Physics Summary

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First Collaboration Meeting
(Oct. 11-14 2022)

Outline

A brief recap of the “Physics” talks.
Thanks to the parallel speakers!

- Lepton flavour universality violation (Admir on Thu.)
- Muon “beam dump” opportunities (Cari on Wed.)
- The case for a forward muon detector (Max on Wed.)
- Dark Matter (Xiaoran on Wed.)
- Making predictions (Yang on Wed., Mauro on Thu.)
- Intermediate steps (Qiang on Wed.)

And to Patrick and Robert for the plenary talks

Lepton Flavour Universality Violation

New Physics in $b \to s\mu\mu$: FCC-hh or a Muon Collider? #1

Aleksandr Azatov (SISSA, Trieste and INFN, Trieste), Francesco Garosi (SISSA, Trieste and INFN, Trieste), Admir Greljo (Bern U.), David Marzocca (INFN, Trieste), Jakub Salko (Bern U.) et al. (May 26, 2022)

e-Print: 2205.13552 [hep-ph]

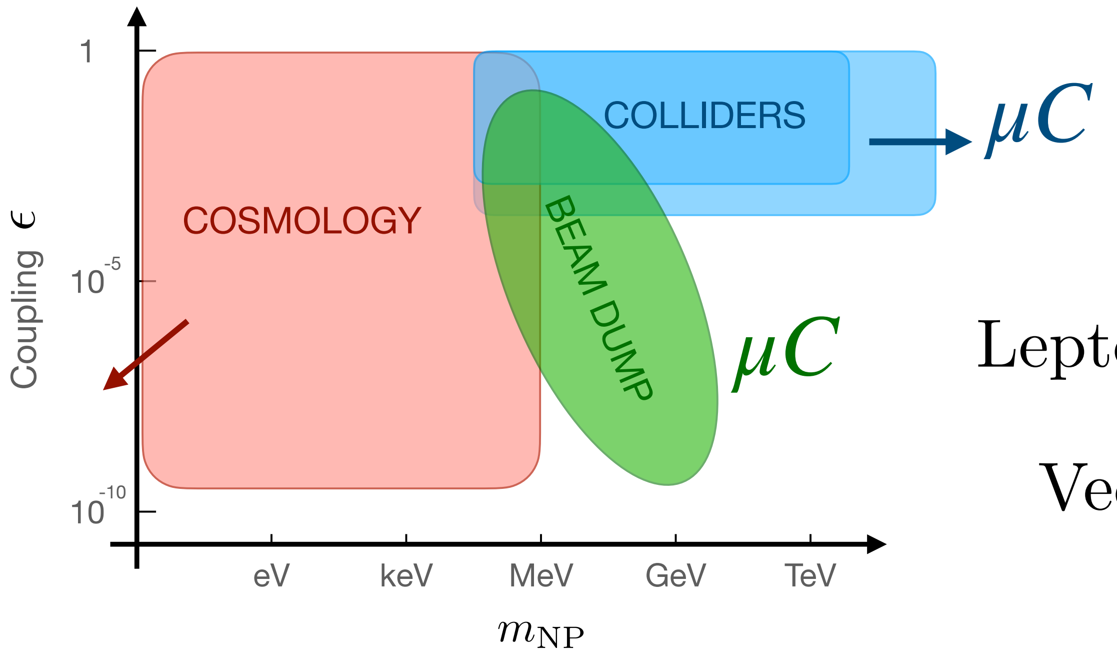
Study of future colliders potential to unveil origin of B-anomalies

> " We find that a 3 TeV MuC has a sensitivity reach comparable to the one of the FCC-hh. ...
> Finally, to completely cover the parameter space suggested by the bsμμ anomalies, among the proposed future colliders, only a MuC of 10 TeV (or higher) can meet the challenge. "

Illustrates how colliding muons for the first time gives **access to currently un-tested muon-philic BSM**

New physics at the muon collider
[Cari Cesarotti]

