The Strange Quark as a probe for new Physics in the Higgs Sector

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News

- Presented results during [FCC workshop]
- Paper sent to ILD for review, 2 referees assigned
  - Received comments yesterday (see gdoc on the agenda)
- Snowmass deadline on March 15th
- Need to decide how to proceed with FTag and H->cs

This work is largely independent from the specific accelerator and experiment considered. The conclusion strongly motivates further explorations of dedicated analysis techniques and detector technologies enhancing strange-tagging performance and, in turn, allowing to better constrain light Yukawa couplings and new physics models at any future Higgs factory. Additional improvements in the analysis sensitivity could arise from the usage of more complex neural networks for flavour tagging and machine learning approaches for the event selection. In the near future, we plan to reinterpret the analysis and perform a search for charged Higgs bosons decaying into a charm- and a strange-initiated jet. It will also be of paramount importance to perform a full simulation study and understand the impact that the introduction of a RICH system would have on object reconstruction, such as particle flow jets, and other physics benchmarks when used in conjunction with silicon or gaseous tracking detectors.

Analysis overview & results

See also M. Basso's talk at Higgs2021

Define Signal/Bkg

- Signal: Z(inv)H(ss)+: Z(ll)H(ss)
- Bkg: Z(inv/ll)H(bb,cc,gg), Z(qq & semil), ZZ(qqqq &semil), ZZ/WW(had), WW(had)

Select Events

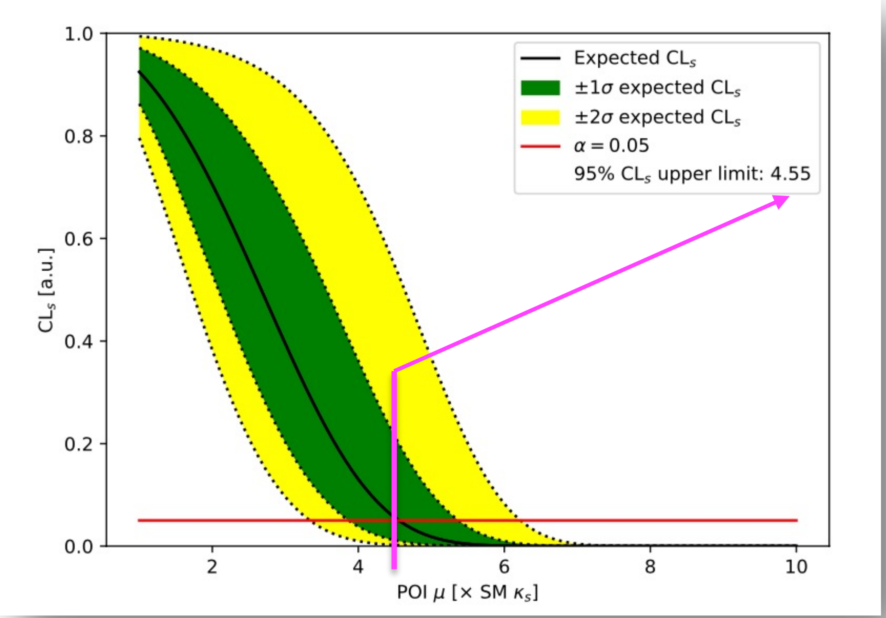
Most powerful cut on M_{jj} (see extra-slides for more details)

