KING'S College LONDON

Software for Studying Supernova Neutrinos

Jost Migenda
they/them

Software matters!

Software matters!

"You're not doing a PhD in Astrophysics,
you're doing a PhD in software development
with applications to Astrophysics."

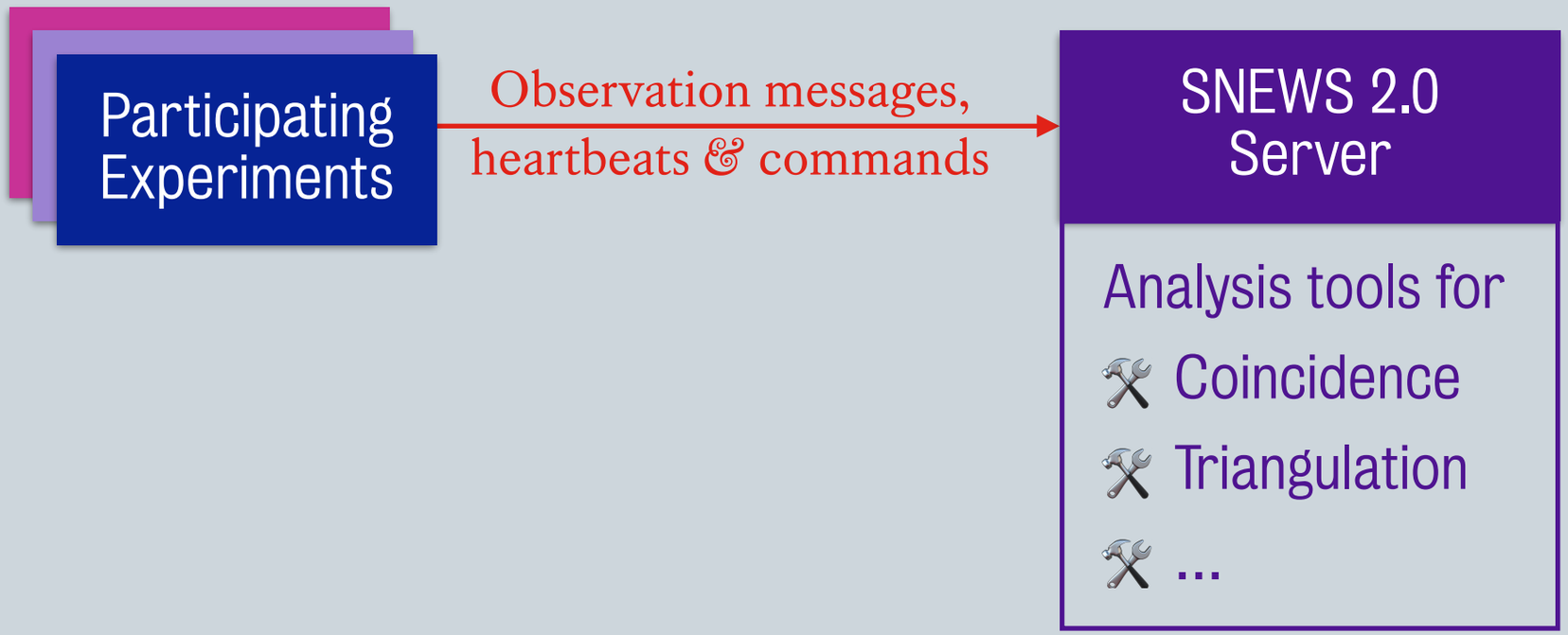
Advice seen on an ECR Discord server

SNEWS 2.0 Software Overview

Participating Experiments

Astronomers, GW detectors, general public

SNEWS 2.0 Software Overview



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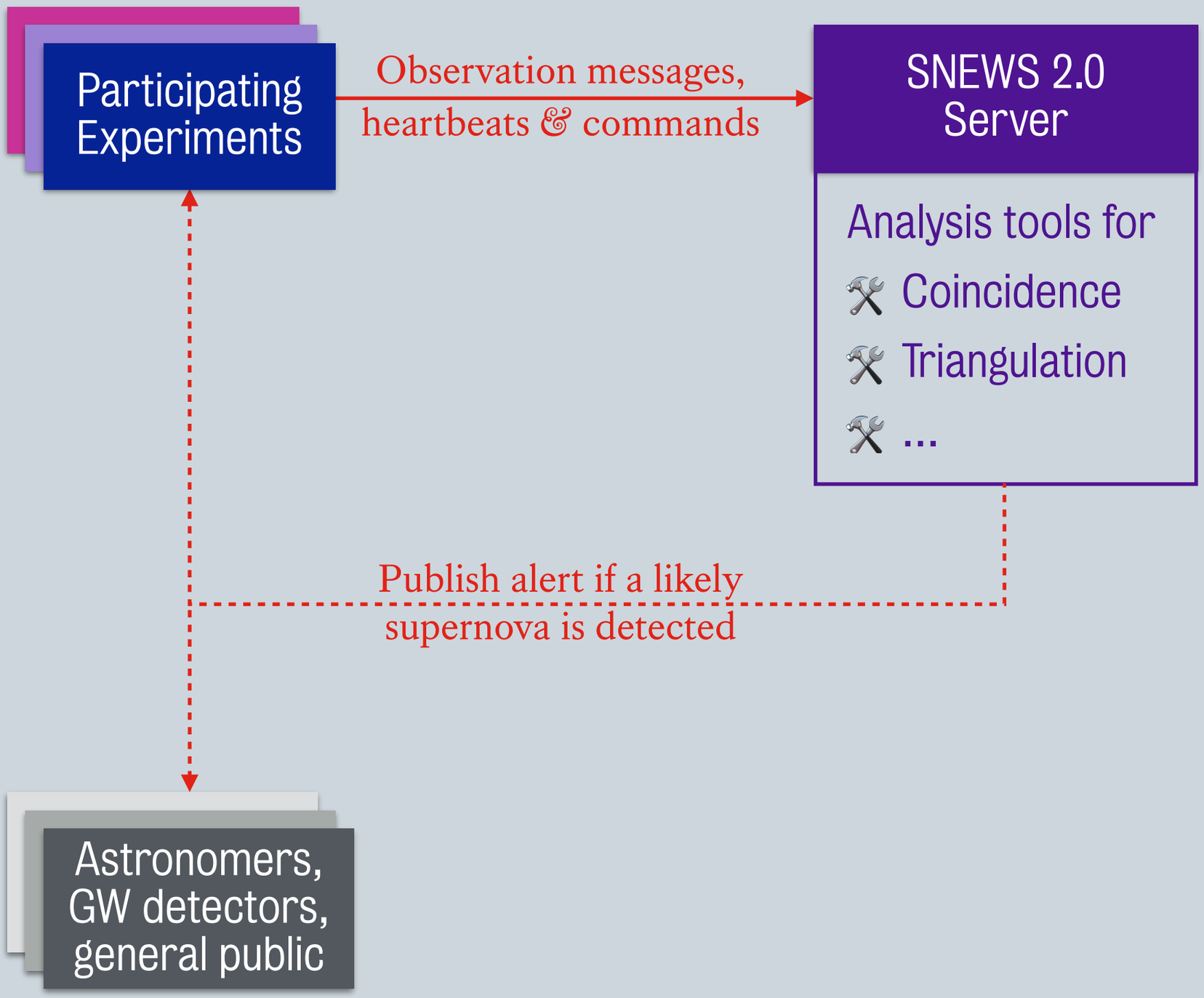

SNEWS 2.0 Software Overview

Participating Experiments

Observation messages, heartbeats & commands

SNEWS 2.0 Server

Analysis tools for

- Coincidence
- Triangulation
- ...

Simulation tools

Develop analysis algorithms, set alert thresholds for experiments, etc.