Future multi-TeV μC provides a complementary physics program

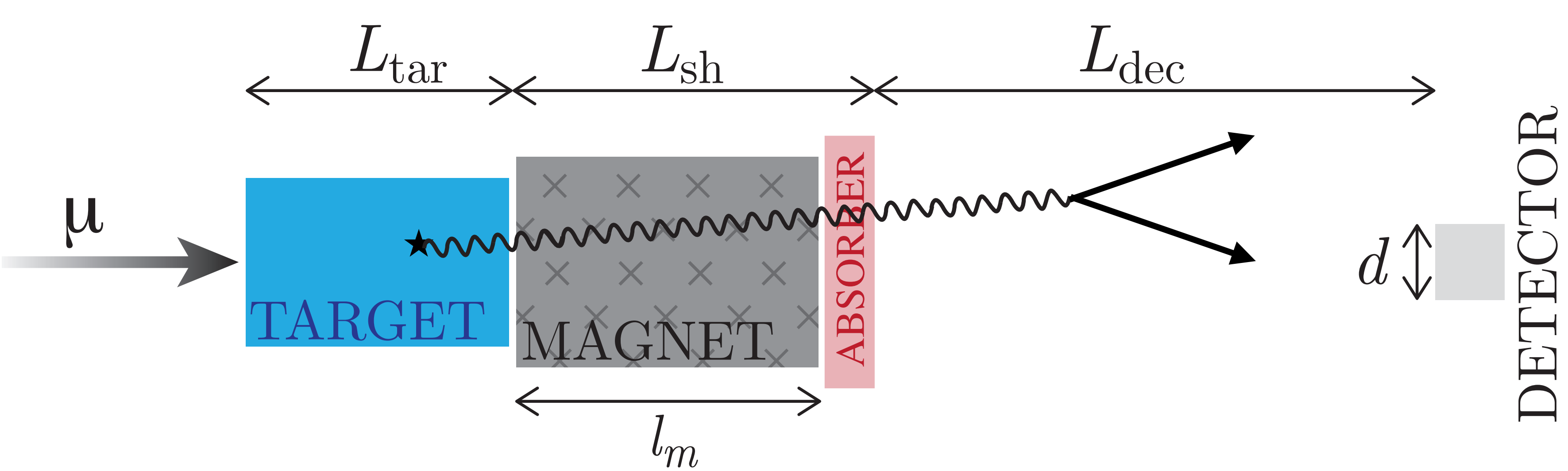


Leptoquarks @ Collider

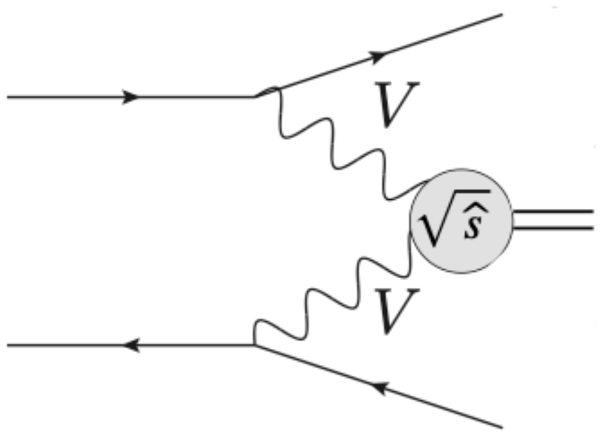
Vector Bosons @ BD

2104.05720 CC, P. Asadi, R Capdevilla, S. Homiller 2202.12302 CC, S. Homiller, R. Mishra, M. Reece

Muon Beam Dump:
-difficult?
-easy?
-~ for free?



The case for a forward muon detector
[Maximilian Ruhdorfer]