Build Signal discriminant

Sum of leading and sub-leading strange-jet score

s-Yukawa coupling

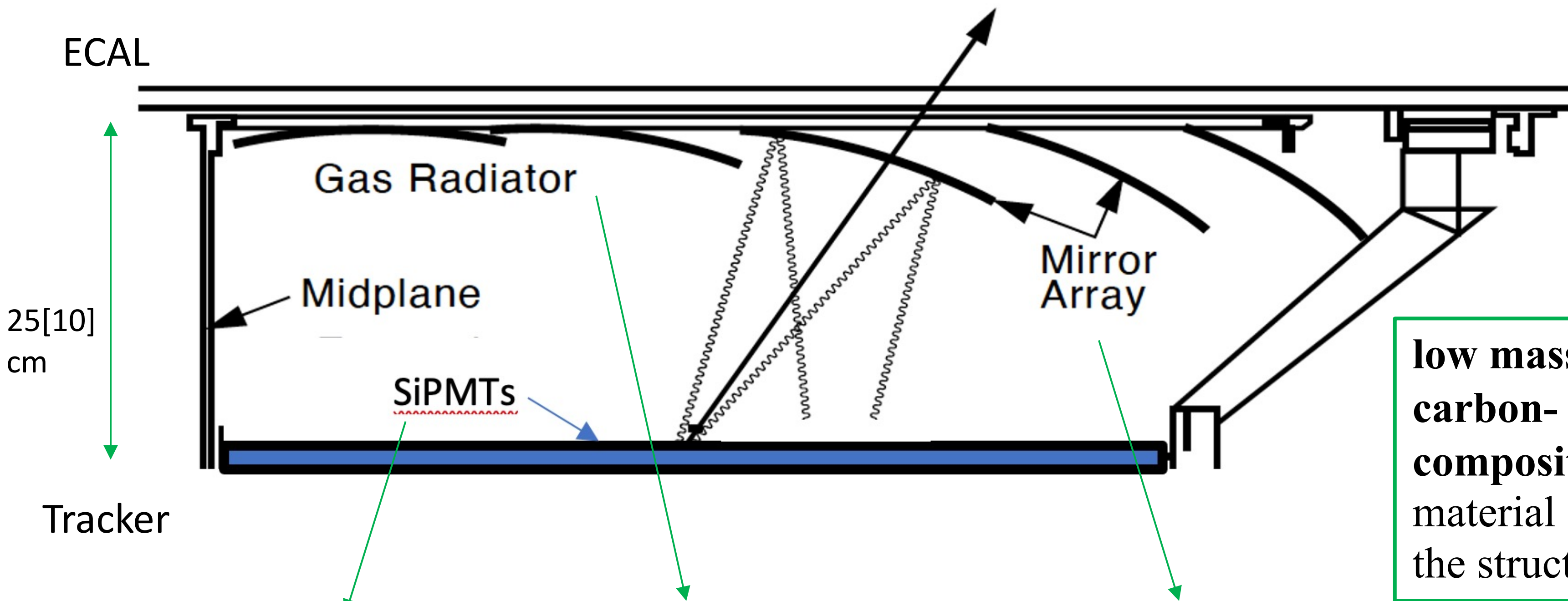
Probe various BSM regimes



Most stringent constraints on k_s derived so far!

Compact Gaseous RICH with SiPMTs

- **Past → Future**:
  - Much **smaller RICH** radial length (CRID ~ 1m), **SiPMTs** rather than TPCs for photon detection
- **Many parameters to look into!**



low mass carbon-composite material for the structure

Fast timing device (<100 ps) to provide ToF covering the lower p range and complementing the RICH

Pure **C_4F_{10}** at 1 bar (boiling point -1.9 C at 1 bar, good refraction index)

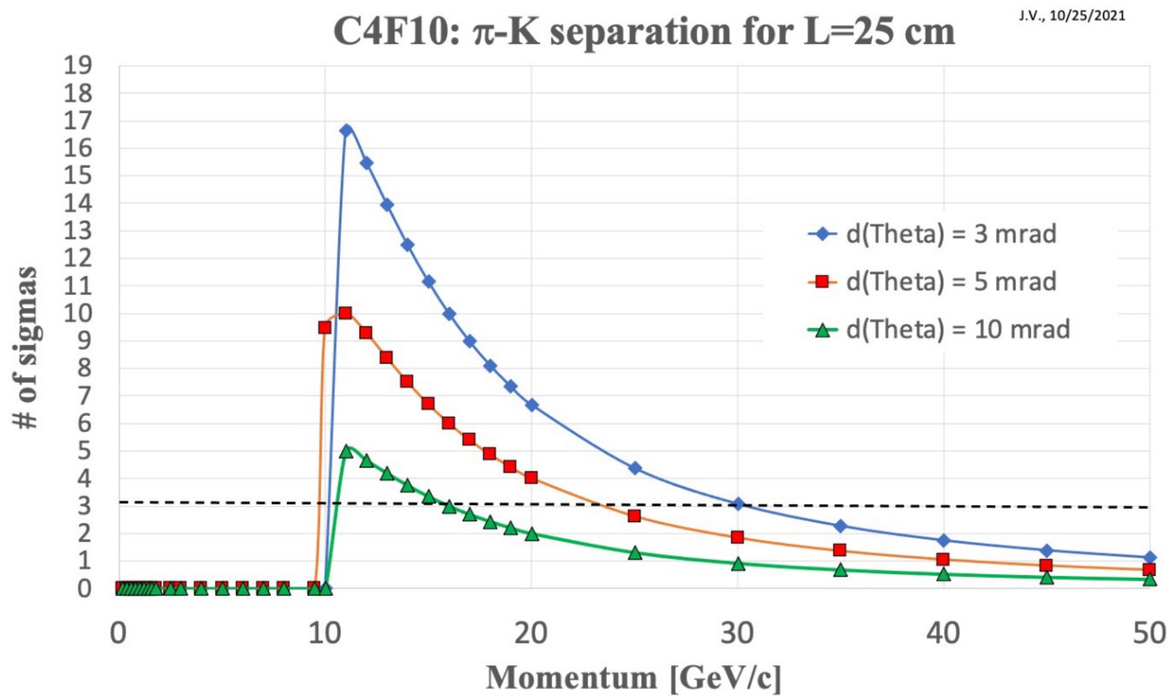
Beryllium with reflective coating

PID Performance of the Compact RICH with SiPMTs

# of sigmas = $\dfrac{\theta_\pi - \theta_K}{\sigma_\theta/\sqrt{N}}$

σ_θ is total Cherenkov angle resolution

N is number of photoelectrons per ring



If the Cherenkov error resolution is above the 5 mrad level, it will severely impact performance!

