Neutrinos from the Cosmos

KM3NeT outing Dalfsen

Outline

- Why: Astrophysical neutrinos

- How: Conventional method
- How: New method

- So?: Status and needs

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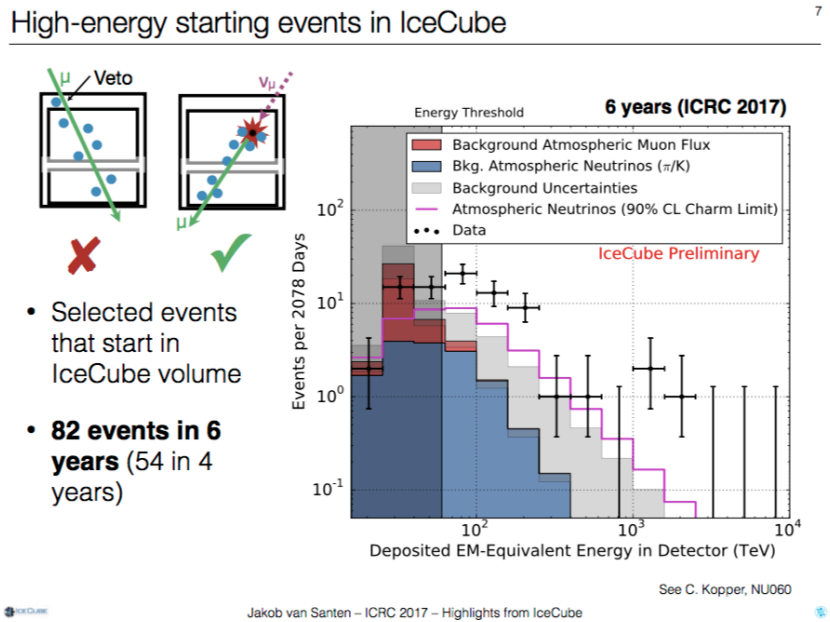
Astrophysical Neutrinos



- Significant excess over atmospheric neutrino background seen in IceCube
- What are the sources?

Expected Sources

Sources of UHECR & UHE neutrinos

Above few EeV: UHECR sources likely **extragalactic**:

- Absence of correlation of UHECR directions with Galactic plane
- Large-scale dipolar anisotropy (O. Taborda, Pierre Auger, ICRC17)

Candidate sources of UHEν

Murase & Waxman PRD **94**, 103006 (2016) and refs. therein

COSMIC-RAY ACCELERATORS
CR & ν produced in source
$p\gamma \longrightarrow n\,\pi^{+} \longrightarrow \nu$'s

Active Galactic Nuclei (AGN)
Gamma-Ray Bursts (GRB)

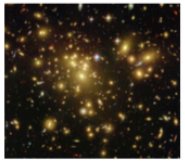
AGN: Accretion onto rmassive Black Hole

GRB: core-collapse massive stars

COSMIC-RAY RESERVOIRS
CR prod. in source, ν in environment
$pp \longrightarrow p\,n\,\pi$'s $\longrightarrow \nu$'s

Starburst Galaxies (SBG)
Galaxy clusters

SBG: Star-forming, Supernovae, GRB



Clusters: AGN, galaxy mergers,..

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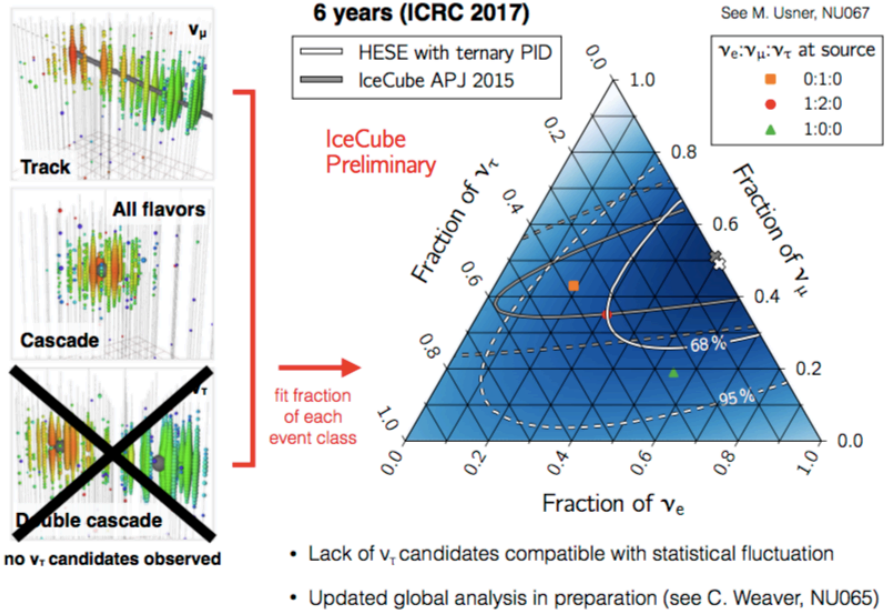
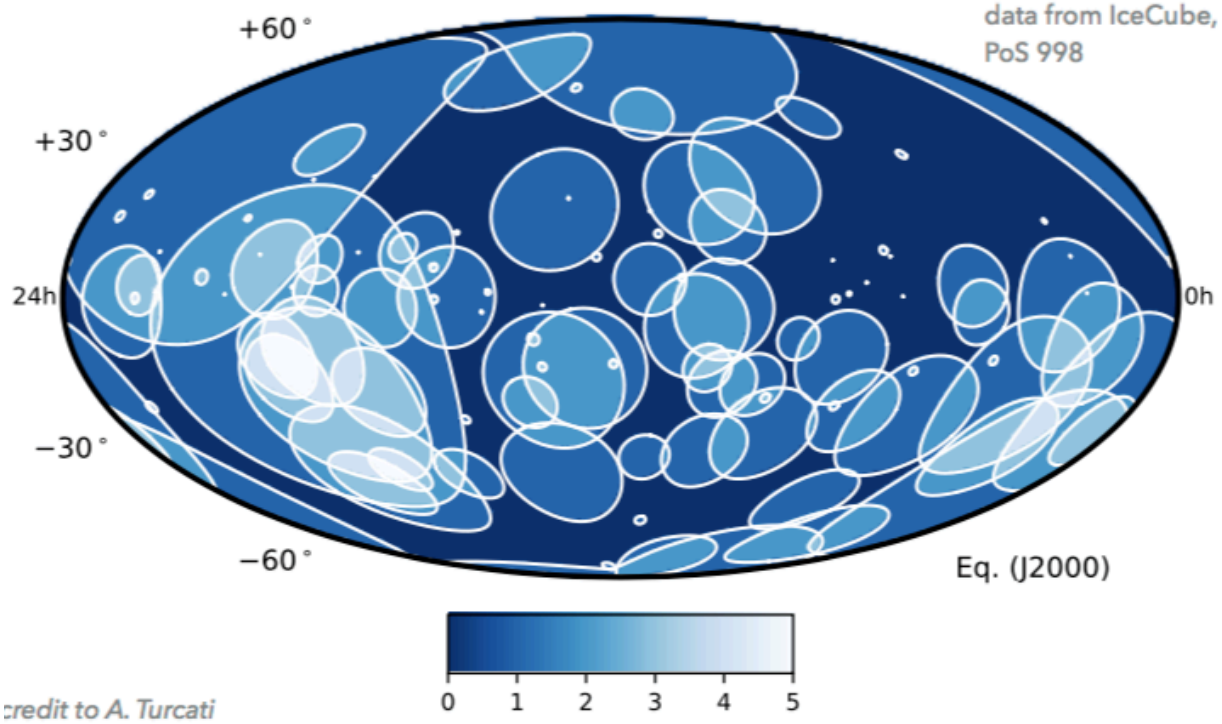
- UHE neutrinos & CRs seem to be extragalactic
  - Not very surprising
- Several source candidates:
  - AGNs, GRBs, SBG, GCs

Flavour ratio



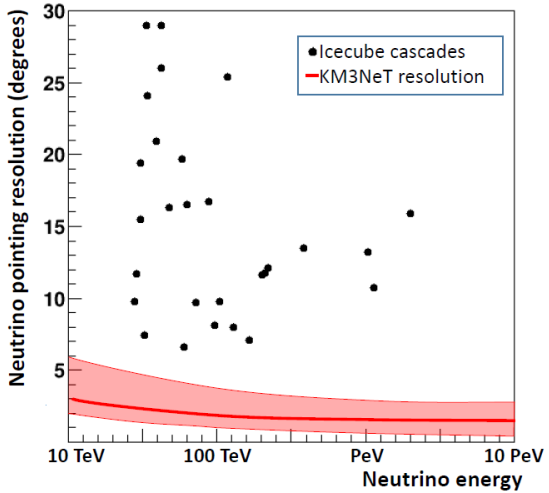
- Flavour ratio (best fit): ν_e:ν_μ:ν_τ= 1:1:0
- Results seem compatible with pure ν_μ source(s) or : ν_e:ν_μ= 1:2 source(s)

