Throughput Computing 2023

OSG All-Hands Meeting   HTCondor Week

KOTO's computing experience on the Open Science pool

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KOTO: search for the very rare decay $K_L^0 \to \pi^0 \nu\bar{\nu}$

Target: Search for the $K_L^0 \to \pi^0 \nu\bar{\nu}$ decay

→ Only happens once every 33 billion kaon decays in the theory.

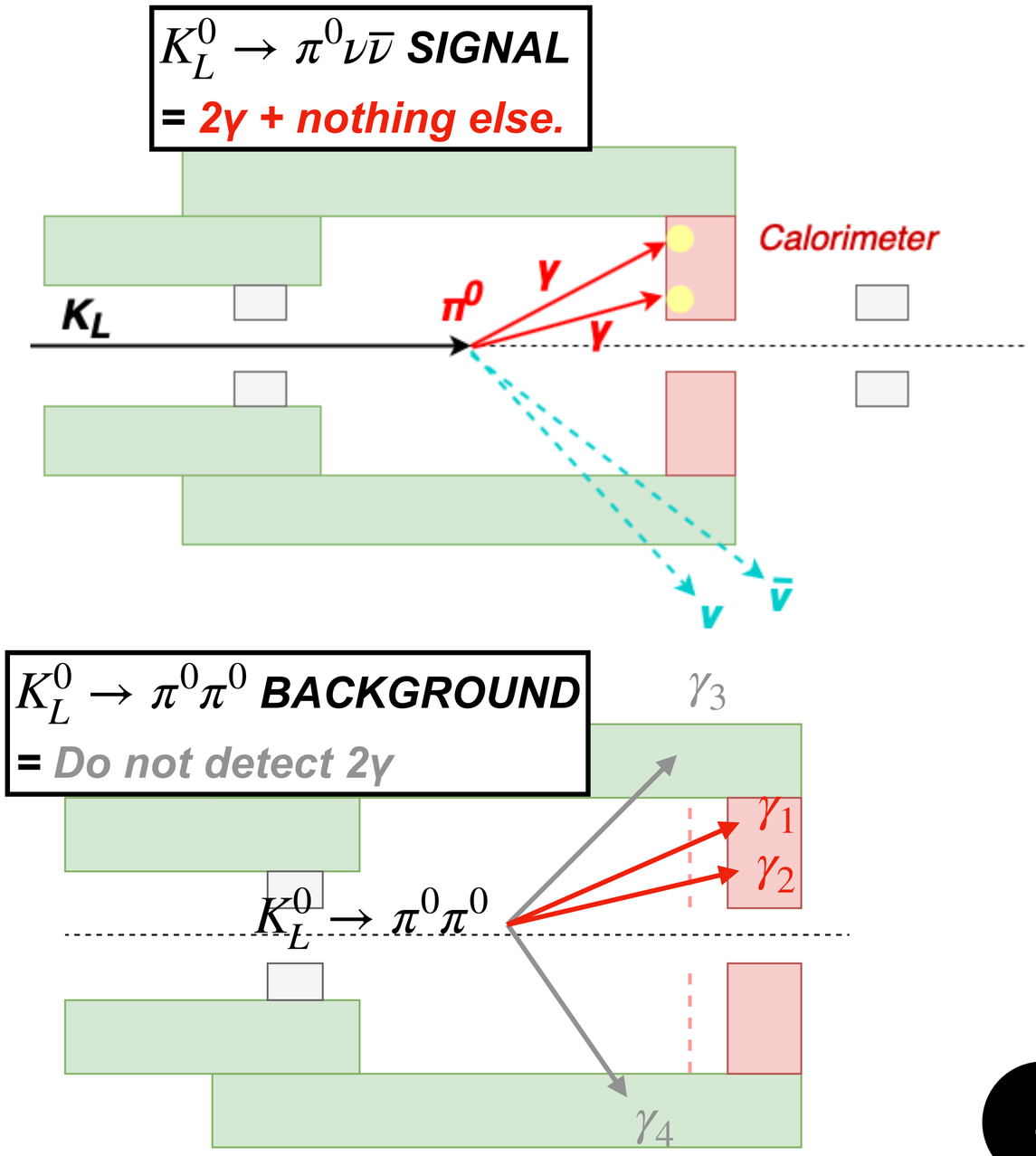
→ A golden mode that may further hint how the nature creates the matter-dominated Universe.