Publish alert if a likely supernova is detected

Astronomers, GW detectors, general public

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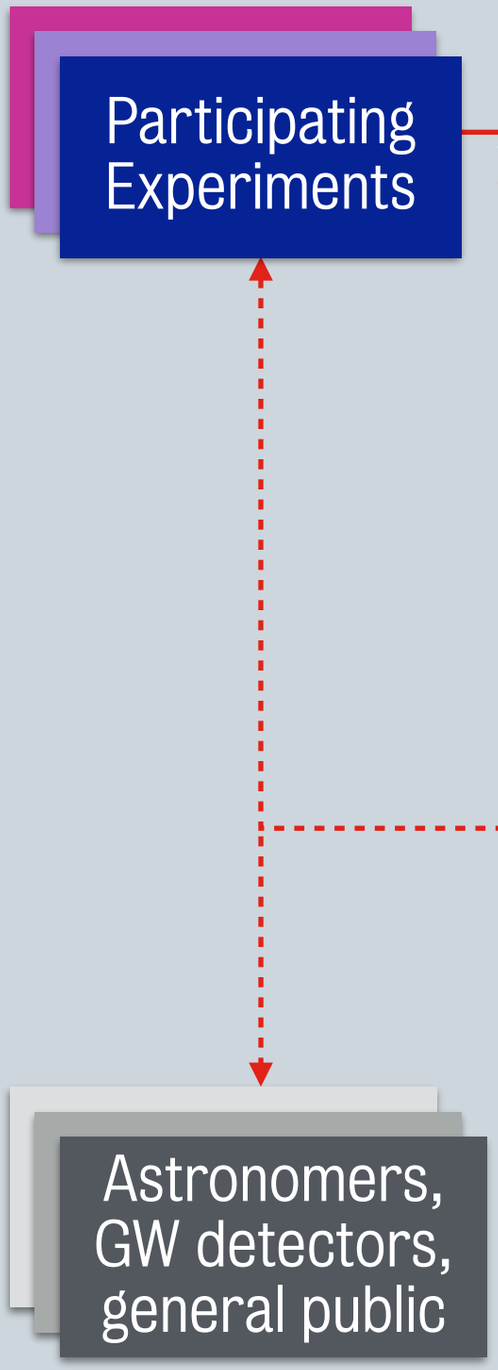

Publicly available on GitHub:

- SNEWS Publishing Tools
- Online analysis tools
- SNEWPY

Collaboration with SCiMMA

- Scalable Cyberinfrastructure for Multi-Messenger Astrophysics
  - NSF-funded project used by IceCube, LIGO, …
  - Develops HOPSKOTCH: "a scalable, high-throughput low-latency platform for handling real-time data streams for MMA applications"

- SNEWS & SCiMMA started close collaboration in 2020
  - SNEWS: Don't need to implement & maintain basics like identity/access management, pub-sub infrastructure, …
  - SCiMMA: Real-world test of early protoype, rapid user feedback

- Paper: "Collaborative Experience between Scientific Software Projects using Agile Scrum Development" (arXiv:2101.07779, DOI:10.1002/spe.3120)

SNEWS Publishing Tools

- Developing SNEWS Publishing Tools on top of HOPSKOTCH
- Publish or subscribe from notebook or CLI

```
from snews_pt.snews_pub import SNEWSTiersPublisher
from datetime import  datetime
test_time = datetime.utcnow().strftime("%y/%m/%d %H:%M:%S:%f")

message = SNEWSTiersPublisher(detector_name='XENONnT',
                              machine_time=test_time,
                              neutrino_time=test_time,
                              p_val=0.0007,
                              p_values=[0.001, 0.02, 0.005],
                              t_bin_width=0.5,
                              firedrill_mode=False)

message.send_to_snews()
```

```
------------------------------------------------------------------
Sending message to CoincidenceTier on kafka://kafka.scimma.org/snews.experiments-test
_id                 :19_CoincidenceTier_22/08/03 02:05:43:869112
detector_name       :XENONnT
machine_time        :22/08/03 02:05:43:869112
neutrino_time       :22/08/03 02:05:43:869112
p_val               :0.0007
meta                :{}
schema_version      :1.1.0
sent_time           :22/08/03 02:05:43:878058
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```

```
jost@Macintosh ~/D/A/S/S/S/snews_pt (main)> snews_pt publish my_alert.json
```

```
schema_version      :1.1.0
sent_time           :22/08/03 02:05:43:878058
```

SNEWS Publishing Tools

- Developing SNEWS Publishing Tools on top of HOPSKOTCH

- Publish or subscribe from notebook or CLI

```
In [*]: from snews_pt.snews_sub import Subscriber
        Subscriber().subscribe()

        You are subscribing to ALERT
        Broker:kafka://kafka.scimma.org/snews.alert-firedrill
```