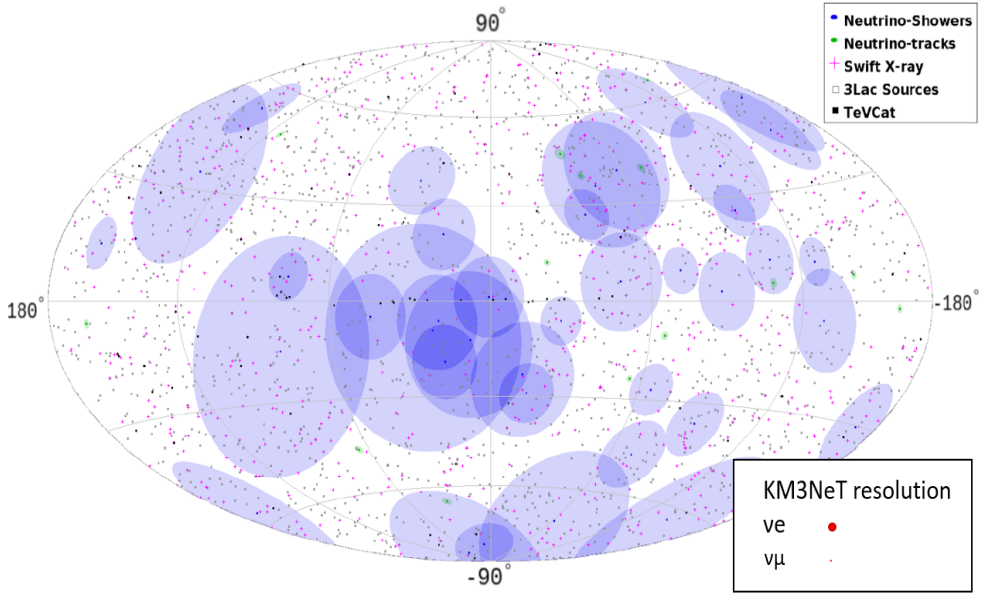
IceCube Skymap



KM3NeT vs IceCube

KM3NeT vs IceCube





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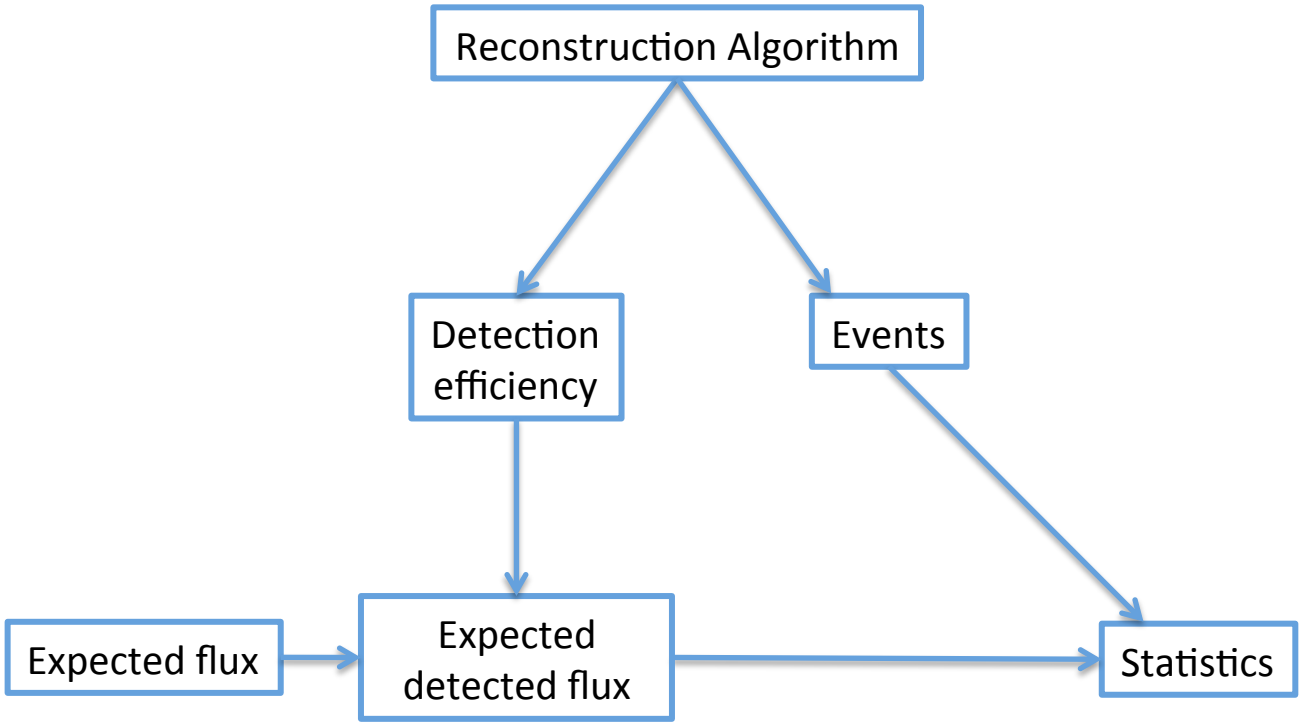

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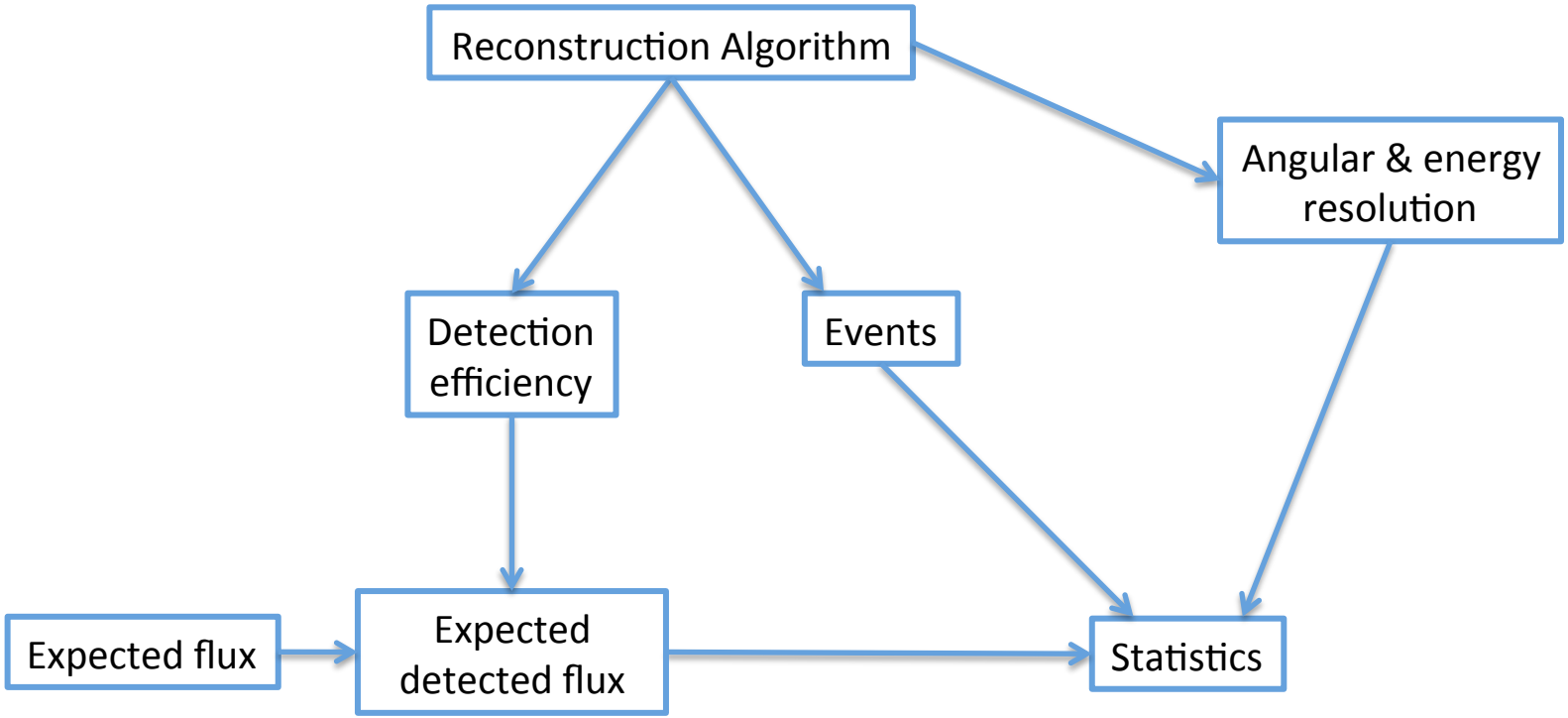