Taken from 2203.07256

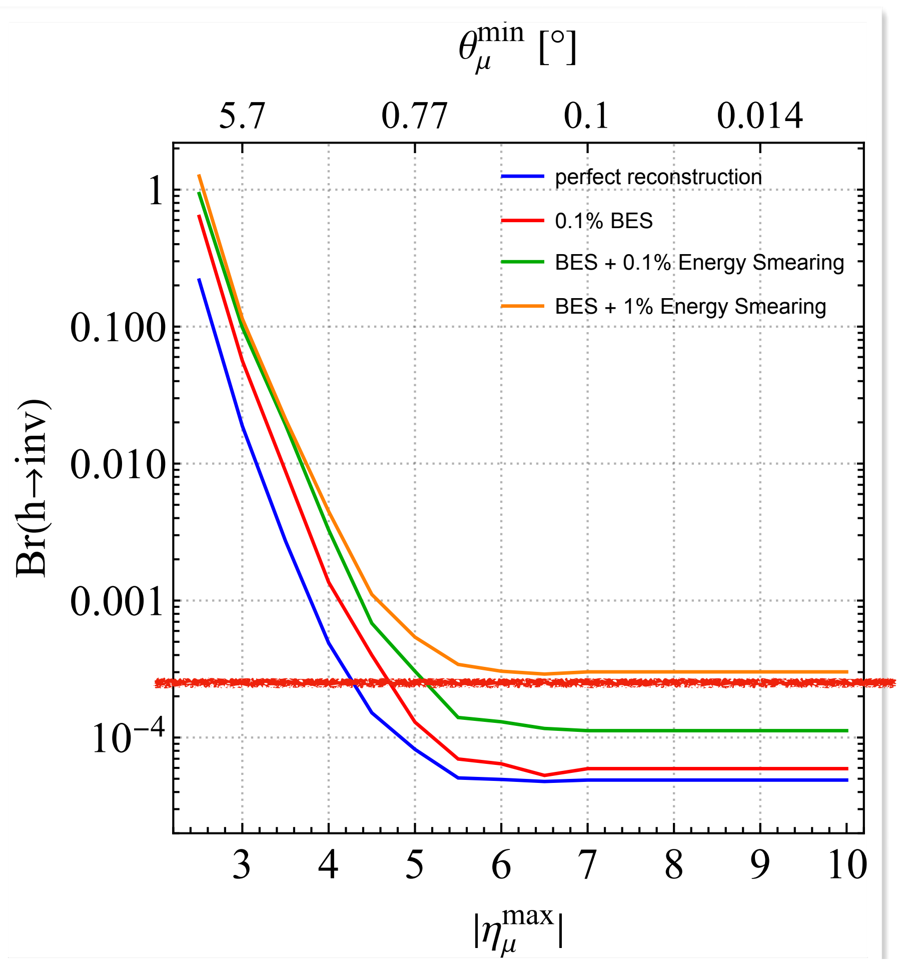
Resolving forward muons is essential for:

1. Better BG separation in Higgs coupling measurements (e.g ZZ fusion vs WW fusion)

See e.g. Forsl

2. Studying signatures with invisible particles (DM, LLPs,…)

- Sensitivity to BR($h \to$ inv) with all effects combined



1. Perfect 4-momentum reconstruction

2. 0.1% BES

3. 0.1% BES + 0.1% energy uncertainty

4. 0.1% BES + 1% energy uncertainty

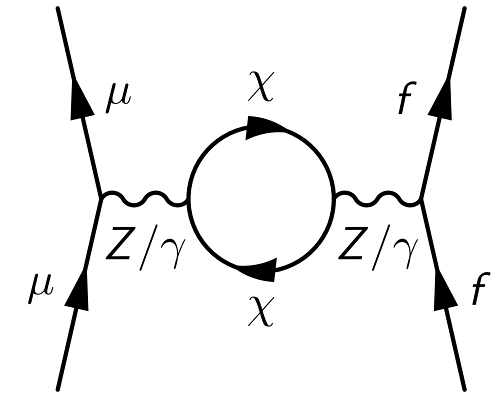
FCC-hh projection: $2.5 \cdot 10^{-4}$

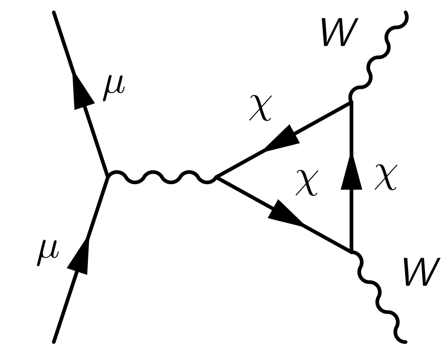
Only at MuC, neutral VBF tagging could be possible

Detector studies needed

Dark Matter
[Xiaoran Zhao]

- mono-X,di-X and DT for low mass region $M_\chi < \frac{\sqrt{s}}{2}$
- Indirect probes are good at thresholds $M_\chi \sim \frac{\sqrt{s}}{2}$
- and can probe high mass $M_\chi > \frac{\sqrt{s}}{2}$
- Soft/collinear radiations shift NC to NC+CC
- Hard radiations affect the dynamics and sensitivities
- Statistic uncertainties in $\mathcal{O}(0.1 \sim 1\%)$ level: need further improvements on theoretical predictions(NLO+NLL or higher?)