```
(snews) kara-unix@iap-nb-034:auxiliary$ ls custom*
custom_script.py
(snews) kara-unix@iap-nb-034:auxiliary$ snews_pt subscribe -p custom_script.py
Redirecting output to custom_script.py
You are subscribing to ALERT
Broker:kafka://kafka.scimma.org/snews.alert-firedrill
```

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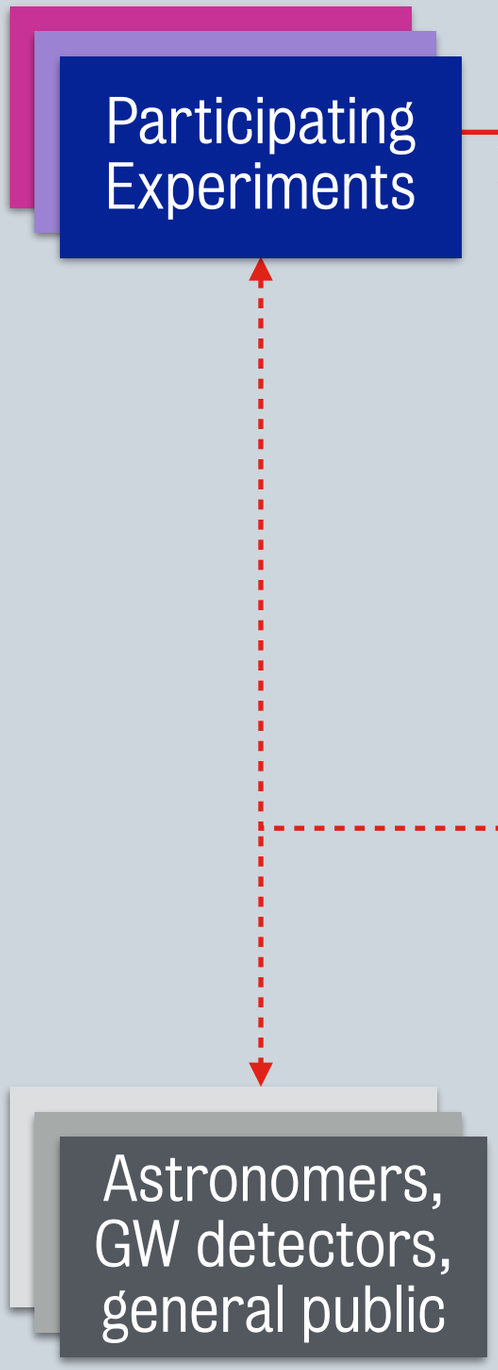

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Real-time Analysis Tools

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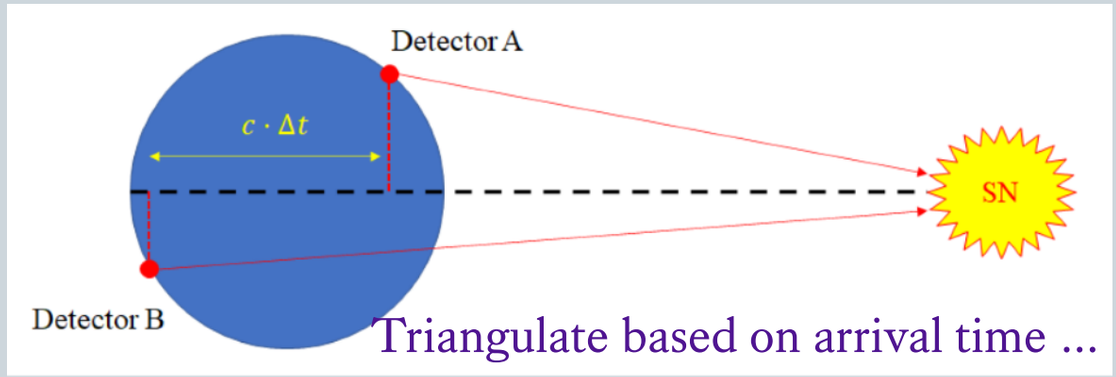
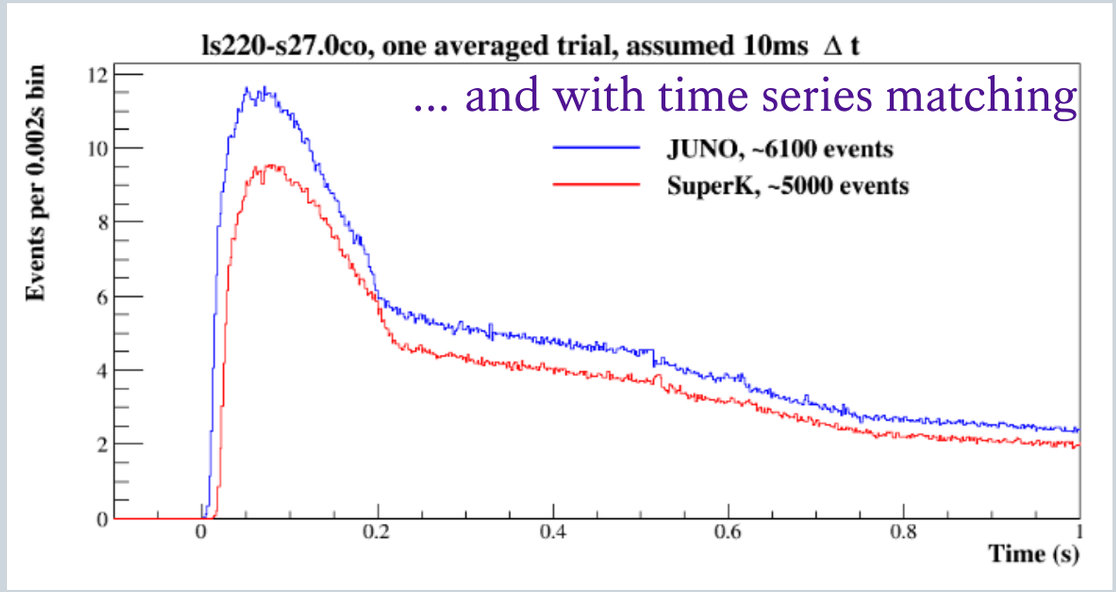
- Coincidence System
  - Look for coincidences between detectors
  - Includes heartbeat handler



Triangulate based on arrival time ...



- SNEWPDAG
  - Directed Acyclic Graph built from different plugins
  - Estimate distance, triangulate direction, compare with progenitor distribution, ...

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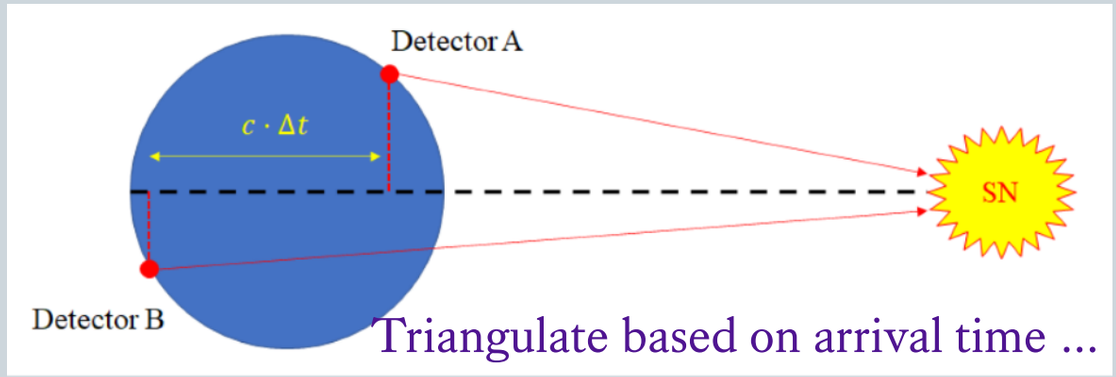