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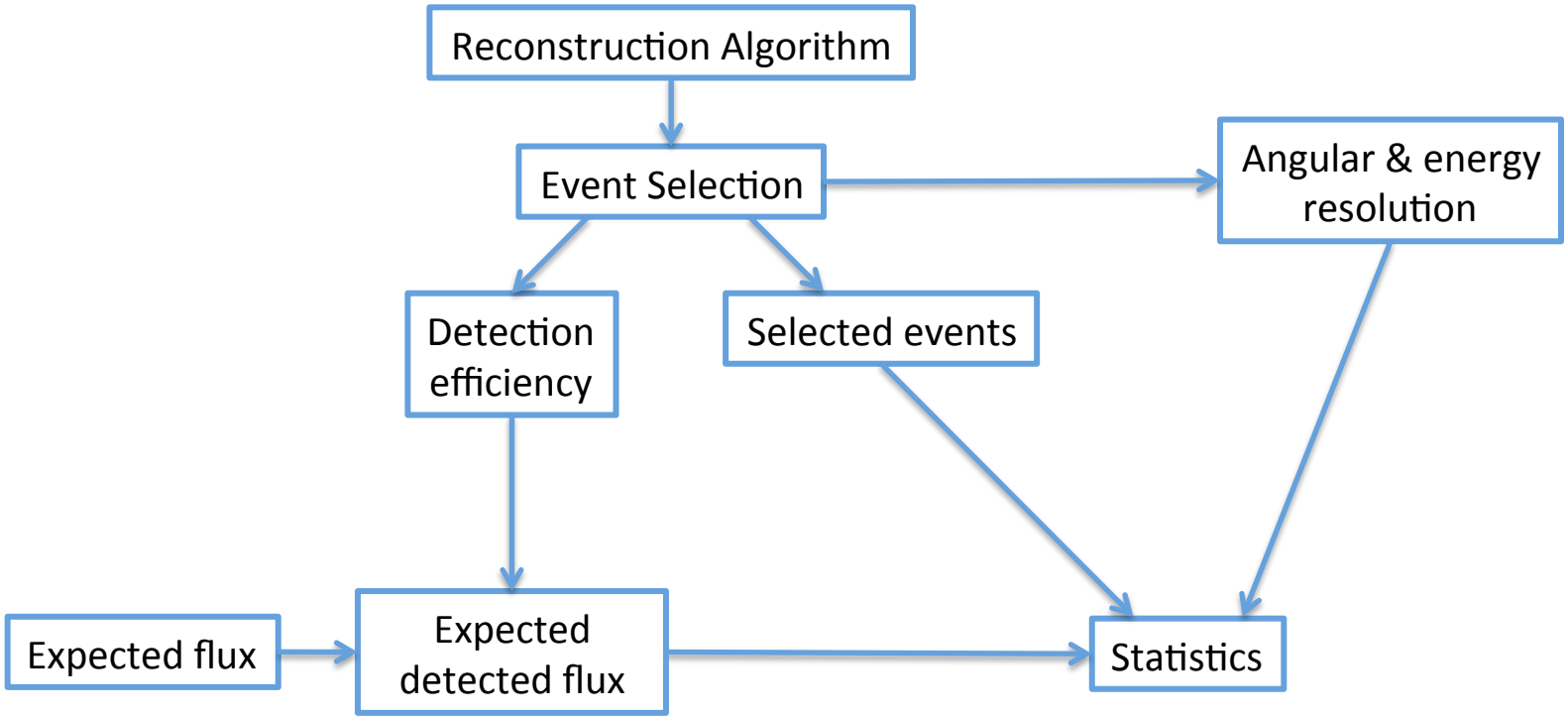

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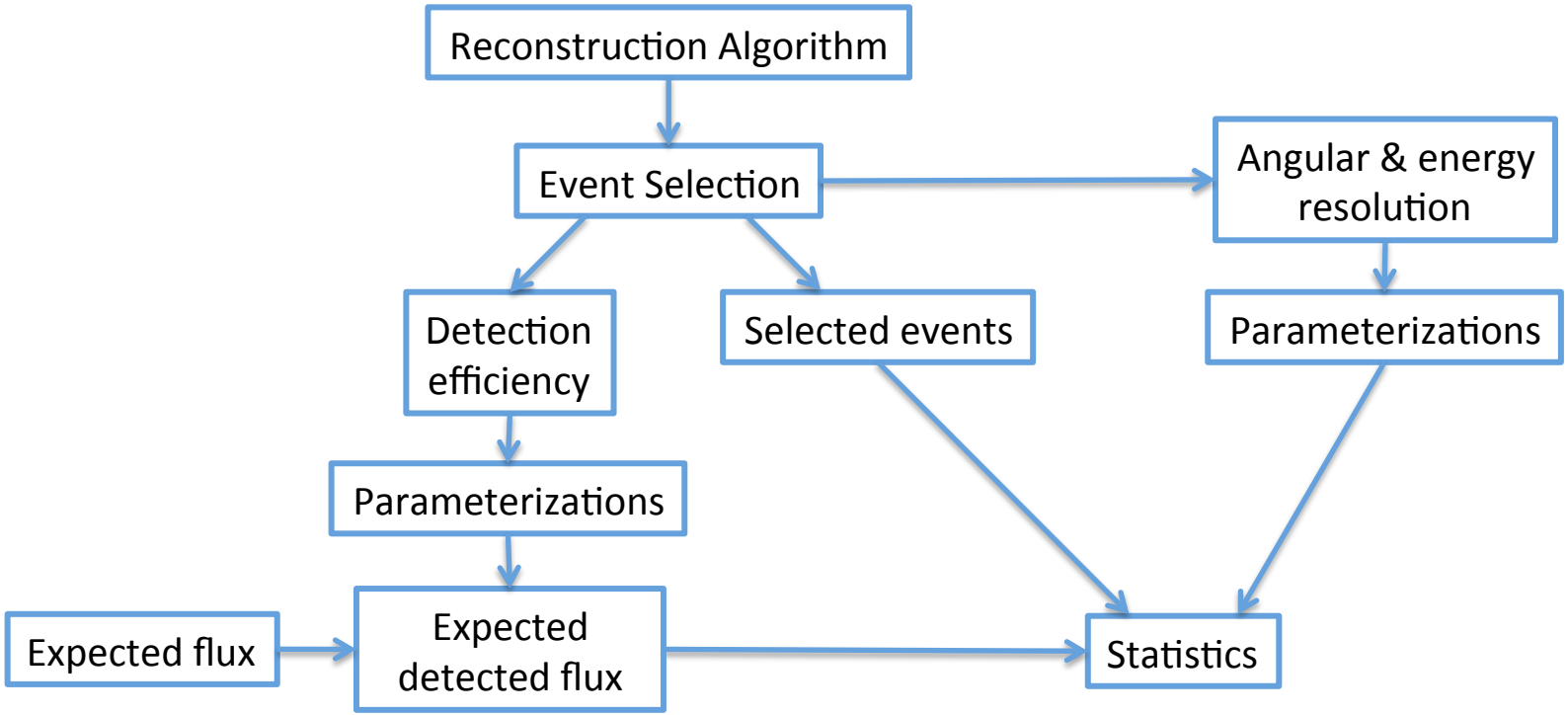

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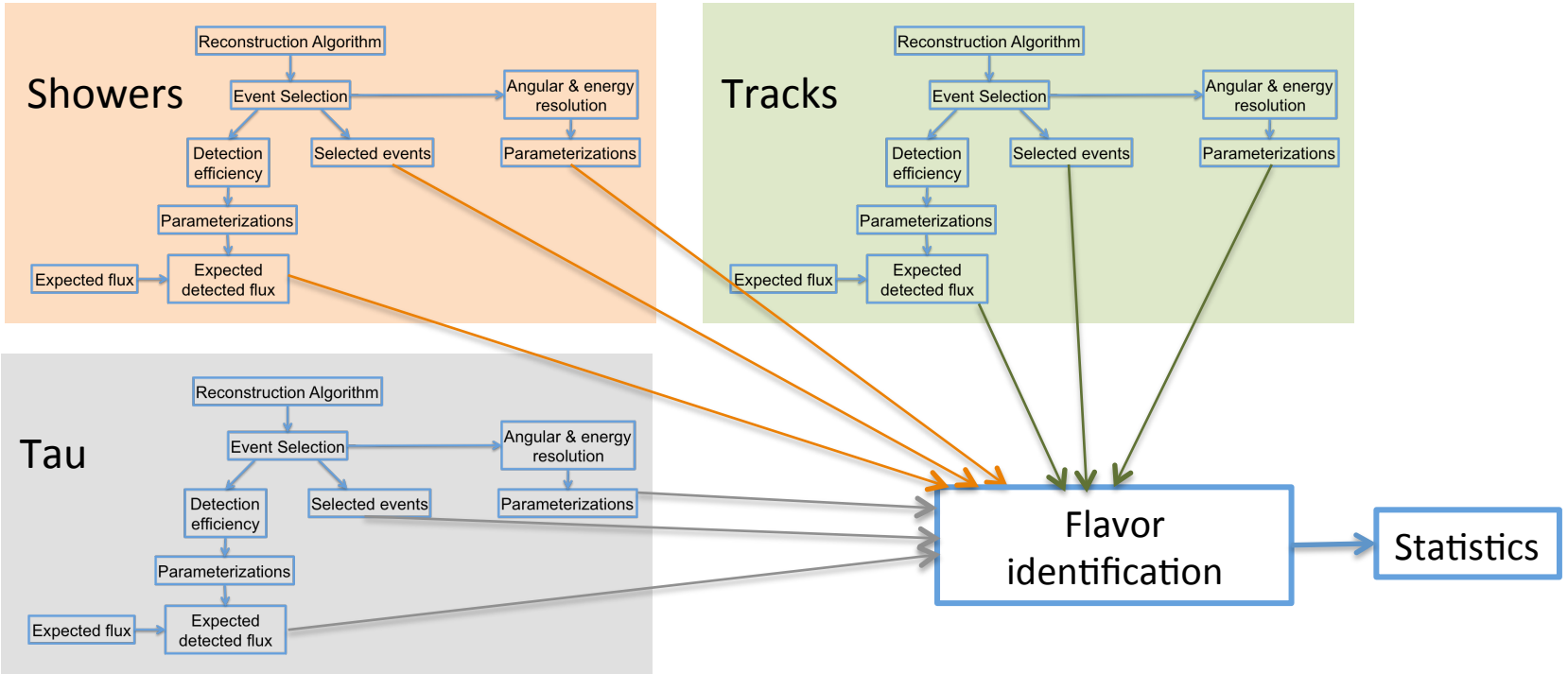

