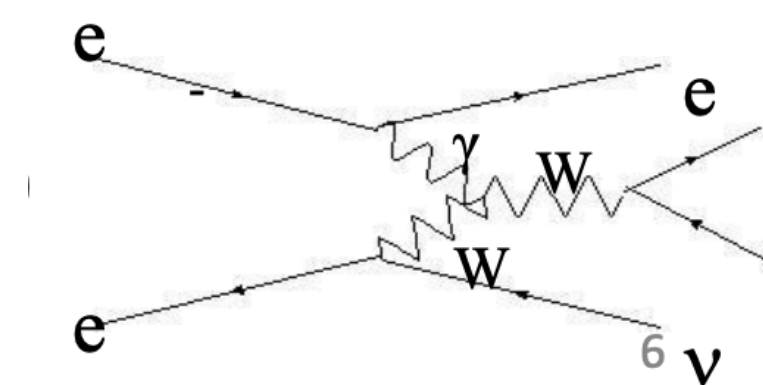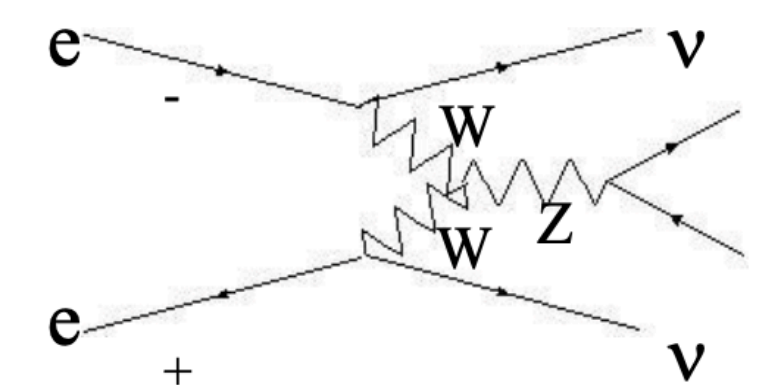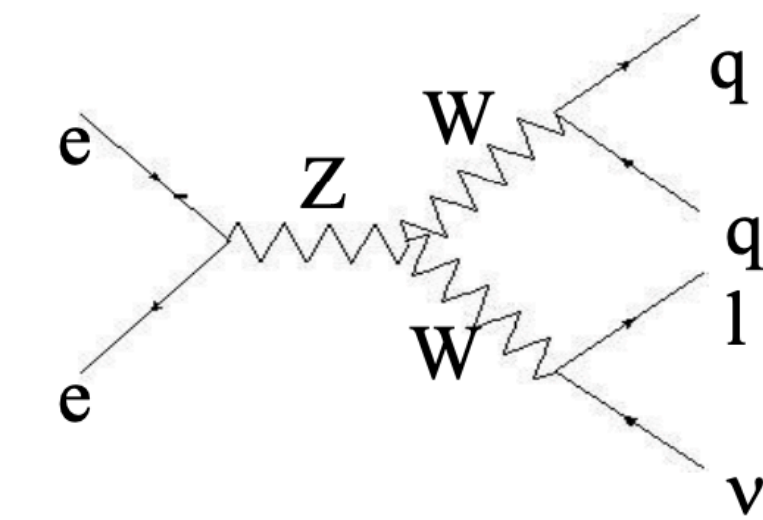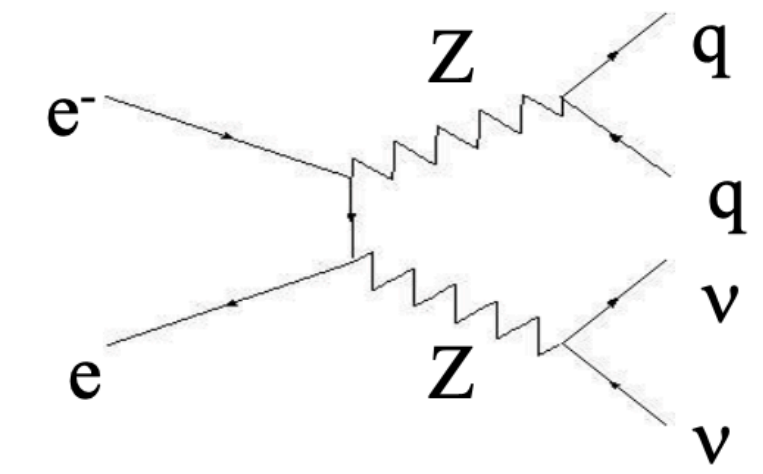
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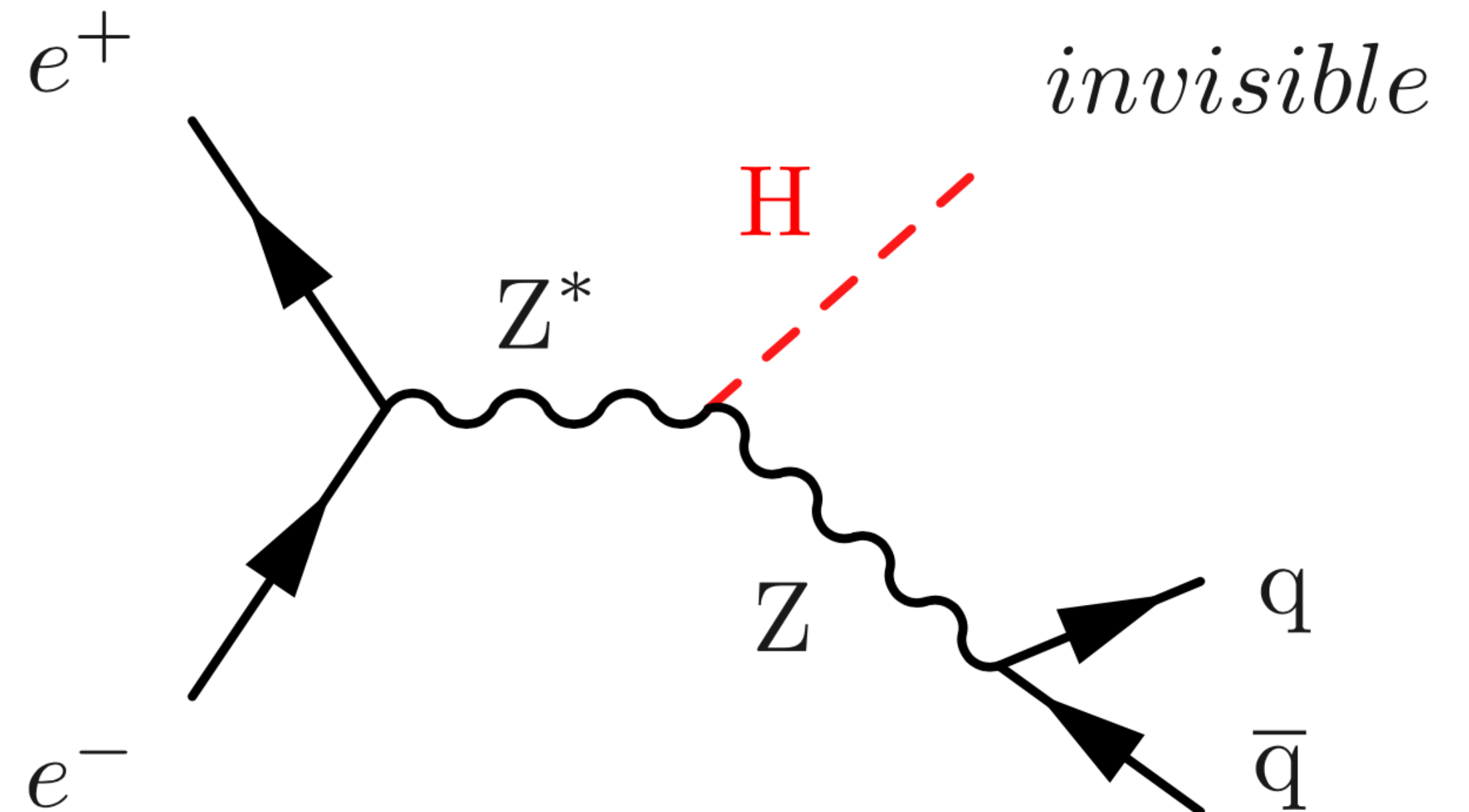
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- started writing some documentation (log)

Plans

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- measurement of the expected sensitivity to invisible Higgs boson decays

  - cut-based analysis (project student)

  - (multivariate analysis)

- comparison of ILD and SiD results

- key4HEP 'audit'

  - key4HEP example analysis

  - (tutorial)

Additional Information