Observed Universe: MATTER >> *ANTI-MATTER*

Why OSG?

KOTO simulates copious events that can mimic signals using Monte Carlo method.

- Quantitatively evaluate the threat of each possible source.
- The accuracy relies on the number of simulated events.
- OSG is a perfect platform for KOTO to perform the Monte Carlo simulation.



History of OSG at KOTO

2022/05

Initiated the OSG project

Simulated the first KOTO event using OSG machines.

2022/08

Built the KOTO library

Started installing the full KOTO simulation library at OSG.

2023/02

Deployed the stable version

Confirmed the results produced from OSG were expected.

2023/03

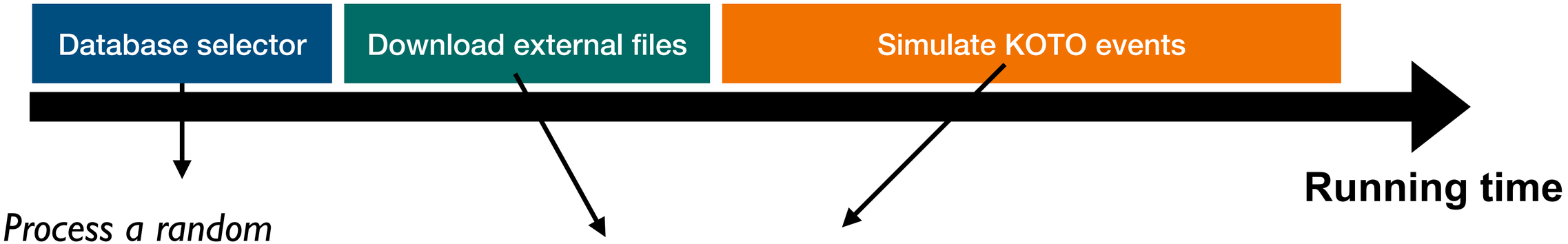
Mass production

Kept job submissions for KOTO.

Strategy to overcome the KOTO database problem

✓ KOTO implements a huge database (external files 20TB) to perform the simulation.

✓ Introduce "drawers" in database; only select the files to be used.

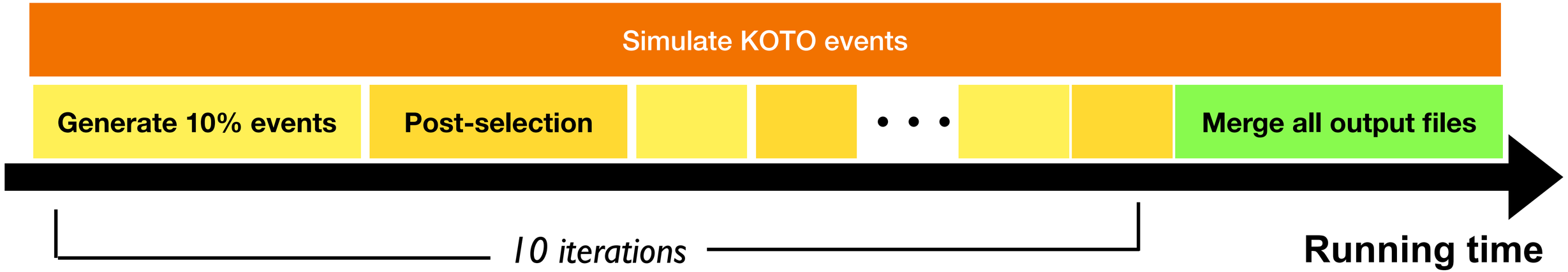


Process a random procedure to select the "drawer" in database.

Minimize the external file size and maximize #events to reduce the overhead time.