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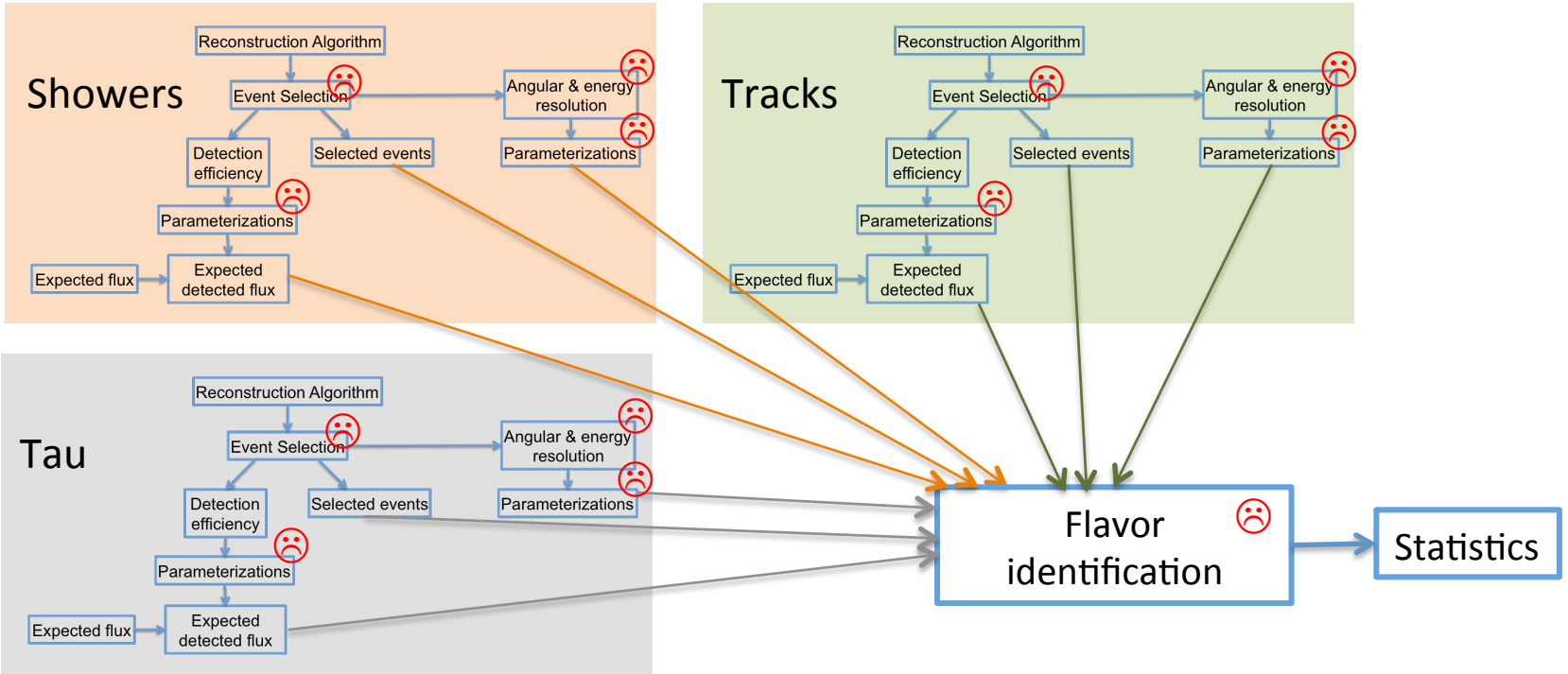

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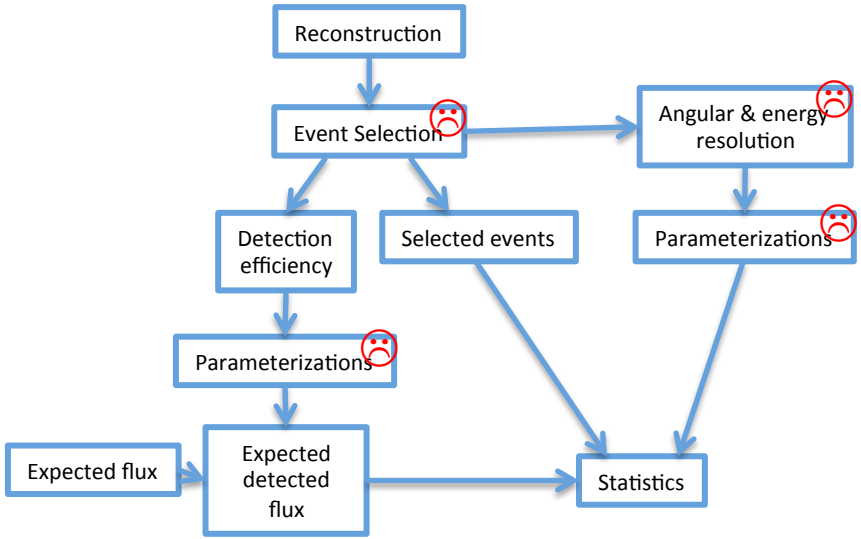
Old method



New method

New Method

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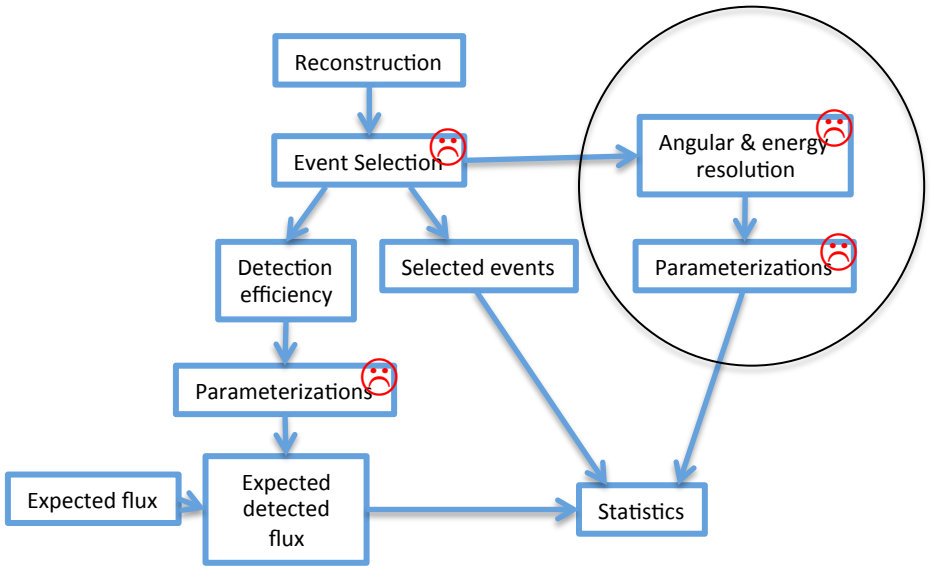

New method

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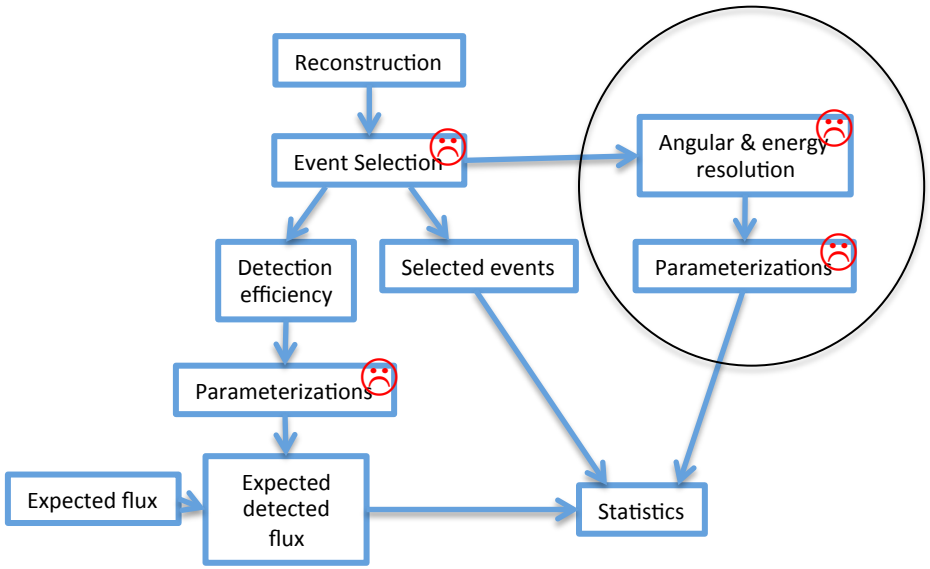