	3 TeV			10 TeV			30 TeV		
	DL	$e^{\mathrm{DL}}-1$	$\mathrm{SL}(\frac{\pi}{2})$	DL	$e^{\mathrm{DL}}-1$	$\mathrm{SL}(\frac{\pi}{2})$	DL	$e^{\mathrm{DL}}-1$	$\mathrm{SL}(\frac{\pi}{2})$
$\ell_L \to \ell'_L$	-0.46	-0.37	0.25	-0.82	-0.56	0.33	-1.23	-0.71	0.41
$\ell_L \to q_L$	-0.44	-0.36	0.25	-0.78	-0.54	0.34	-1.18	-0.69	0.42
$\ell_L \to e_R$	-0.32	-0.27	0.13	-0.56	-0.43	0.17	-0.85	-0.57	0.21
$\ell_L \to u_R$	-0.27	-0.24	0.11	-0.48	-0.38	0.15	-0.72	-0.51	0.18
$\ell_L \to d_R$	-0.24	-0.21	0.10	-0.43	-0.35	0.13	-0.64	-0.47	0.16
$\ell_R \to \ell'_L$	-0.32	-0.27	0.13	-0.56	-0.43	0.17	-0.85	-0.57	0.21
$\ell_R \to q_L$	-0.30	-0.26	0.12	-0.53	-0.41	0.16	-0.79	-0.55	0.21
$\ell_R \to \ell'_R$	-0.17	-0.16	0.07	-0.30	-0.26	0.09	-0.46	-0.37	0.12
$\ell_R \to u_R$	-0.12	-0.12	0.05	-0.22	-0.20	0.07	-0.33	-0.28	0.08
$\ell_R \to d_R$	-0.09	-0.09	0.04	-0.17	-0.16	0.05	-0.25	-0.22	0.06

Note: we are currently not able to make sufficiently accurate predictions for this study (and many others)

Monte Carlo Tools
[Mario Chiesa]

Conclusions

- only few MC event generators for high-energy μ-colls available, generally only at LO accuracy
- in principle it is possible to transpose all the technology developed for high-precision generators for hadron colliders to the leptonic environment
- in practice, some new challenges arise, mainly connected to the large $\sqrt{s}$ and the large final-state multiplicities, Sudakov corrections

EW and QCD physics at the muon collider

[Yang Ma]

Improving understanding of **partons in the proton**

MuC is **also** a Vector Bosons Collider

(but **also** a muon collider: this is its **dual** nature)

Compare the “EW LHC” with LHC

pp VS $\mu\mu$

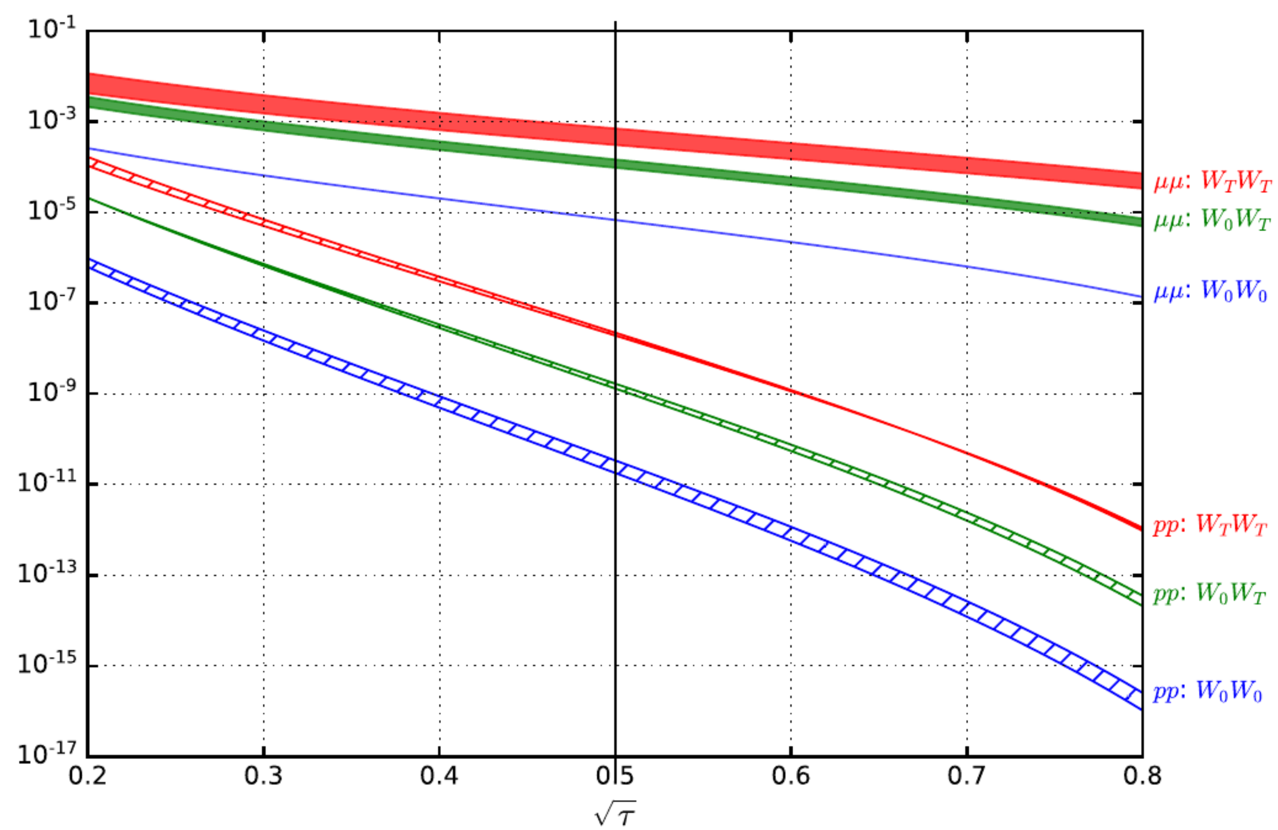
$$\mathcal{L}_{W^+_{\lambda_1} W^-_{\lambda_2}} = \int_\tau^1 \frac{d\xi}{\xi} f_{W_{\lambda_1}}(\xi, \mu_f) f_{W_{\lambda_1}}(\frac{\tau}{\xi}, \mu_f)$$