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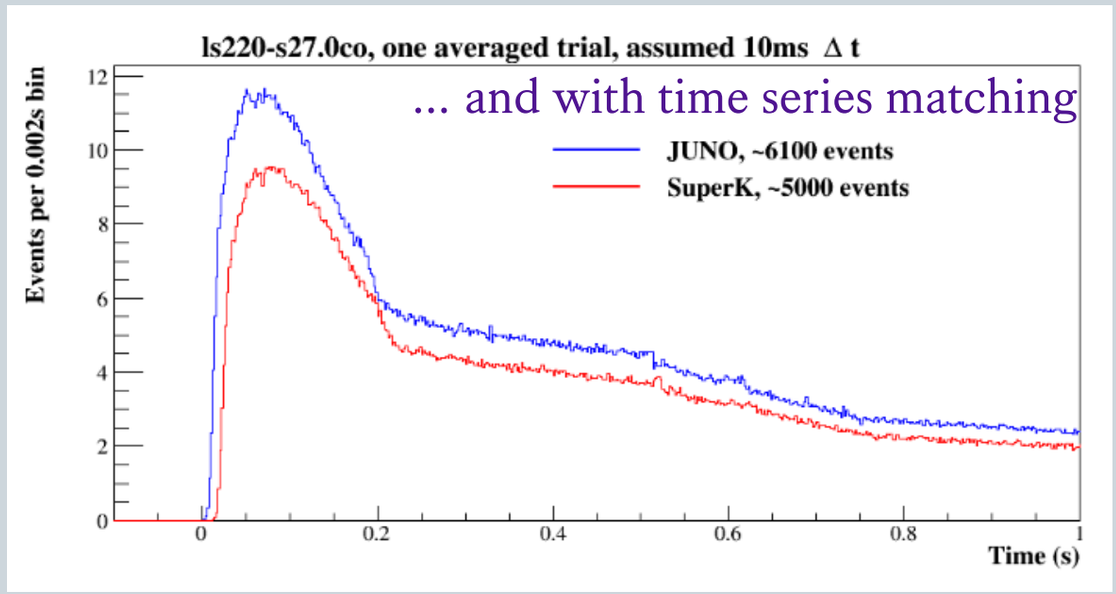

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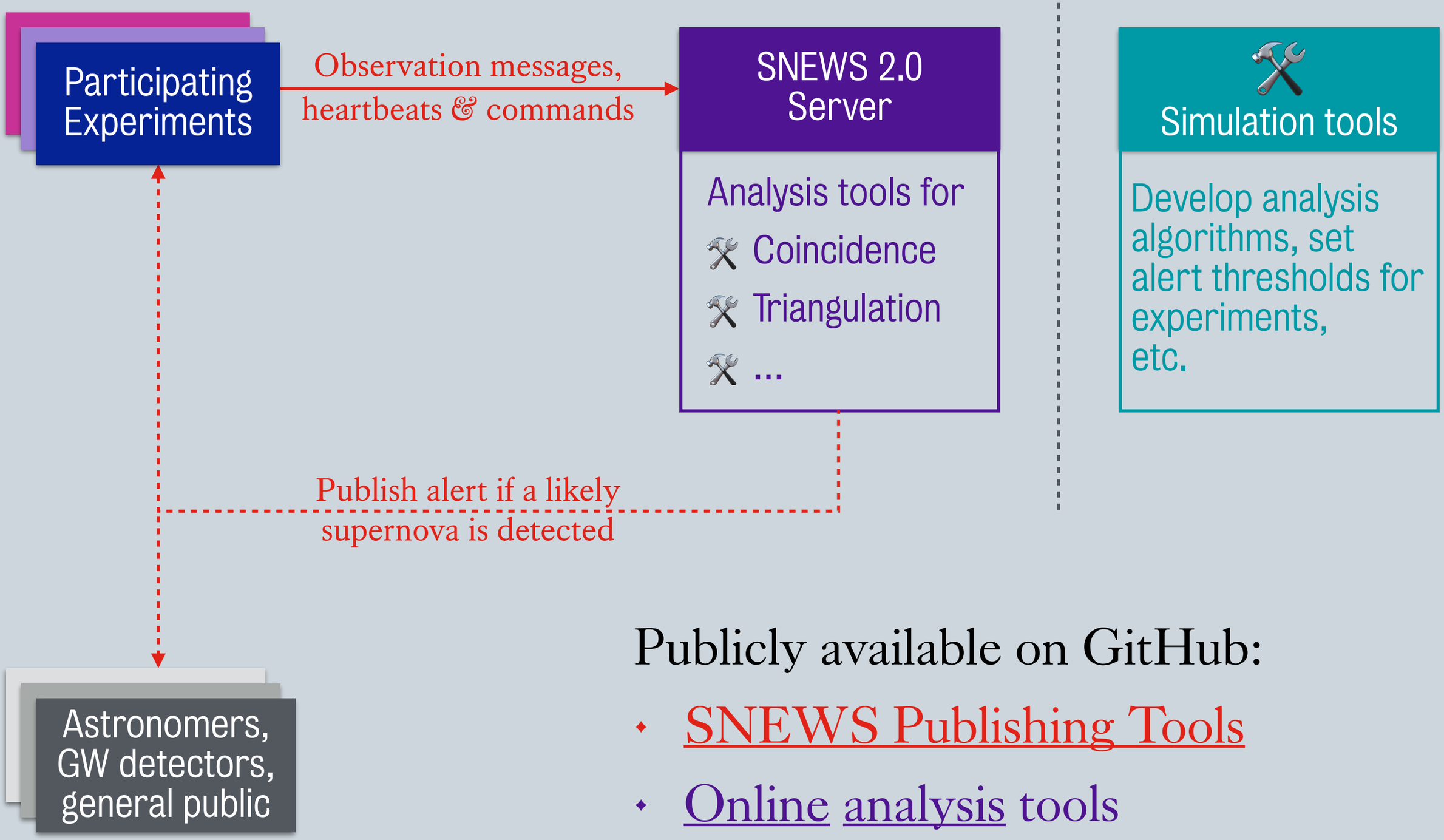
See talks by Kate (this afternoon) and Jeff (tomorrow)!

SNEWS 2.0 Software Overview



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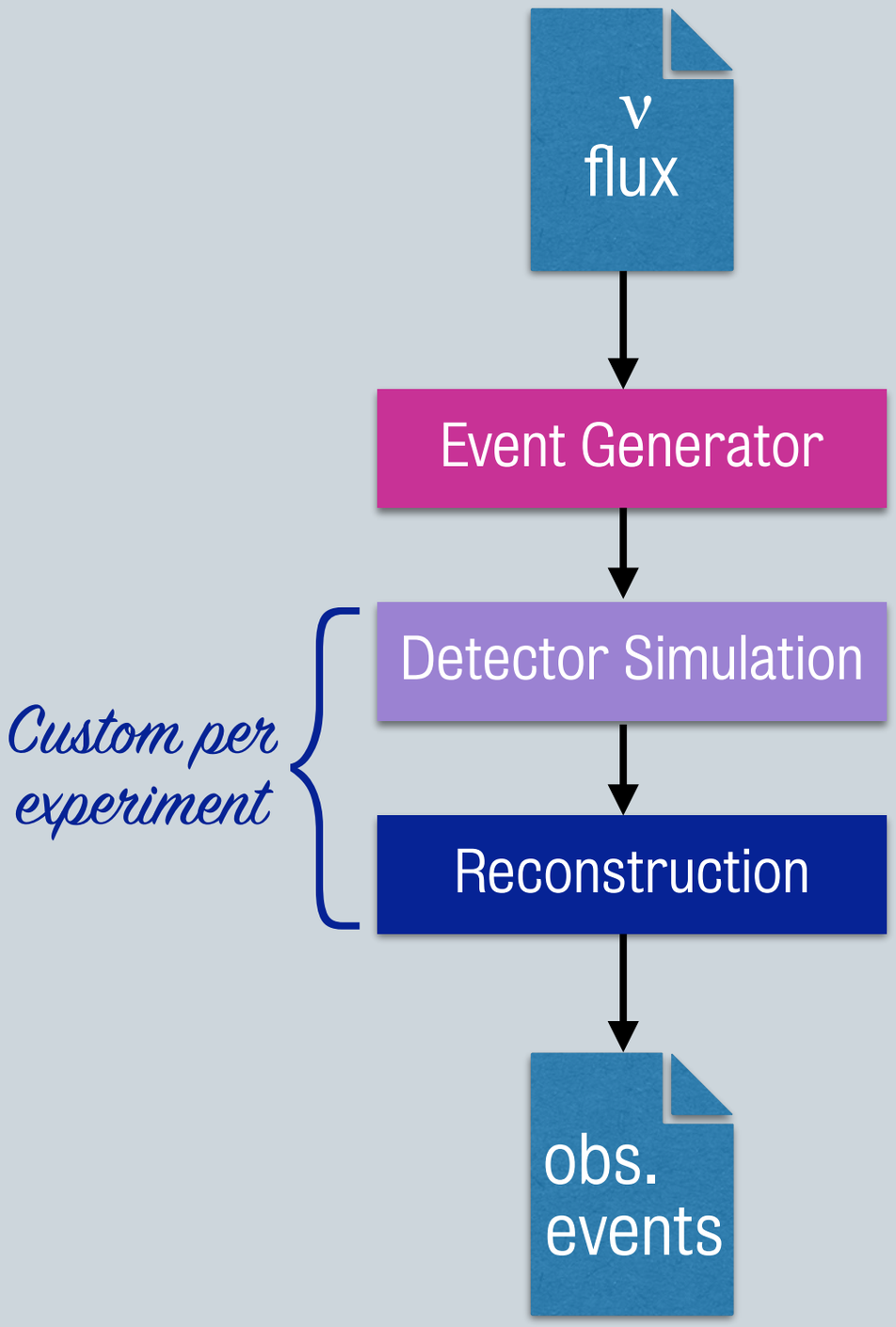
Determining the Detector Response



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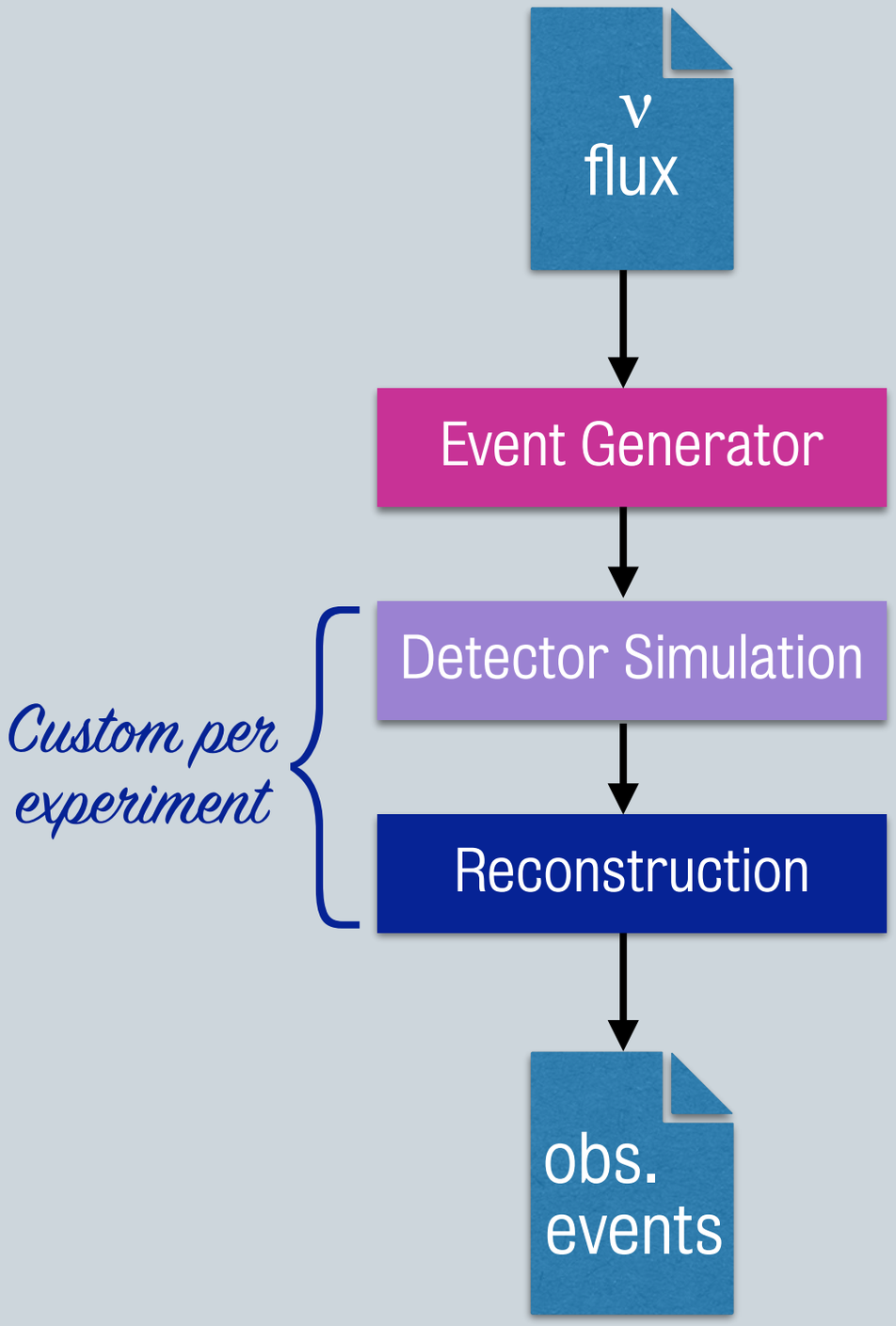

- Implement cross sections, energy & angular distribution of outgoing particles, and more

- Existing event generators
  - MARLEY (Ar)
  - sntools (H_2O, LS, WbLS)
  - *… and some proprietary ones*

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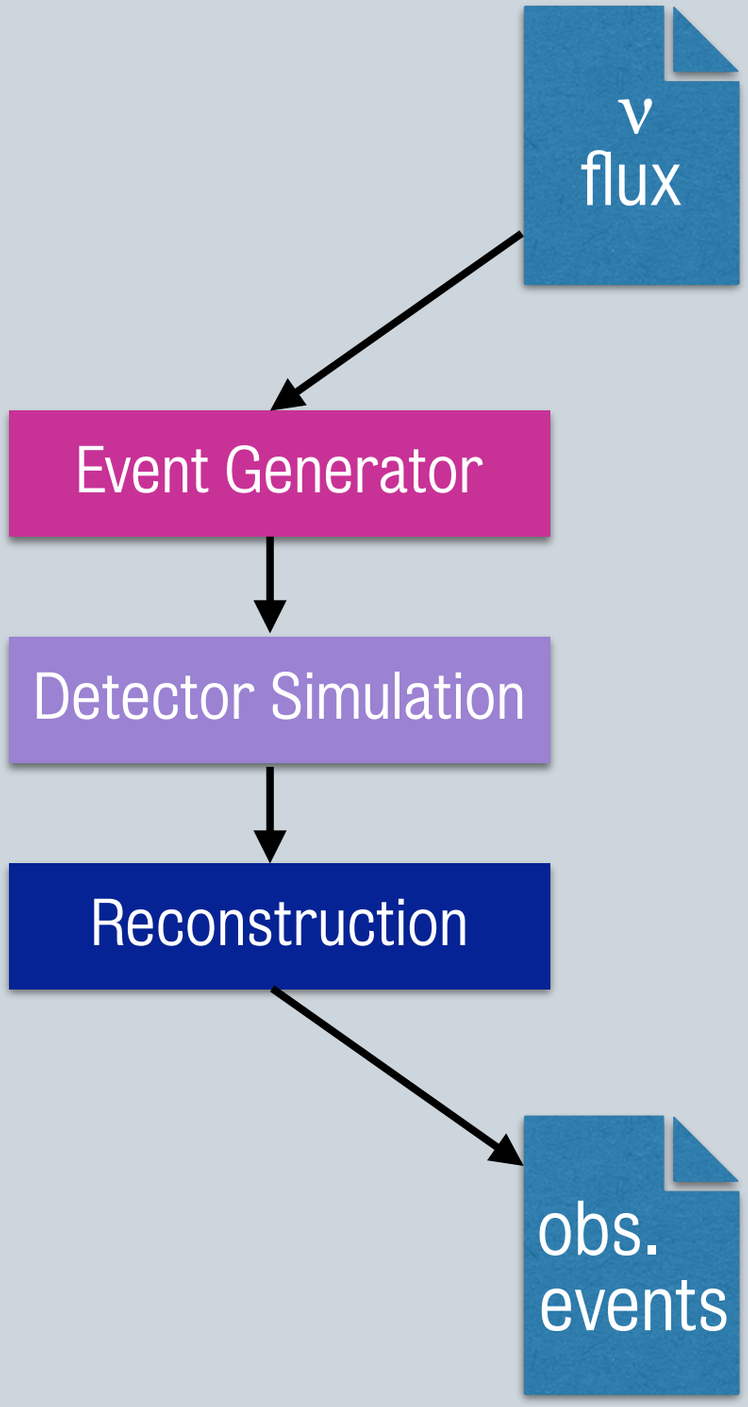

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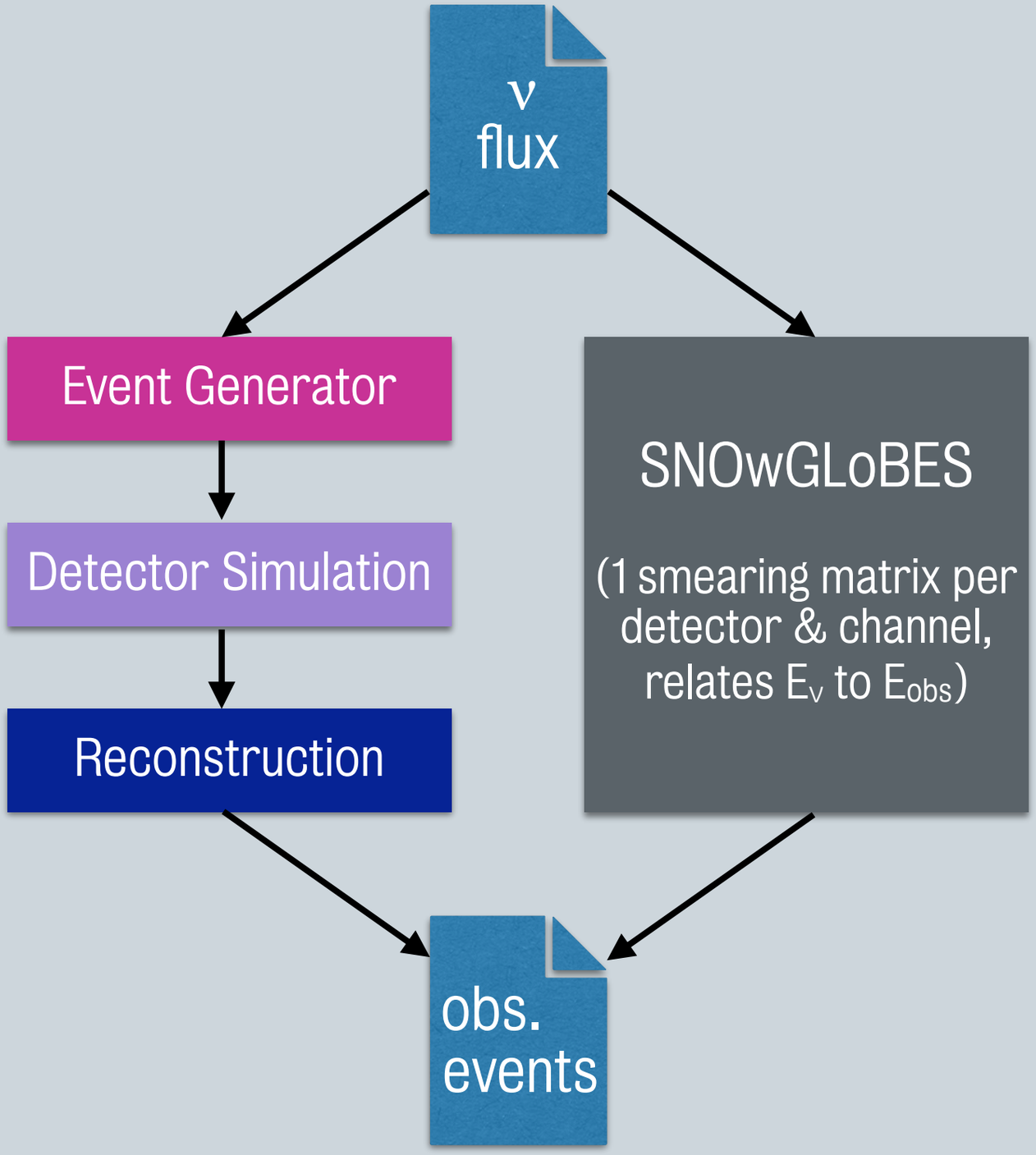

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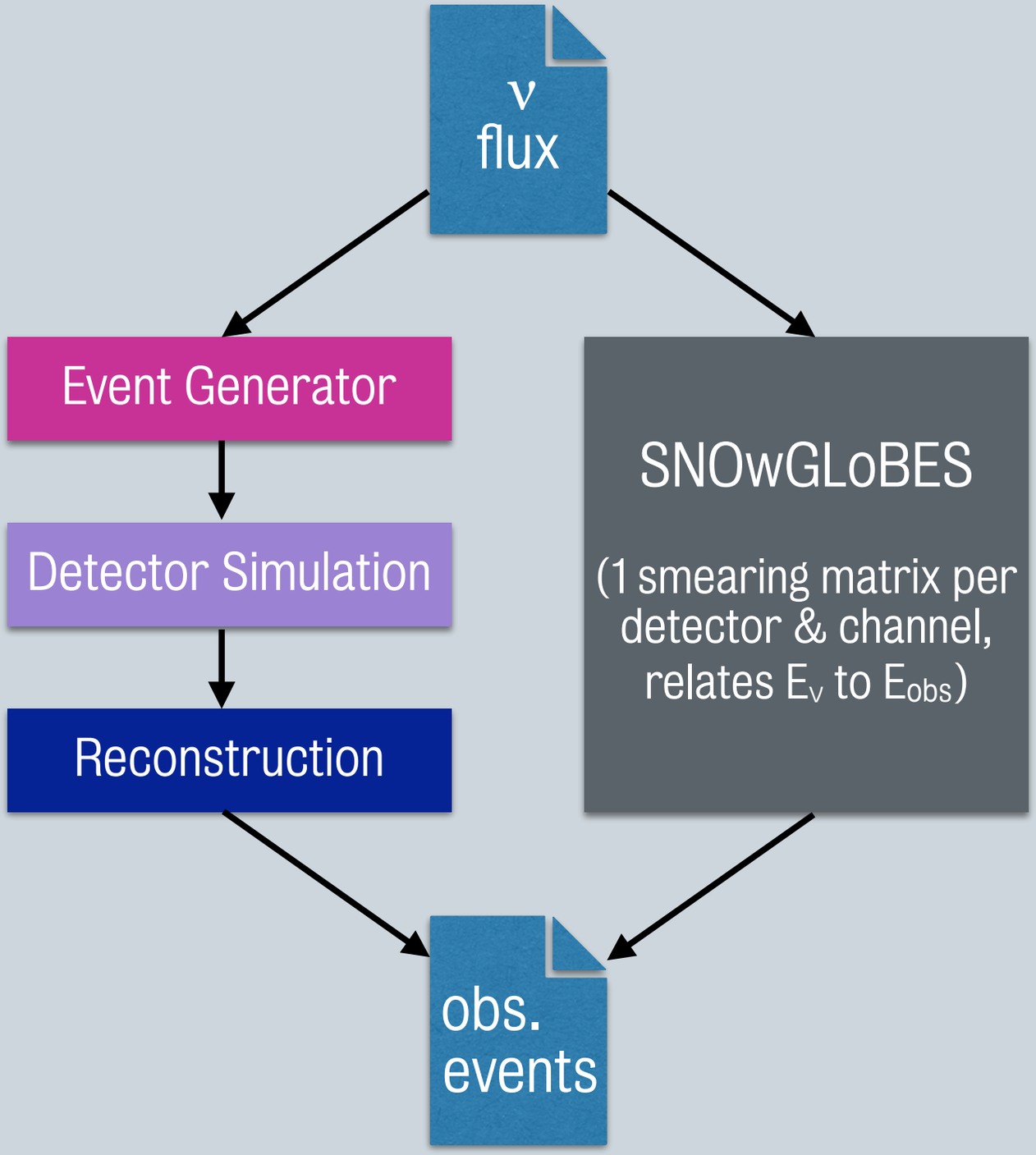

