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A study of dark photon simulation at e^+e^- colliders based on high performance computing

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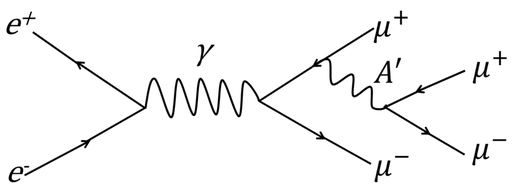
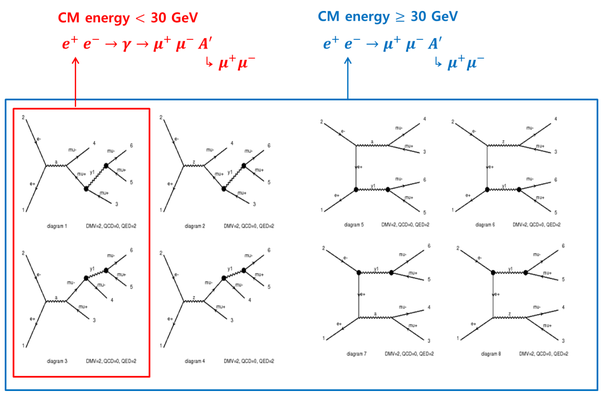
Introduction

Signal mode and simplified model

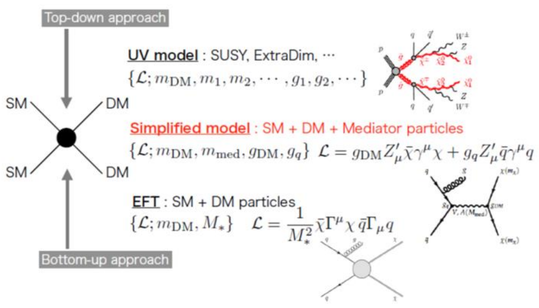
- **A' couples only to heavy flavor lepton [1, 2]**

$$e^+ e^- \rightarrow \mu^+ \mu^- A'$$
$$\hookrightarrow \mu^+\mu^-$$

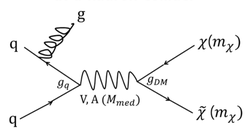




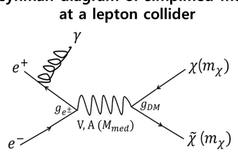
- **Simplified model [3, 4]**



Feynman diagram of simplified model at a hadron collider



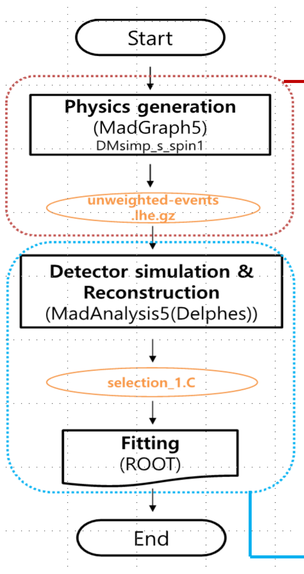
Feynman diagram of simplified model at a lepton collider



- The Standard Model particles + Dark Matter + Mediator particles (dark photon)
- A': dark photon with spin1
- Imported in MadGraph5

Methods

Flowchart of softwares



Specification	KISTI-5 KNL	KISTI-5 SKL	Local Linux machine
OS	CentOS 7.4	CentOS 7.4	Scientific Linux 6.5
Processor	Intel Xeon Phi 7250@1.4 GHz	Intel Xeon Skylake (Gold 6148) @2.4 GHz	Intel Xeon CPU X5560@2.8 GHz
Architecture	Many-core	Multicore	Multicore
Number of cores/CPU	68	20	4
Number of CPUs/node	1	2	8
Number of cores/node	**68**	**40**	**32**
Number of total nodes	8,305	132	1
Number of total cores	564,740	5,280	32

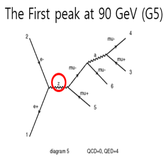
Study of Dark Matter at e+e- collider

Background (SM)

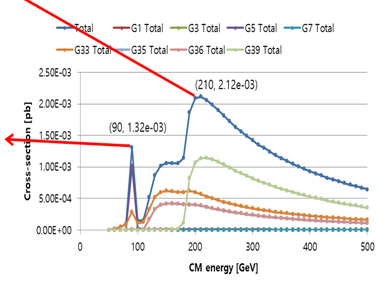
$$e^+ e^- \rightarrow \mu^+ \mu^- \mu^+ \mu^-$$