Consider the two colliders in the same ring

$$\sqrt{s}_{\mu\mu} = \sqrt{s}_{pp}$$

For $2 \to 1$ processes, take a benchmark

$$\sqrt{\tau} = \frac{M}{\sqrt{s}} = \frac{1}{2}$$



[2005.10289]

The ratio $\mu\mu/pp$ is larger than 10^4!

Possible intermediate steps towards a MuC

[Qiang Li]

An neutrino-neutrino collider is quite sensitive to neutrino physics

- Several days of run to observe neutrino annihilation

An neutrino-lepton collider is quite sensitive to W mass

- 10MeV accuracy with 0.1/fb!

An electron-muon collider is sensitive to CLFV and Higgs Physics

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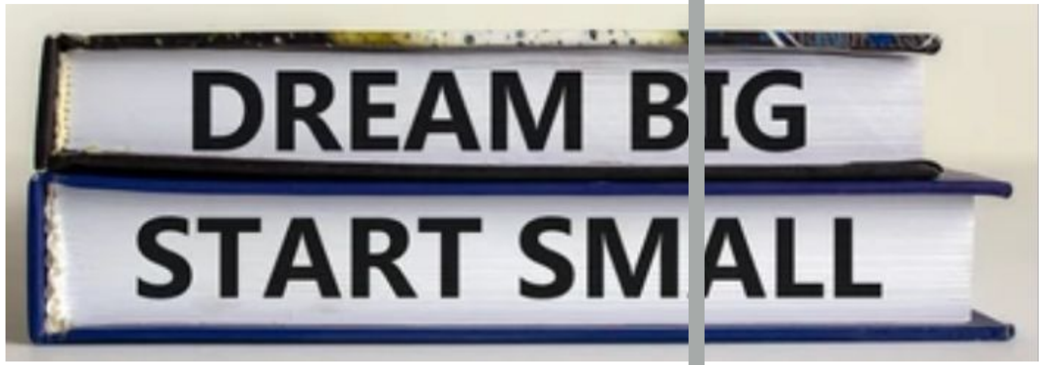

Stages

- MuC of lower or much lower energy than 10TeV
- Cheaper and faster to finance and build
- Almost all what is there, must be reusable for 10
- For TeV-scale MuC, 3 TeV baseline seems adequate
- In the 100 GeV scale, options are Higgs-pole and top threshold. More studies needed

Physics along the way

- What can be done while facility being build, or at the demonstration or R&D stage
- Couple MuC to other programs.
- Plenary talks by Patrick and Robert