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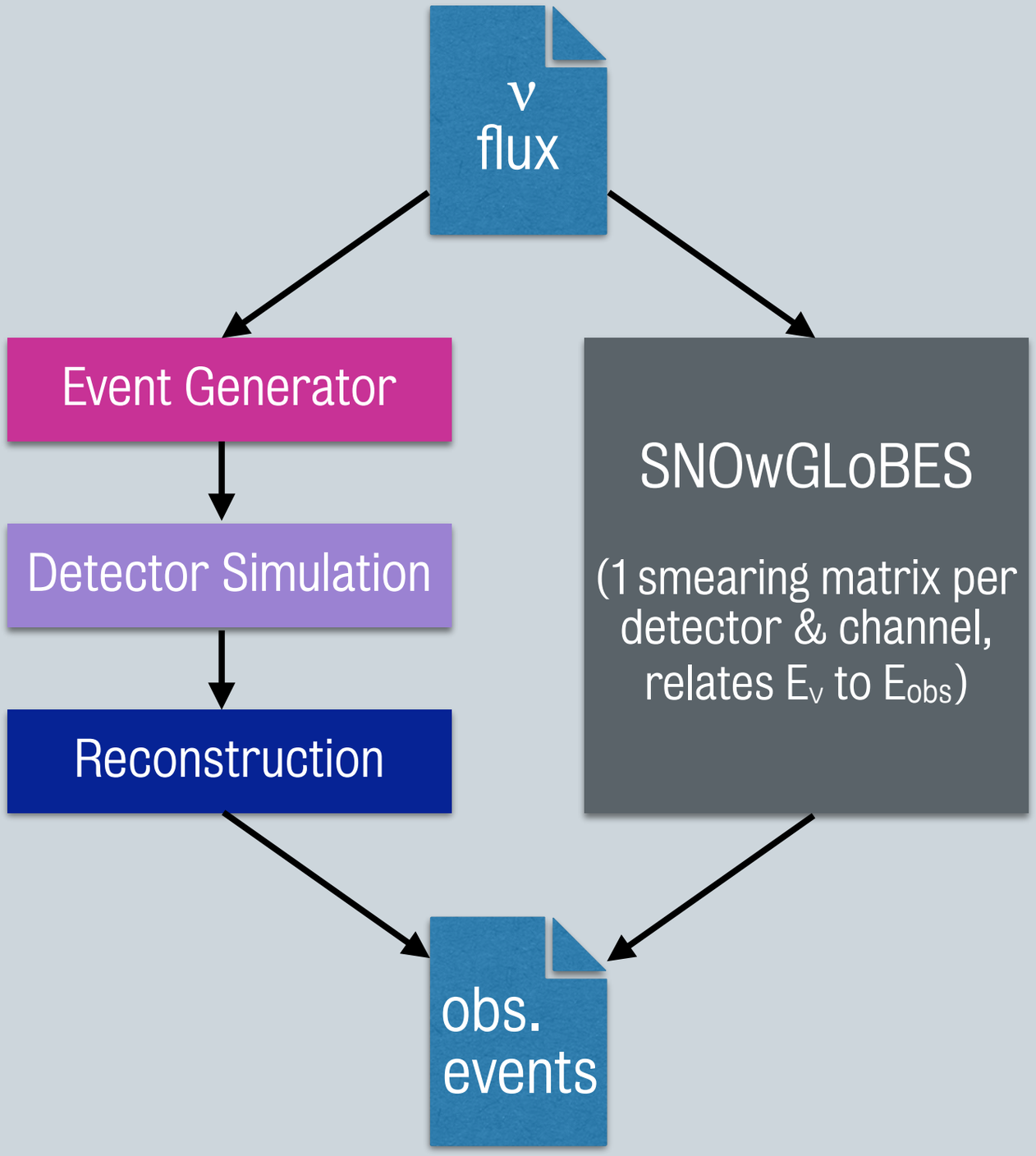
- Orders of magnitude faster & covers *many* use cases
- Still need event generator for advanced studies (e.g. directionality, n capture)

Determining the Detector Response

Where to get fluxes from different SN models?



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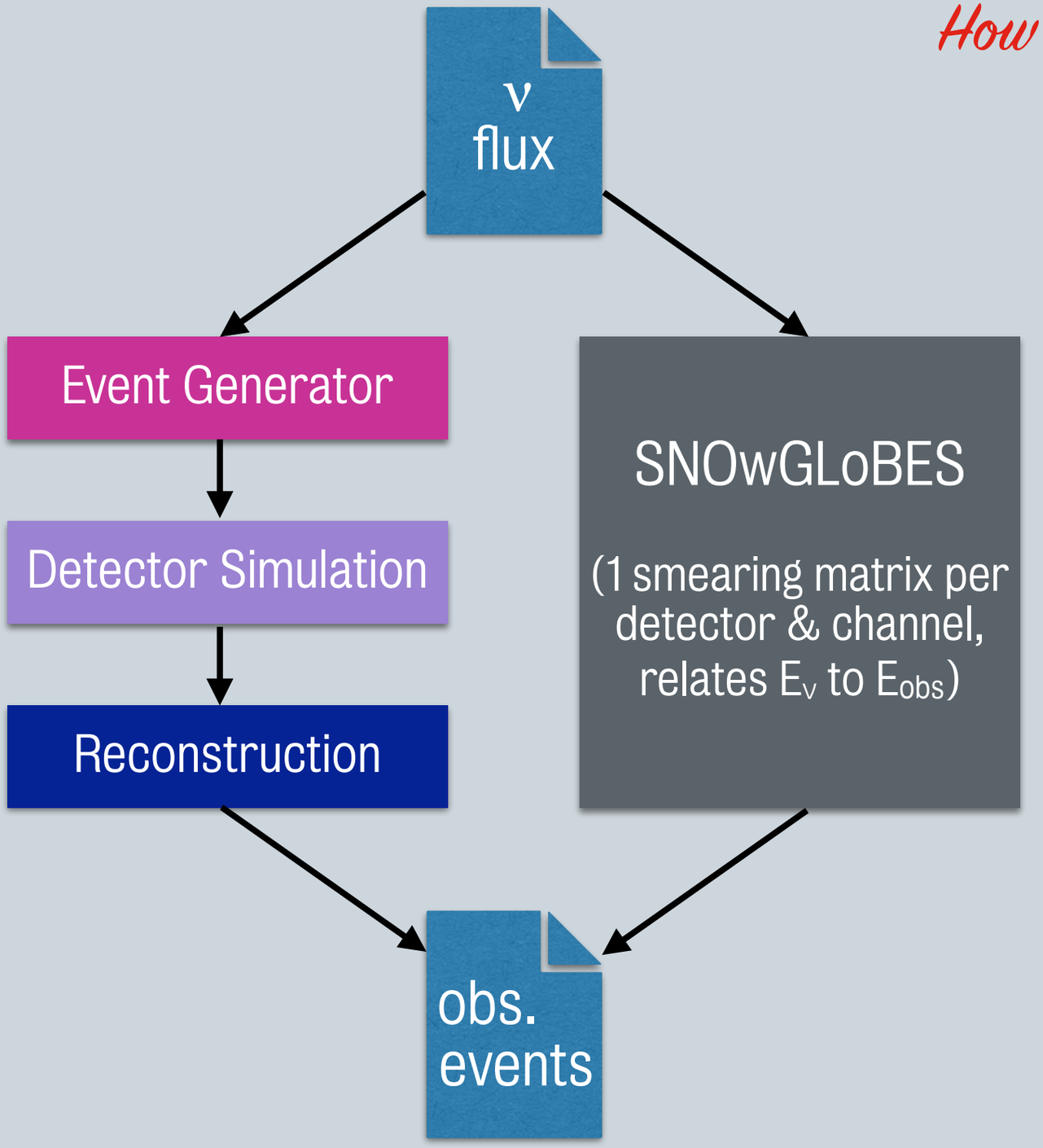

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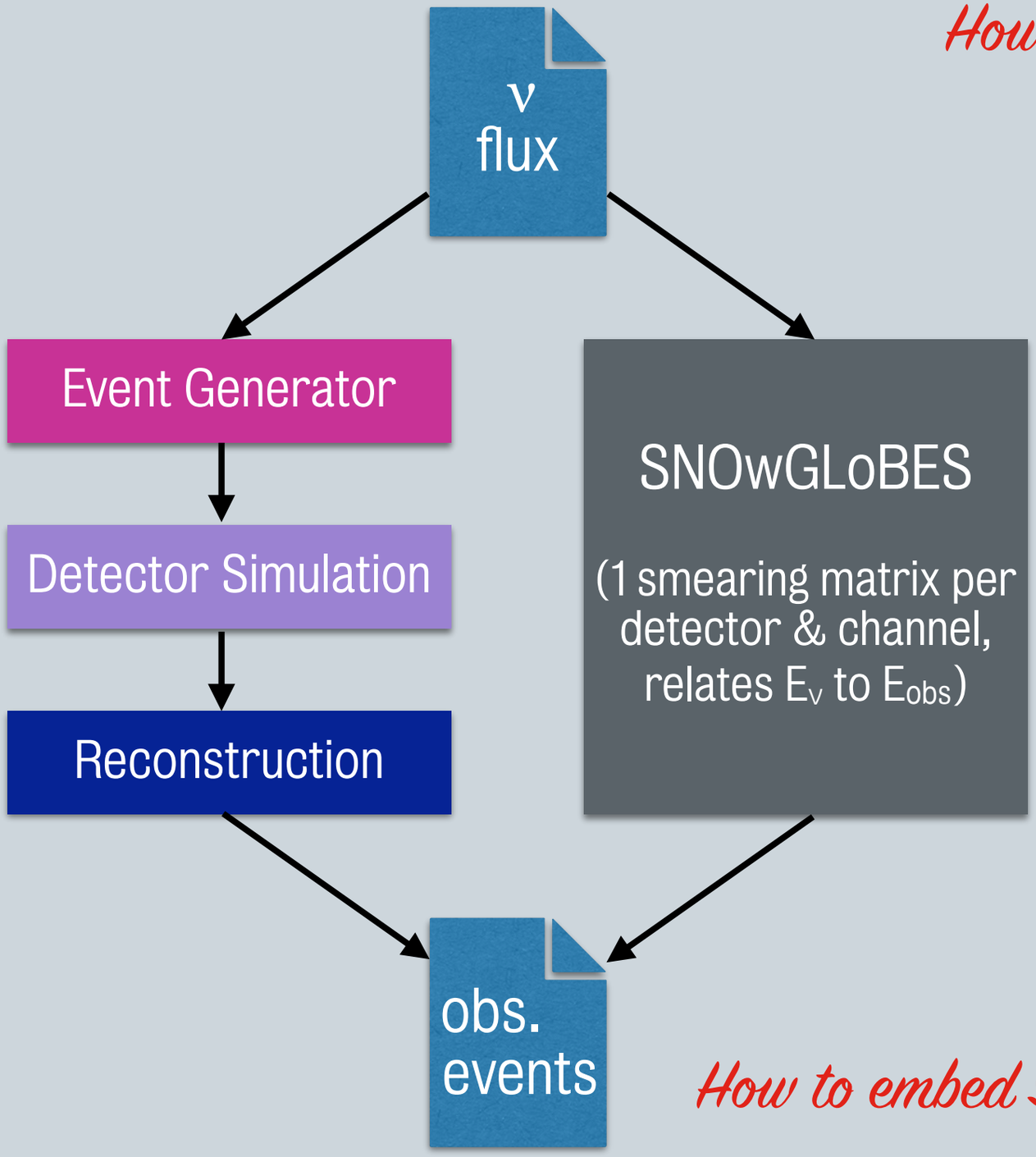

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SNEWPY Offers ...

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ApJ 925 (2022) 107
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Can use these in your code!

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Integrating SNEWPY in sntools

- sntools: event generator for SN neutrinos in water Cherenkov & liquid scintillator detectors
- Used by Hyper-K, SNO+, WATCHMAN, THEIA & more …
- Open Source:
  - github.com/JostMigenda/sntools
  - JOSS paper: DOI:10.21105/joss.02877