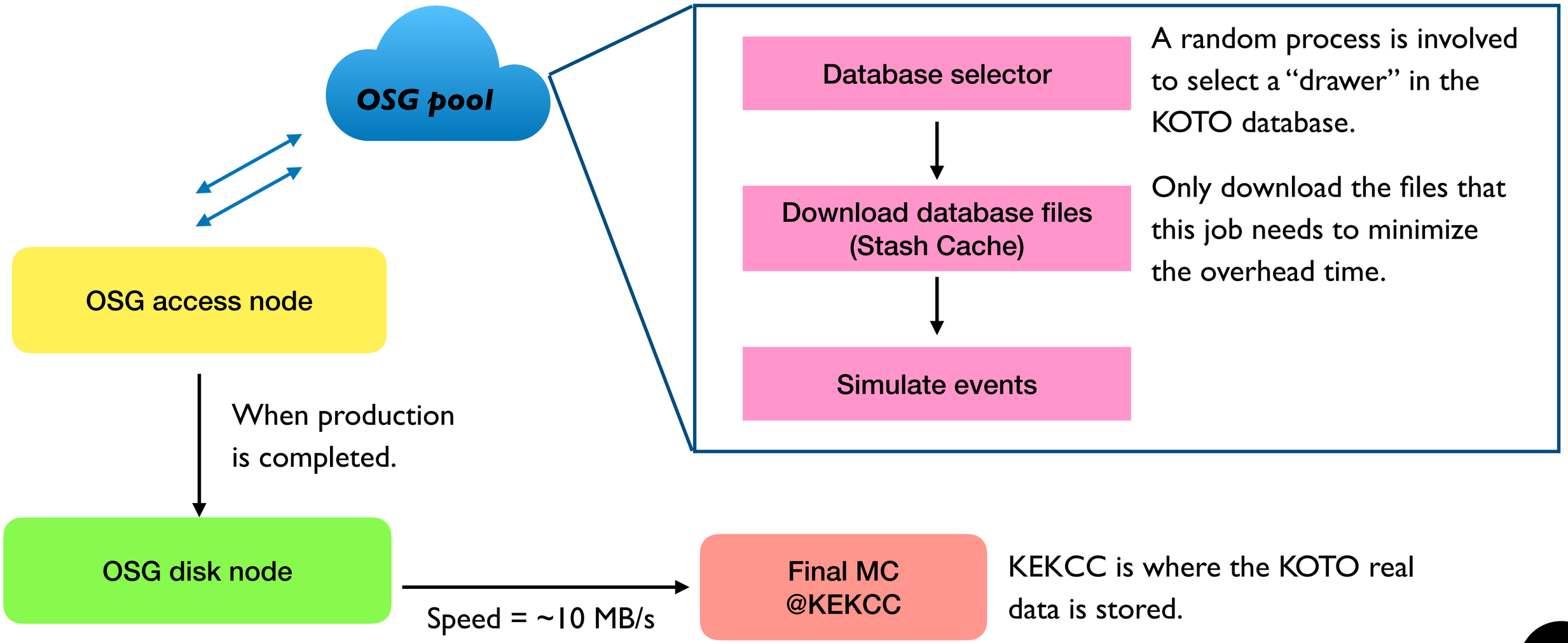
Strategy to overcome the disk space problem

- ✓ KOTO's standard output file is huge (20 GB).
  - ✓ Hope to keep the overhead time small.
  - ✓ Produce 10% of events first and only keep events in interest.
  - ✓ Repeat this procedure 10 iterations.