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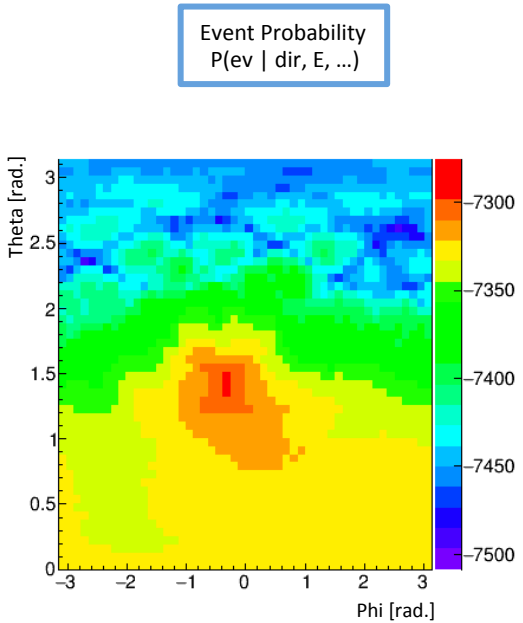

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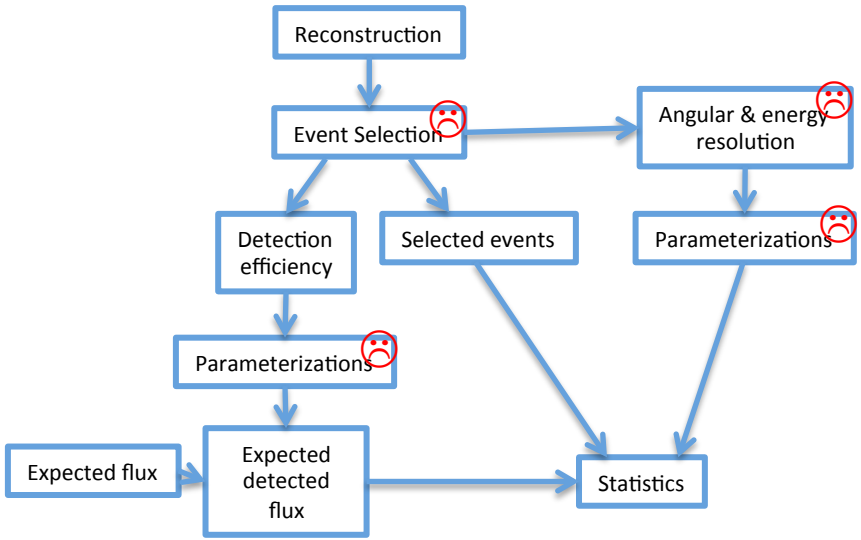

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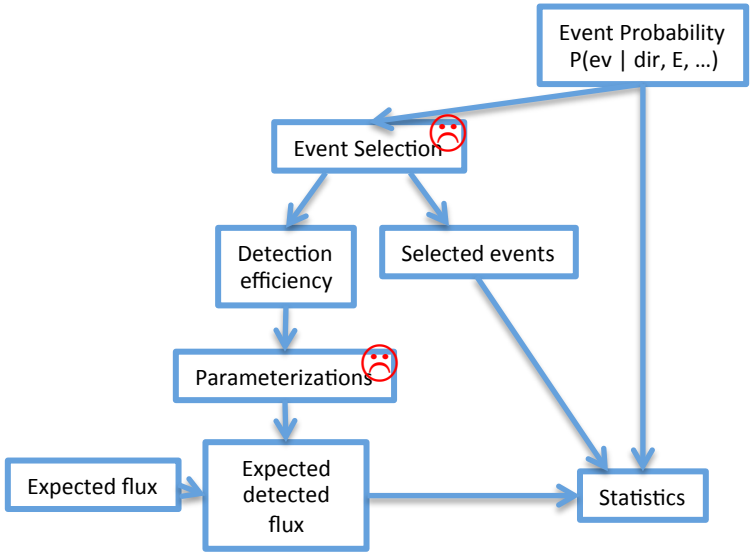

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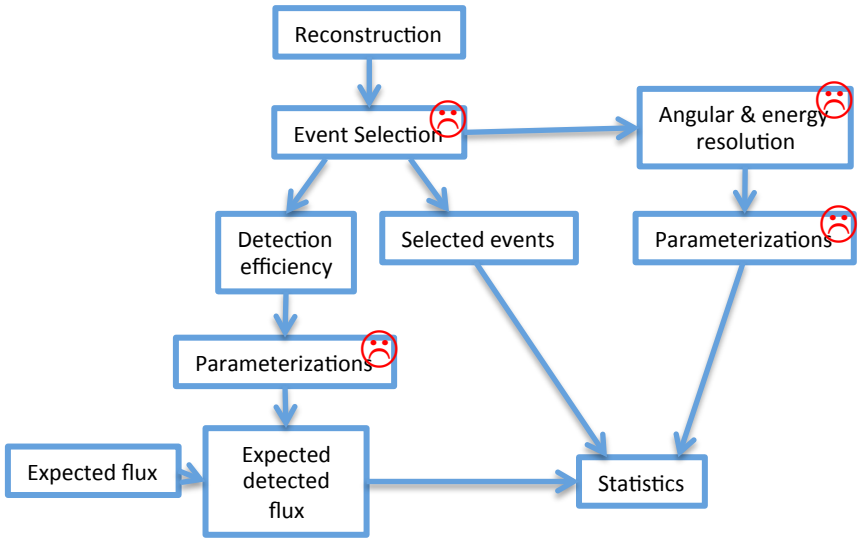

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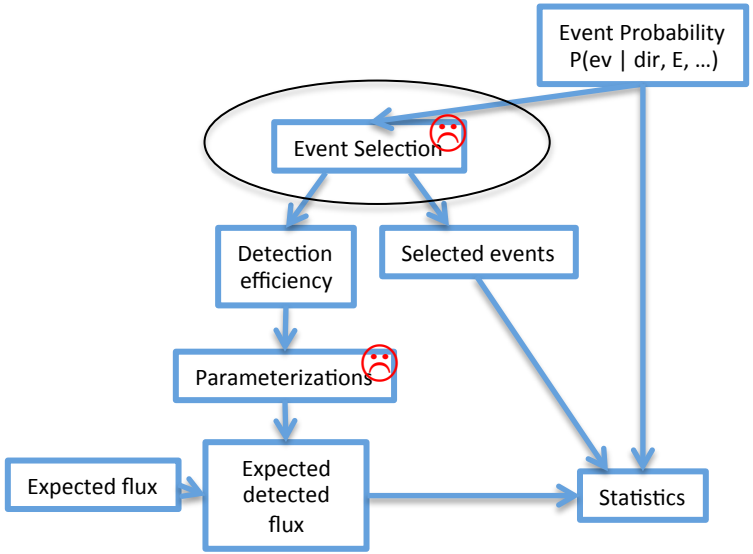

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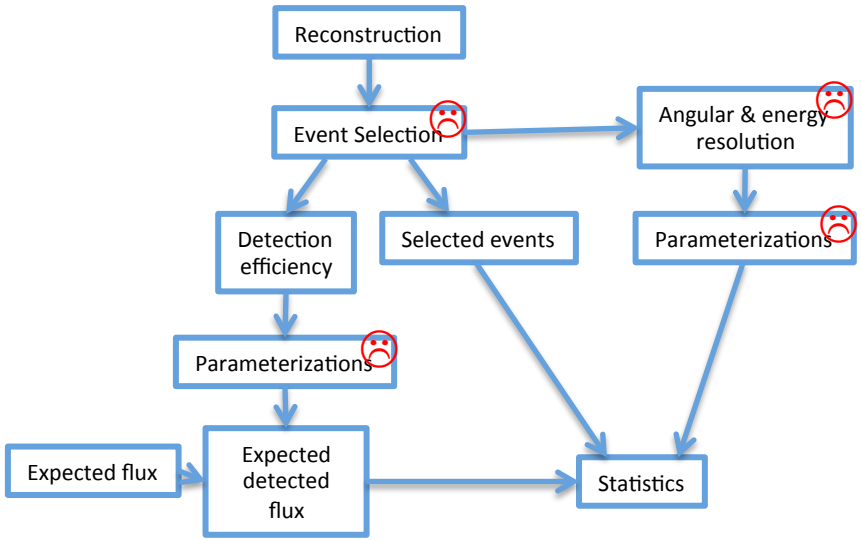