Maximum at 210 GeV (G39)

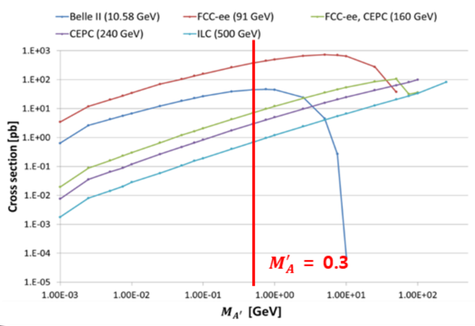
The First peak at 90 GeV (G5)



Cross-section depending on **CM energy**

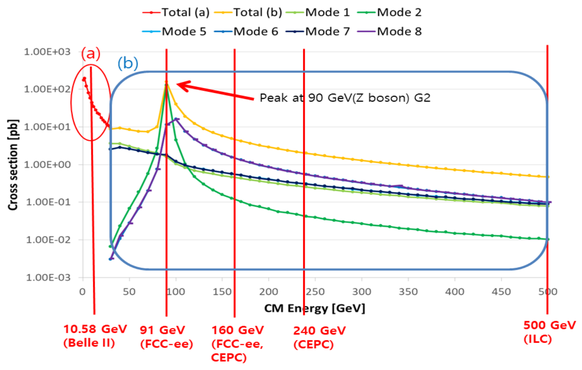


Cross section depending on **dark photon mass**

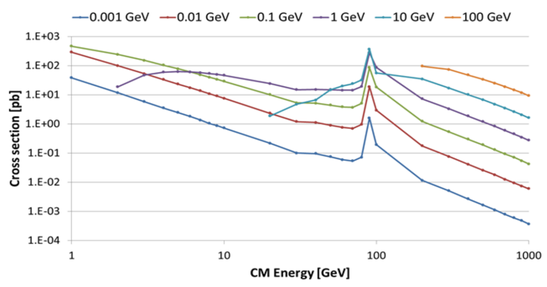


Signal at generation level

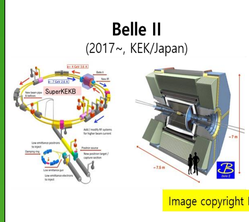
Cross section depending on **CM energy**

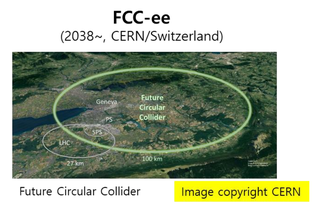


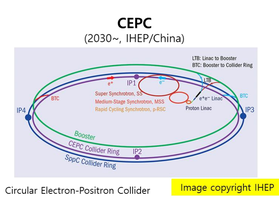
Cross-section depending on **both CM energy and dark photon mass**

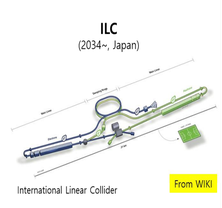


Current and Future e+e- Colliders



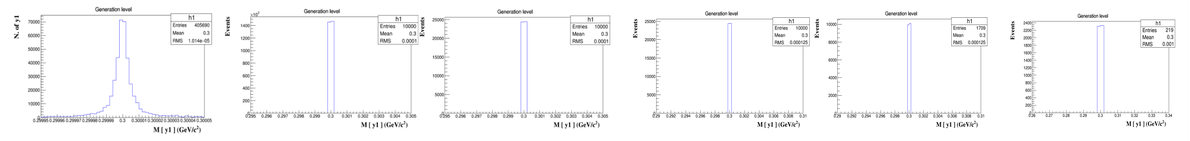




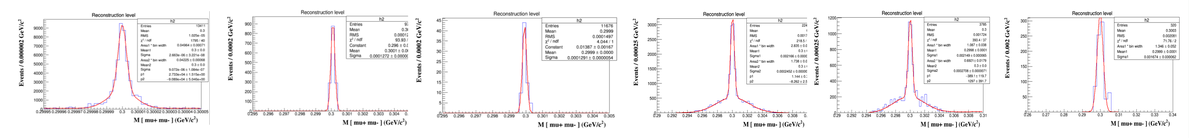


Belle II (10.58 GeV) | **FCC-ee (91 GeV)** | **FCC-ee (160 GeV)** | **CEPC (160 GeV)** | **CEPC (240 GeV)** | **ILC(500 GeV)**