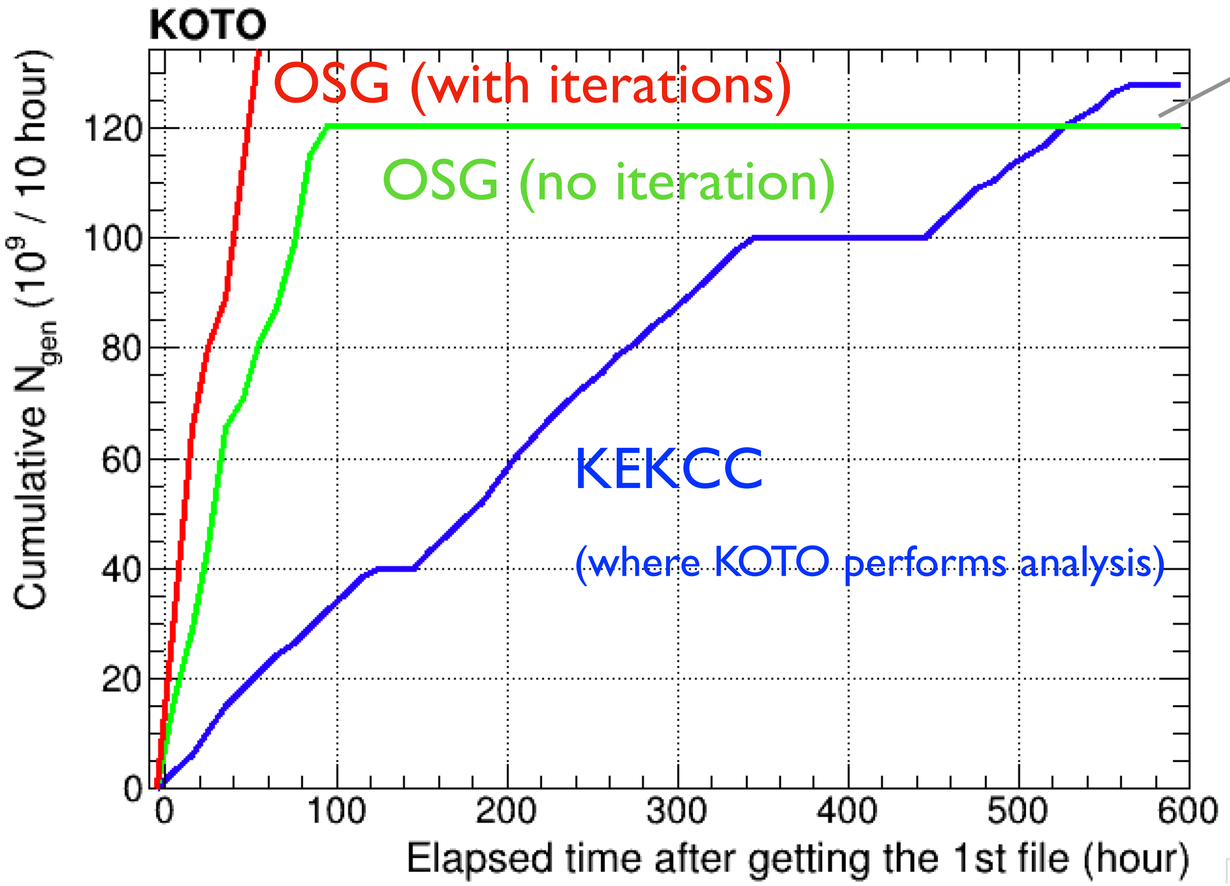
Workflow for OSG production

Required time ~ 12 hr



Production rate comparison

Use the output file's epoch (unix time) to evaluate the simulation production time.