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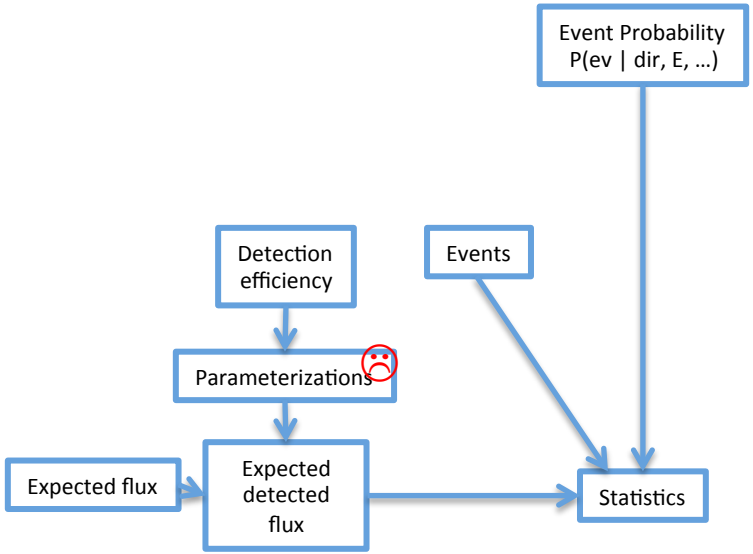

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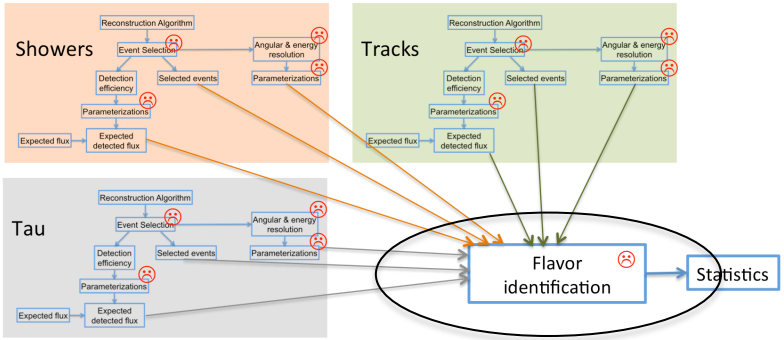

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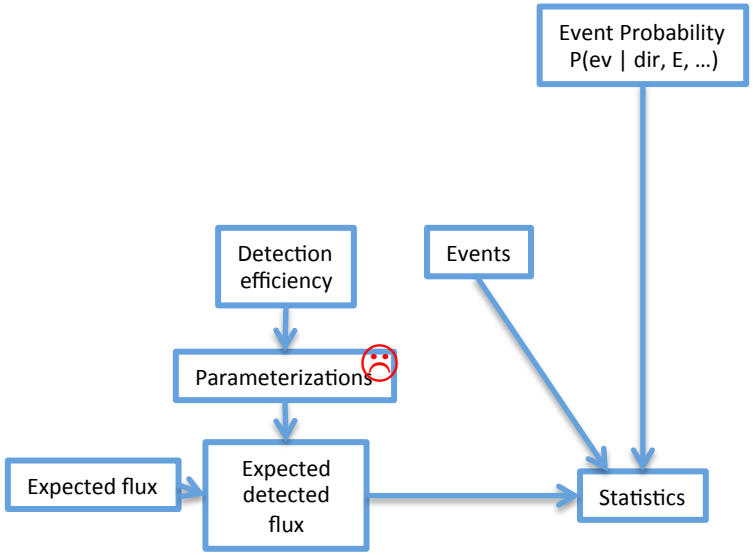

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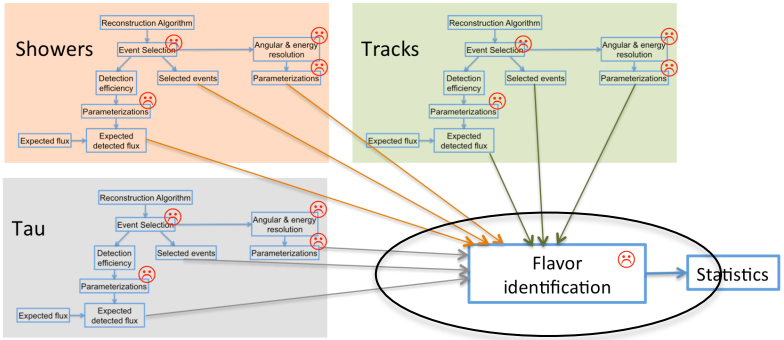

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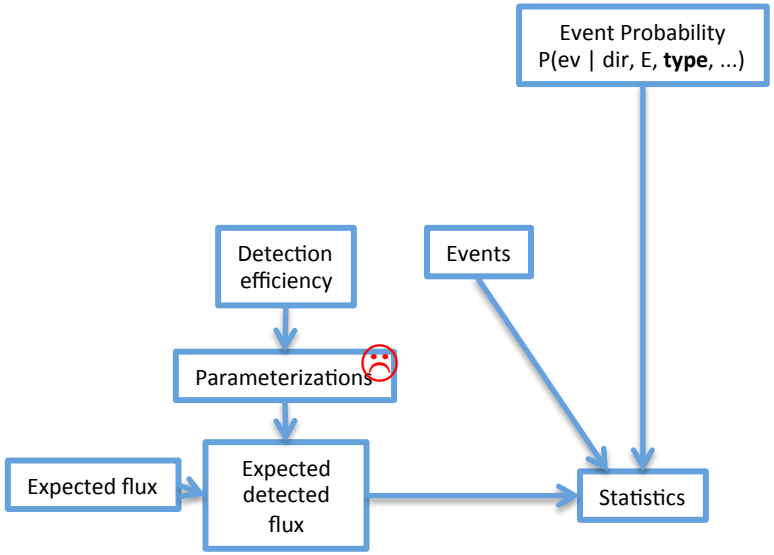

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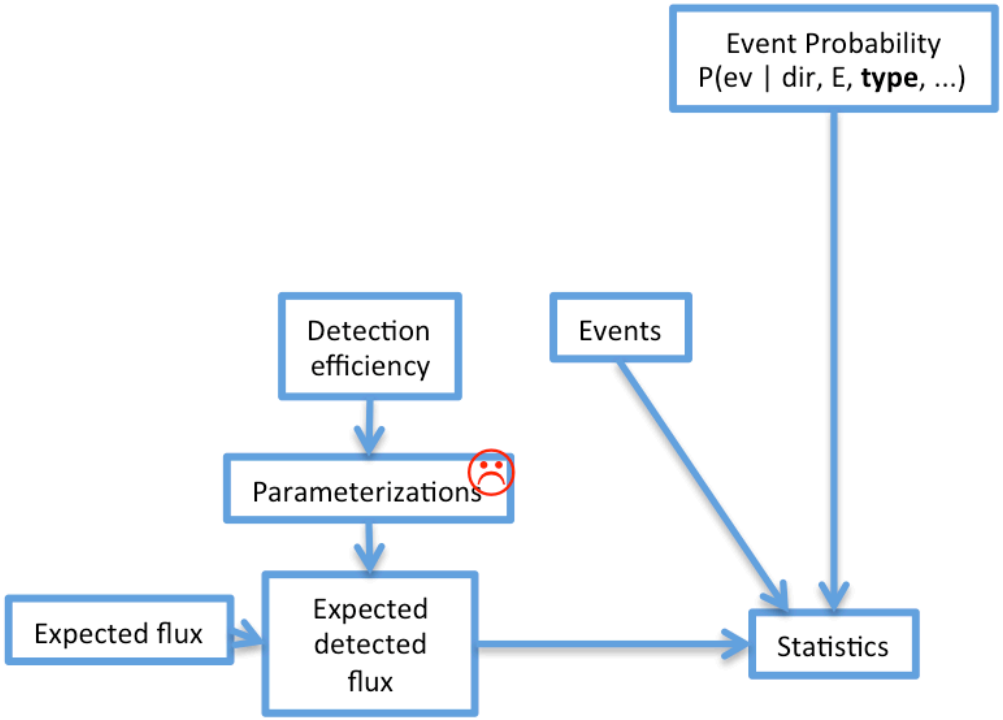
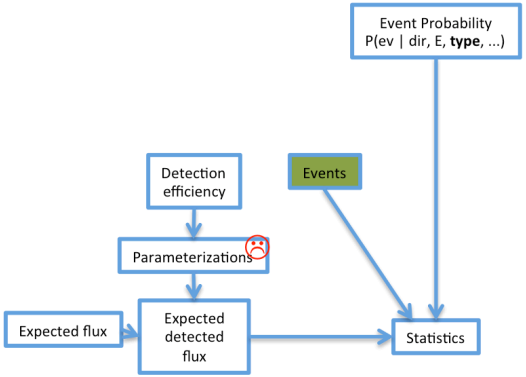
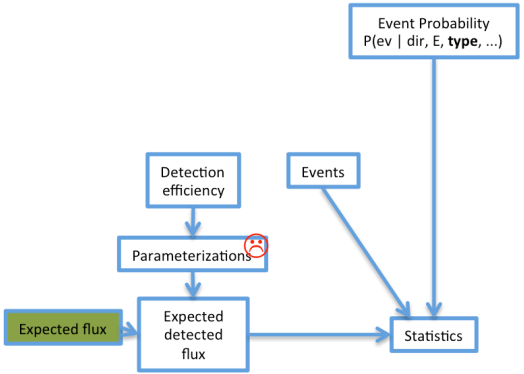