- Integrates SN models & flavor transformations from SNEWPY
  - For devs: Save work & eliminate major source of bugs
  - For users: Smooth transition from quick initial estimates (SNOwGLoBES) to advanced analyses (sntools)

Similar for IceCube's ASTERIA generator (DOI:10.5281/zenodo.3926834)

Usage of SNEWPY

- SNEWS-internally
- By other software (e.g. sntools, ASTERIA)
- In non-SNEWS papers:

DOI:10.1051/epjconf/202328005002

Exploiting synergies between neutrino telescopes for the next galactic core-collapse supernova

Meriem Bendahman[1,3], *Anne-Cécile* Buellet[2], *Matteo* Bugli[2], *Joao* Coelho[1], *Alexis* Coleiro[1], *Gwenhaël* de Wasseige[1], *Sonia* El Hedri[1,*], *Thierry* Foglizzo[2], *Davide* Franco[1], *Isabel* Goos[1], *Jérôme* Guilet[2], *Antoine* Kouchner[1], *Yahya* Tayalati[3], *Alessandra* Tonazzo[1], *Cristina* Volpe[1]

arXiv:2203.05141

Neutrino Echos following Black Hole Formation in Core-Collapse Supernovae

Samuel Gullin,[1] Evan P. O'Connor,[1] Jia-Shian Wang,[2] and Jeff Tseng[2]