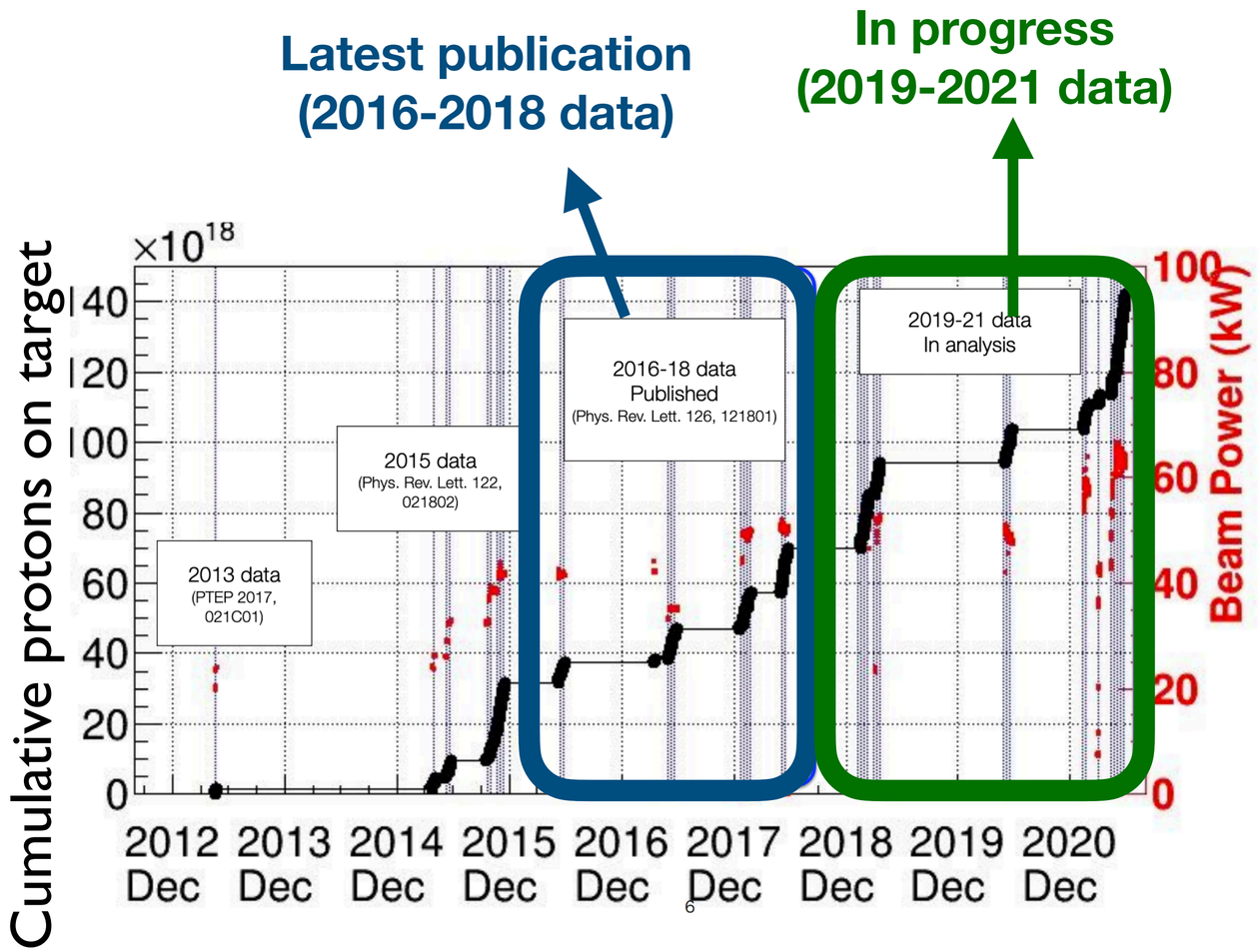
Run out the disk space.

- Average production rate (one account)
  - KEKCC = 3 x 10^9 / 10 hour.
  - OSG = 12 x 10^9 / 10 hour (no iteration).
    = 24 x 10^9 / 10 hour (with iterations).
    [Speed x 8]

Achievements

OSG contributes to the new data set.