Events

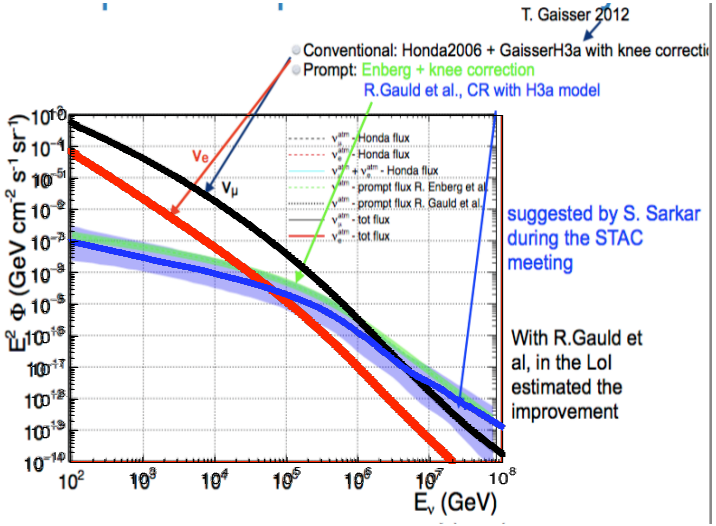
- Standard MC chain:
  - Genhen/mupage
  - km3
  - JTriggerEfficiency
- Optional:
  - km3 -> JSirene
- Very optional:
  - Make own generator



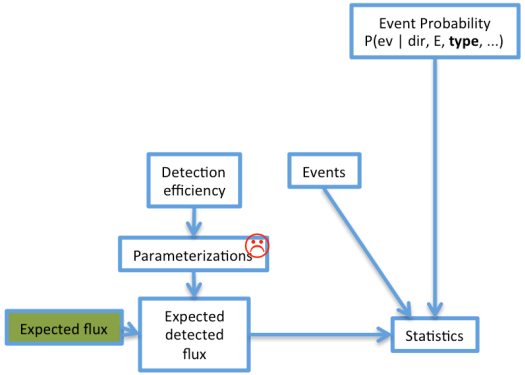
Expected Flux



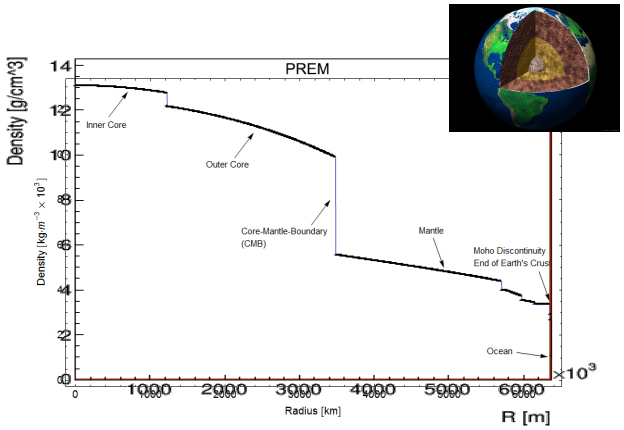
- Input flux:
  - Source flux or atm. neutrino flux

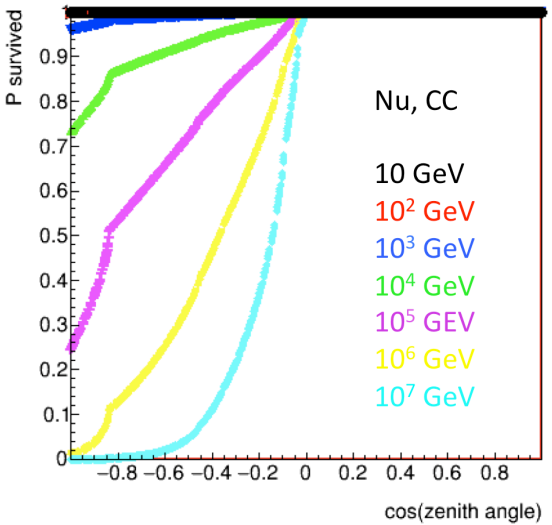


Expected Flux



- Input flux:
  - Source flux or atm. neutrino flux
- Earth propagation
  - Prem earth model





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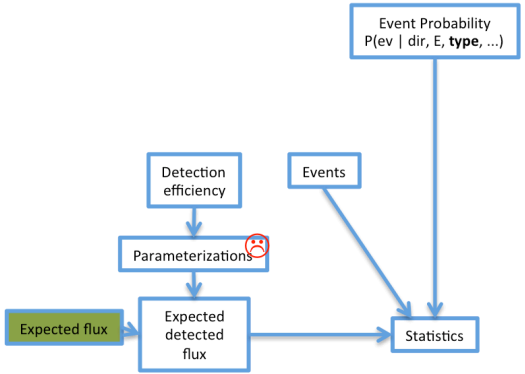
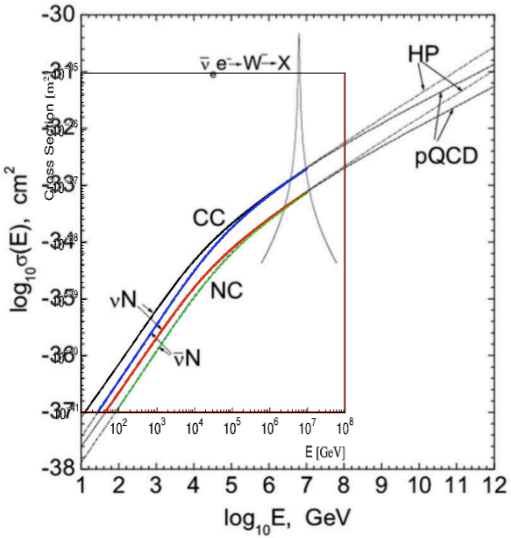
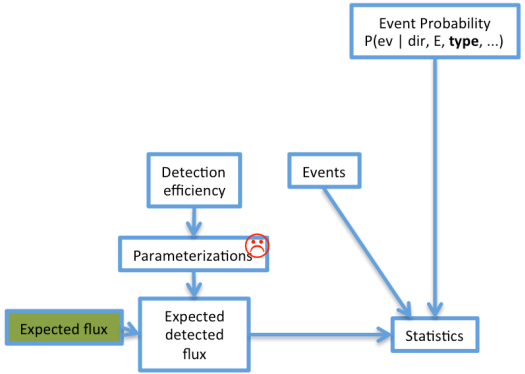


- Input flux:
  - Source flux or atm. neutrino flux
- Earth propagation
  - Prem earth model
- Cross section
  - Standard LoI cross-section



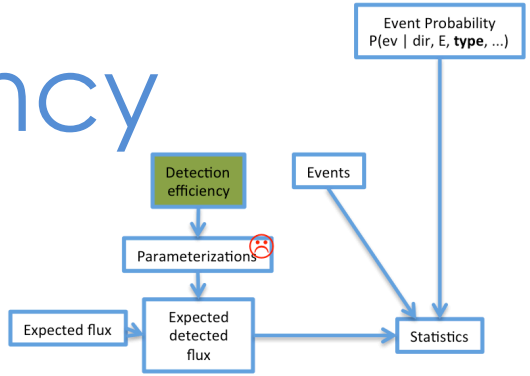
Expected Flux

- Input flux:
  - Source flux or atm. neutrino flux
- Earth propagation
  - Prem earth model
- Cross section
  - Standard LoI cross-section
- Bjorken-y
  - TODO
- Hadronic showers
  - TODO