Generation level



Reconstruction level



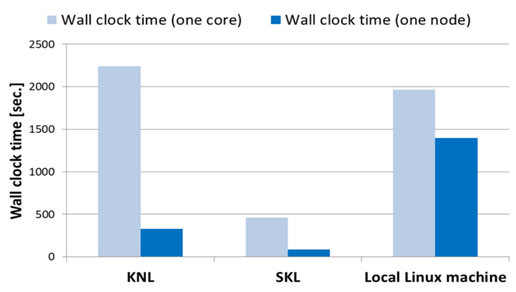
- **Detector acceptance of experiments**

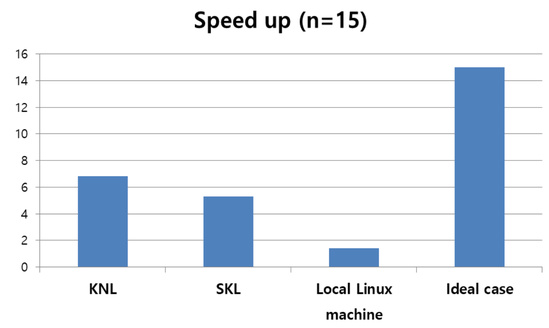
Experiments	CM energy [GeV]	Signal process	Delphes (η cut only)	Delphes card	Detector acceptance (%)
Belle II	10.58 GeV (e^-: 7 GeV, e^+: 4 GeV)	$e^+e^- \rightarrow \gamma \rightarrow \mu^+\mu^- A'$ with $A' \rightarrow \mu^+\mu^-$	$-1.317 \leq \eta \leq 1.901$	delphes_card_CMS.tcl η cut edit	**11.325 ± 0.121**
FCC-ee	91 GeV ($e^\pm$: 45.5 GeV)	$e^+e^- \rightarrow \mu^+\mu^- A'$ with $A' \rightarrow \mu^+\mu^-$	$-3.0 \leq \eta \leq 3.0$	delphes_card_IDEA.tcl	**0.051 ± 0.000**
	160 GeV ($e^\pm$: 80 GeV)				**0.142 ± 0.017**
CEPC	160 GeV ($e^\pm$: 80 GeV)			delphes_card_CEPC.tcl	**37.484 ± 0.356**
	240 GeV ($e^\pm$: 120 GeV)				**35.543 ± 0.839**
ILC	500 GeV ($e^\pm$: 250 GeV)		$-2.4. \leq \eta \leq 2.4$	delphes_card_ILD.tcl	**14.539 ± 0.562**

- CEPC has the highest detector acceptance among experiments.
- FCC-ee has the lowest detector acceptance due to low tracking efficiency of muon.

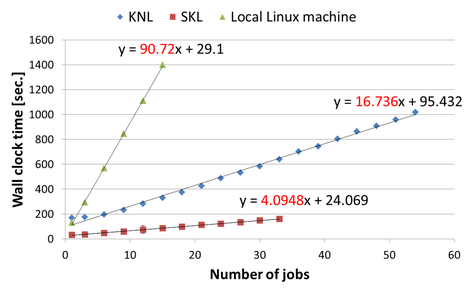
CPU time studies

- **Study of CPU times on machines**





- **Study of CPU times on number of jobs**



- The smaller the slope, the better the parallel processing efficiency.
- In terms of parallel processing efficiency according to the number of jobs, the SKL is about 22 times better than the Local Linux machine.

Summary

- We have used dark photon that couples only to heavy lepton for signal process.
- We have studied the physical quantities of generation-level and reconstruction-level at the various CM energies.
- We have compared different machines to study efficiency of parallel processing.
- The results will help to optimize HEP software using HPC.

Reference

[1] Insung Yeo and Kihyeon Cho, J. Astron. Space Sci. 35 (2018) 67-74.
[2] Shuve Brian and Itay Yavin, Physical Review D 89.11 (2014) 113004.
[3] Daniele, et al., Alves, Journal of Physics G: Nuclear and Particle Physics, 39(10) (2012) 105005.
[4] Kentarou Mawatari's ppt (KAIST-KAIX workshop 07/15/19).
[5] Kihong Park and Kihyeon Cho , J. Astron. Space Sci. 35, (2021) 55-63.