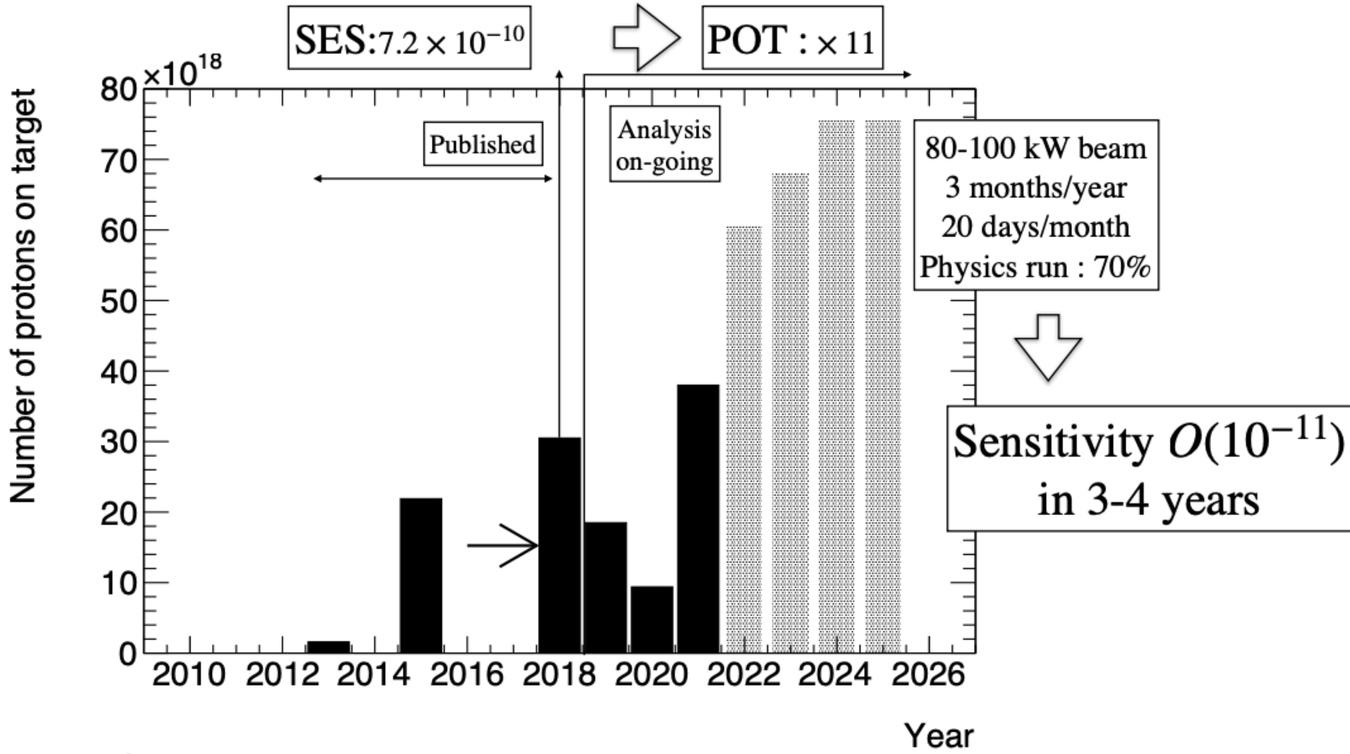
- Produce more training samples for the neural network to enhance its performance.
- Further estimate the probability for some of the background mechanisms that were hard to study before.



KOTO future with OSG

More data is coming in the future.

OSG is needed to reach the sensitivity.



More physics topics may be studied at KOTO with the OSG resources.

Pair production of dark particles in meson decays

Matheus Hostert,[1,2,3,*] Kunio Kaneta,[1,2,†] and Maxim Pospelov[1,2]

PHYSICAL REVIEW D **83,** 031101(R) (2011)

Search for the decay $K_L^0 \to 3\gamma$

Y. C. Tung,[1] Y. B. Hsiung,[1] J. K. Ahn,[2] Y. Akune,[3] V. Baranov,[4] K. F. Chen,[1] J. Comfort,[5] M. Doroshenko,[6,*] Y. Fujioka,[3] T. Inagaki,[6,7] S. Ishibashi,[3] N. Ishihara,[7] H. Ishii,[8] F. Iwai,[8] T. Iwata,[9] J. Kato,[9] S. Kobayashi,[3] S. Komatsu,[8] T. K. Komatsub[illegible] T. Matsumura,[12] A. M[illegible] T. Nomura,[13,†] S. Porokhovoy,[4] K. Sa[illegible] Y. Stepanenko,[4] T. Tsukamoto

Detailed Study of the $K_L \to \pi^0\pi^0\pi^0$ Dalitz Plot

E. Abouzaid,[4] M. Arenton,[11] A.R. Barker,[5,*] L. Bellantoni,[7] E. Blucher,[4] G.J. Bock,[7] E. Cheu,[1] R. Coleman,[7] M.D. Corcoran,[9] B. Cox,[11] A.R. Erwin,[12] C.O. Escobar,[3] A. Glazov,[4] A. Golossanov,[11] R.A. Gomes,[3] P. Gouffon,[10] Y.B. Hsiung,[7] D.A. Jensen,[7] R. Kessler,[4] K. Kotera,[8] A. Ledovskoy,[11] P.L. McBride,[7] E. Monnier,[4,†] H. Nguyen,[7] R. Niclasen,[5] D.G. Phillips II,[11] E.J. Ramberg,[7] R.E. Ray,[7] M. Ronquest,[11] E. Santos,[10] W. Slater,[2] D. Smith,[11] N. Solomey,[4] E.C. Swallow,[4,6] P.A. Toale,[5] R. Tschirhart,[7] Y.W. Wah,[4] J. Wang,[1] H.B. White,[7] J. Whitmore,[7] M. J. Wilking,[5] B. Winstein,[4] R. Winston,[4] E.T. Worcester,[4] T. Yamanaka,[8] E. D. Zimmerman,[5] and R.F. Zukanovich[10]

Summary

- KOTO introduced the Monte Carlo simulation using OSG since 2022 and began the continuous job submission since March 2023.
- OSG has a major contribution to KOTO's latest data set and will play a crucial role in the future.