Detection Efficiency

- MonitorDetectionEfficiency.cc
  - N times JSirene + JTriggerEfficiency



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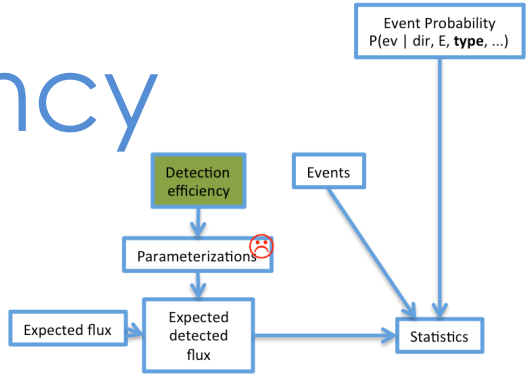
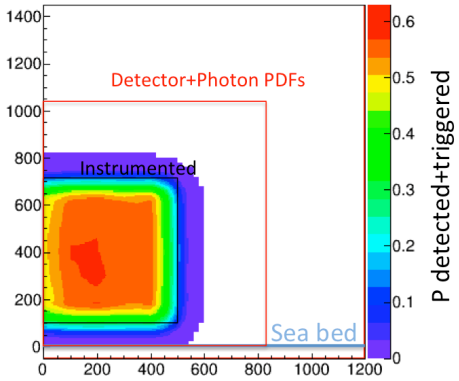
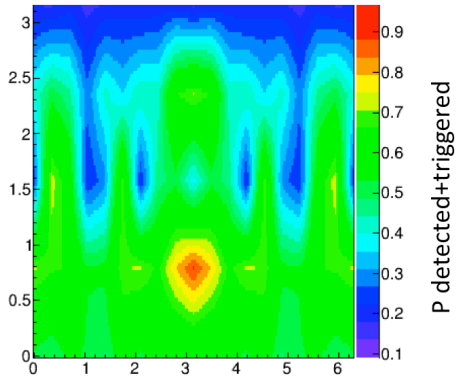


- MonitorDetectionEfficiency.cc
  - N times JSirene + JTriggerEfficiency
- P^{det}(pos, dir, E, …) stored as tables
  - No need for parameterizations

Position



Direction @R=0, Z=400



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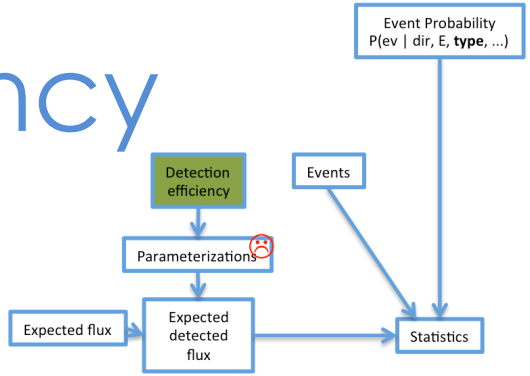
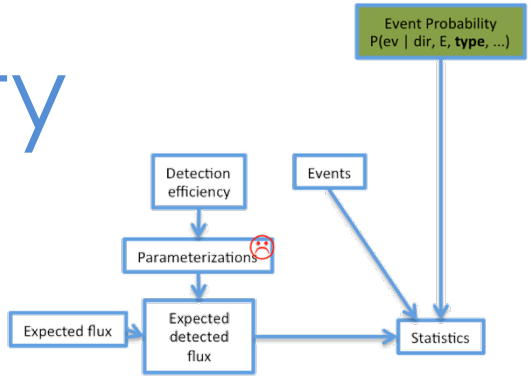


- MonitorDetectionEfficiency.cc
  - N times JSirene + JTriggerEfficiency
- P^{det}(pos, dir, E, …) stored as tables
  - No need for parameterizations
- TODO:
  - Cuts to reject atm. muon events

Event Probability



- Probability to observe detected event given neutrino param. X
  - x={pos, dir, t, E, by, type}

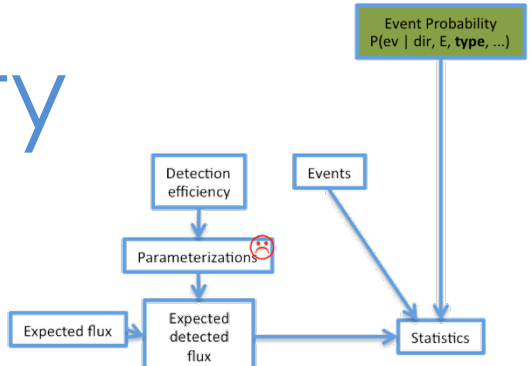
$$P(ev \mid x) = \prod_{hit\ PMTs} \left[P_i^{hit} \cdot P_i^{t\ 1st}\right] \cdot \prod_{non\ hit\ PMTs} \left[1 - P_i^{hit}\right]$$

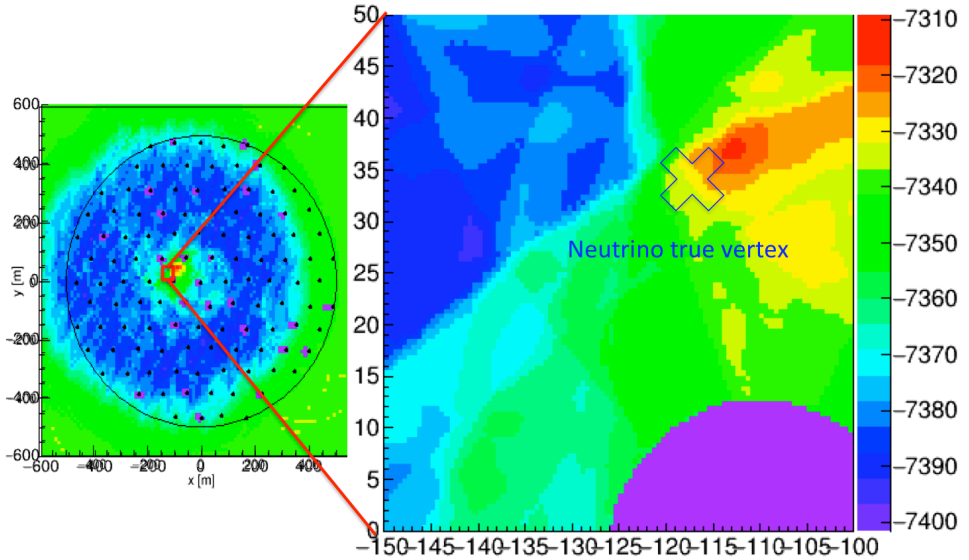
$$P_i^{hit} = 1 - \exp\left(-\int_{-\infty}^{\infty} \hat{n}_i(t)\, dt\right)$$

$$P_i^{t\ 1st} \cdot P_i^{hit} = \exp\left(-\int_{-\infty}^{t} \hat{n}_i(t)\, dt\right) \cdot \left(1 - \exp\left(-\hat{n}_i(t)\right)\right)$$

Event Probability

- Probability to observe detected event given neutrino param. X
  - x={pos, dir, t, E, by, type}
- Idea: Monitor once, re-use for different fluxes
  - 6D/7D Interpolation tables





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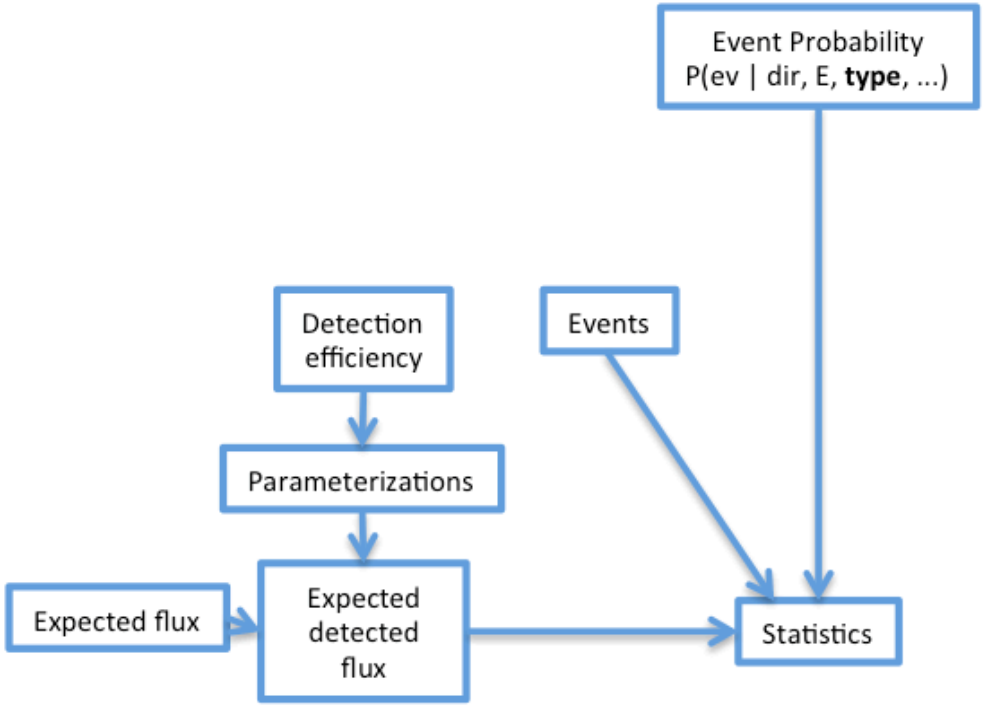

Outlook

- TODO:
  - Bjorken-y distribution
  - Hadronic shower parameterization
  - Atmospheric muon rejection (!)
  - Statistics part
  - ….
- Spin-off/extensions
  - MC generator
  - “old-fashioned” reconstruction
  - All kinds of hypotheses easily tested
  - Usable for ORCA too
  - Tau and other event signatures
- Needed:
  - CPUs (a lot)
  - (Official) tau Monte Carlo
    - Preferably bug-free
  - Disk space (/data/antares/)