PID Performance of the Compact RICH with SiPMTs

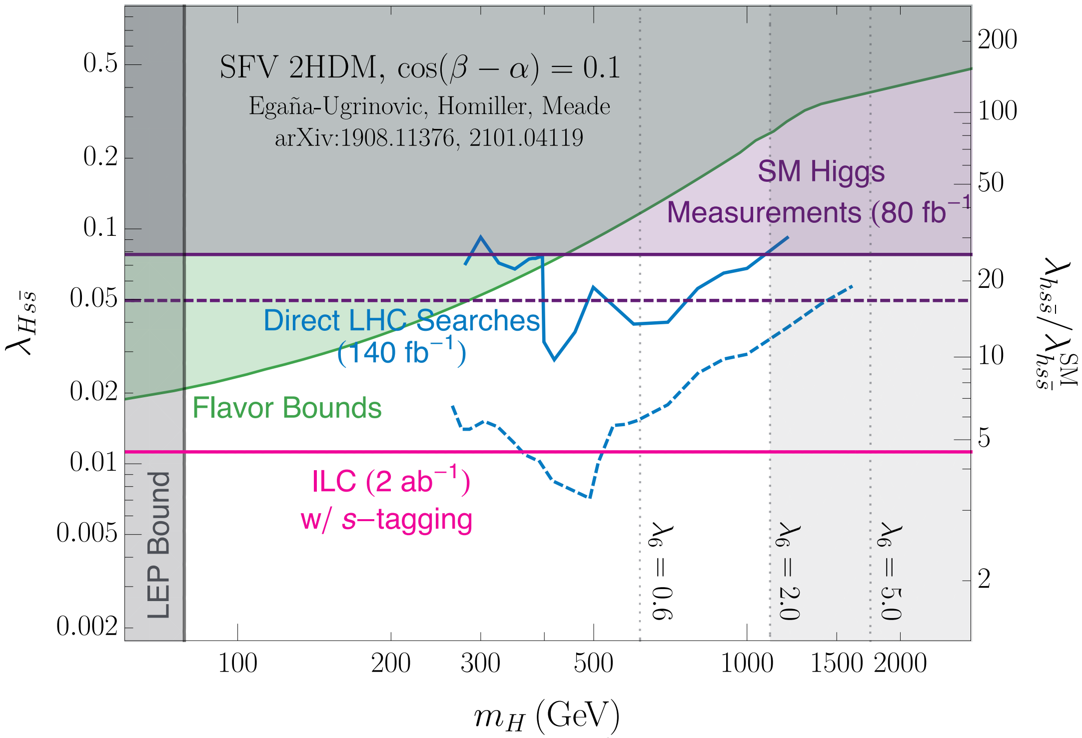
- Smearing effects increase with magnetic field and dip angles while decrease with momenta.
  - The contribution of various effects has been estimated, see much more in the back-up slides

Single photon error source	SiD/ILD RICH detector [mrad]	SLD CRID detector [mrad]
Chromatic error	~0.9	~0.4
Pixel size error ($1mm^2$ - $3mm^2$)	0.8 - 2.3	~0.5
Smearing effect due to magnetic field	1.5 - 2.5 B = 5 T	~0.5 B = 0.5 T
Mirror alignment	< 1	~1
Tracking angular error	< 1	~0.8 [9]
Other systematic errors	a few mrad	a few mrad
Total	**< 5**	**~ 4.3**

These results justify a full Geant 4 simulation!

Summary and Outlook (1)

- Testing **light Yukawa** coupling and, more generally, Yukawa universality is a **key physics benchmark** at future colliders
- The most stringent constraints on the **strange Yukawa** have been derived via a direct SM $\boldsymbol{h \to ss}$ search
  - The results allow to reduce the phase space for new physics down to $\boldsymbol{k_s \sim 5x\ SM}$
  - The analysis sensitivity is boosted by strange tagging in turn enabled by $\boldsymbol{\pi/K}$ **PID at high momenta**
- Next step: BSM interpretations, probe flavor violating decays or 2HDM such as H->cs ($BR \sim 0.5$, about 4 orders of magnitude larger than SM $\mathrm{h} \to ss$) or additional neutral $H \to ss$!



Summary and Outlook (2)

- **Complete re-look at Cherenkov gas detector technology**!
  - A **PID detector** added in between the tracker and the ECAL of a future detector at an e+e- machine can boost the potential of physics searches to study light Yukawas!
  - First studies show that **RICH technology with a compact design** can reach a **3sigma K/π** separation in the necessary **momentum range**
  - Evaluation of the **Cherenkov angle resolution**, and therefore reach of PID performance, has been performed (effects of chromaticity, bending of tracks, pixel size, tracking precision, noise, etc.).

- It **may be possible to accommodate a compact RICH system** while preserving the performance in tracking and calorimetry needed for physics
  - It's not just a question of space, but also of the **impact of the material** introduced between the tracker and ECAL
  - **This needs to be carefully studied**!
    - **Full simulation studies needed** to determine the precise performance, along with impact on the rest of the detector system

ECFA Detector R&D roadmap: Sect. 4.3.1 "The limited space of the interaction region for hermetic-coverage collider experiments (mandatory at the EIC and FCC-ee) requires designing performant RICH detectors with a total length shorter than a metre"

Thanks for your attention!

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