Content of a KOTO docker image

chiehlin0212/koto-dev:latest

DIGEST: sha256:973190fd76638e3928faca0a11482738ff690c3e1023727a0359f63b96b2cd4e

OS/ARCH	COMPRESSED SIZE	LAST PUSHED	TYPE
linux/amd64	2.52 GB	10 days ago by chiehlin0212	Image

https://hub.docker.com/r/chiehlin0212/koto-dev

Preliminary KOTO docker image construction

Build a KOTO docker image supporting

- ROOT (v6.22.02)
- GEANT4 (v10.05.01)
- e14lib (201605v6.2)

Library construction command lines

```
FROM opensciencegrid/osgvo-el7

# install cmake3
RUN yum -y install cmake3
RUN yum -y downgrade --disablerepo=osg \*xrootd\*

# install root
RUN mkdir -p root && \
   cd root && \
   wget https://stash.osgconnect.net/collab/project/KOTO/software/root_v6.22.02.source.tar.gz && \
   tar -xf root_v6.22.02.source.tar.gz && \
   mkdir -p build install && \
   cd build && \
   cmake3 -DCMAKE_INSTALL_PREFIX="./../install" "./../root-6.22.02" -Dx11=OFF -Dxft=OFF -Dbuiltin_xro
otd=ON -Dopengl=OFF && \
   cmake3 --build . --target install && \
```

Translate into docker image

Docker images *Local workspace* *Image size*

chiehlin0212/my-test		latest	5c446c076f94	16 days ago	2.29 GB
opensciencegrid/osgvo-el7	IN USE	latest	1086acac4897	30 days ago	2.03 GB

Update the working image to OSG repository

Remote repository: can be seen by grid computers

Run a job to OSG pool

A job submission requires a configuration script.

```
#!/bin/bash
Universe = Vanilla
Executable     = run_koto.sh
Requirements = HAS_SINGULARITY == TRUE
+SingularityImage = "/cvmfs/singularity.opensciencegrid.org/ppaschos/koto-dev:latest"
transfer_input_files = e14_201605.mac
Error   = output.err.$(Cluster)-$(Process)
Output  = output.out.$(Cluster)-$(Process)
Log     = output.log.$(Cluster)
should_transfer_files = YES
WhenToTransferOutput = ON_EXIT
request_cpus = 1
request_memory = 2GB
request_disk = 2GB
+ProjectName="collab.KOTO"
Queue 1
```

A script that generates 1000 $K_L^0 \to 3\pi^0$ events.

Build KOTO container

Transfer GEANT4 setting file.

The first $K_L^0 \to 3\pi^0$ MC file.

```
root [3] .ls
TFile**         output.root
 TFile*         output.root
  KEY: TTree    detectorTree00;1        detectorTree00
  KEY: TTree    physicalVolumeTree00;1  physicalVolumeTree00
  KEY: TTree    processTree00;1 processTree00
  KEY: TTree    eventTree00;1   eventTree00
  KEY: TTree    eventSeedTree00;1       eventSeedTree00
  KEY: TTree    commandTree;1   commandTree
  KEY: TTree    runTree;1       runTree
  KEY: TH1D     hE14Mome;1      hE14Mome [GeV/c]
root [4] eventTree00->Print()
******************************************************************************
*Tree    :eventTree00: eventTree00                                           *
*Entries :      364 : Total =        75267670 bytes  File  Size =   20502691 *
*        :          : Tree compression factor =   3.66                       *
******************************************************************************
*Br    0 :nPE       : BHPV_nPE[32]/I                                          *
*Entries :      364 : Total  Size=      47246 bytes  File Size  =       2157 *
*Baskets :        2 : Basket Size=      32000 bytes  Compression=  21.67     *
```