[1] *The Oskar Klein Centre, Department of Astronomy, Stockholm University, AlbaNova, SE-106*

[2] *Department of Physics, Oxford University, Oxfor*

arXiv:2109.13242

Detectability of hadron-quark phase transition in neutrino signals of failing core-collapse supernova

Zidu Lin,[1] Shuai Zha,[2] Evan P. O'Connor,[3] and Andrew W. Steiner[1,4]

[1] *Department of Physics and Astronomy, University of Tennessee Knoxville*

[2] *Tsung Dao Lee Institute, Shanghai Jiao Tong University, Shanghai 200240, China*

in Centre, Department of Astronomy, , AlbaNova, SE-106 91 Stockholm, Sweden

ion, Oak Ridge National Laboratory

Dated: March 11, 2022)

Uncovering the neutrino mass ordering with the next galactic core-collapse supernova neutrino burst using water Cherenkov detectors

César Jesús-Valls[1,*]

[1] *Kavli IPMU (WPI), UTIAS, The University of Tokyo, Kashiwa, Chiba 277-8583, Japan*

arXiv:2210.11676

That input file contains the flux of ν_μ *or* ν_τ and *not* the sum of both!

Software matters!

We had a bug in the script that produced the tabulated values in the paper.

Our previous event generator implemented an old cross section that was off by ~30%

Based on three real examples I have witnessed.

Software Matters!

- Software can make or break a physics result!
  - If we all write the same code from scratch, we waste time & produce more bugs!
  - Less physics & worse physics!

- SNEWPY offers shared & well-tested implementations for common tasks
  - Easy to integrate into custom tools ➔ enables smooth transition from quick estimates (SNOwGLoBES) to advanced analyses (e.g. sntools)
  - Have a new SN model? New flavour transformation? Make them easily available to everyone!

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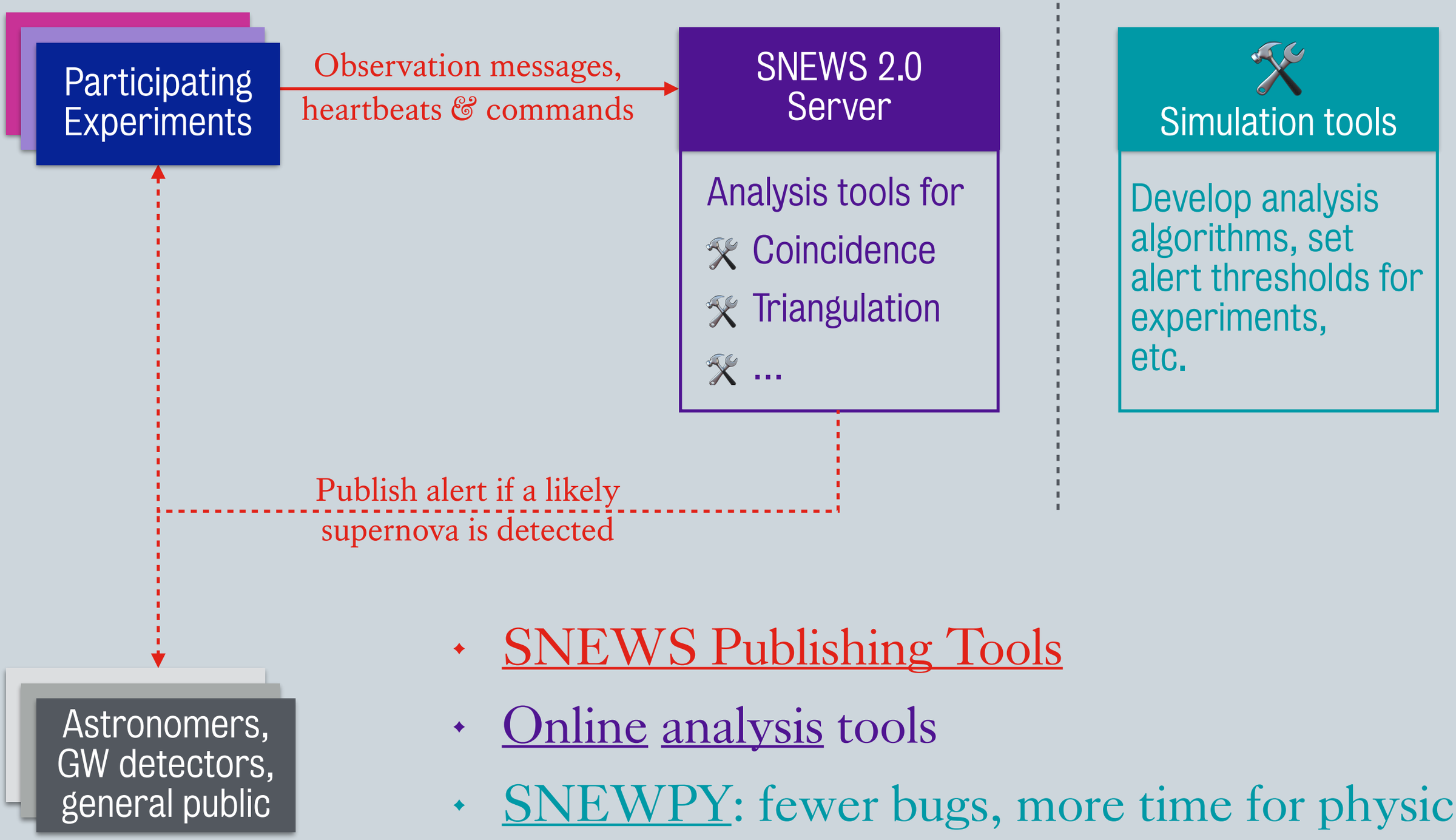
Interested? Talk to us! *Or join us tomorrow for a hackathon!*

Summary



- SNEWS Publishing Tools
- Online analysis tools
- SNEWPY: fewer bugs, more time for physics
- Software matters!