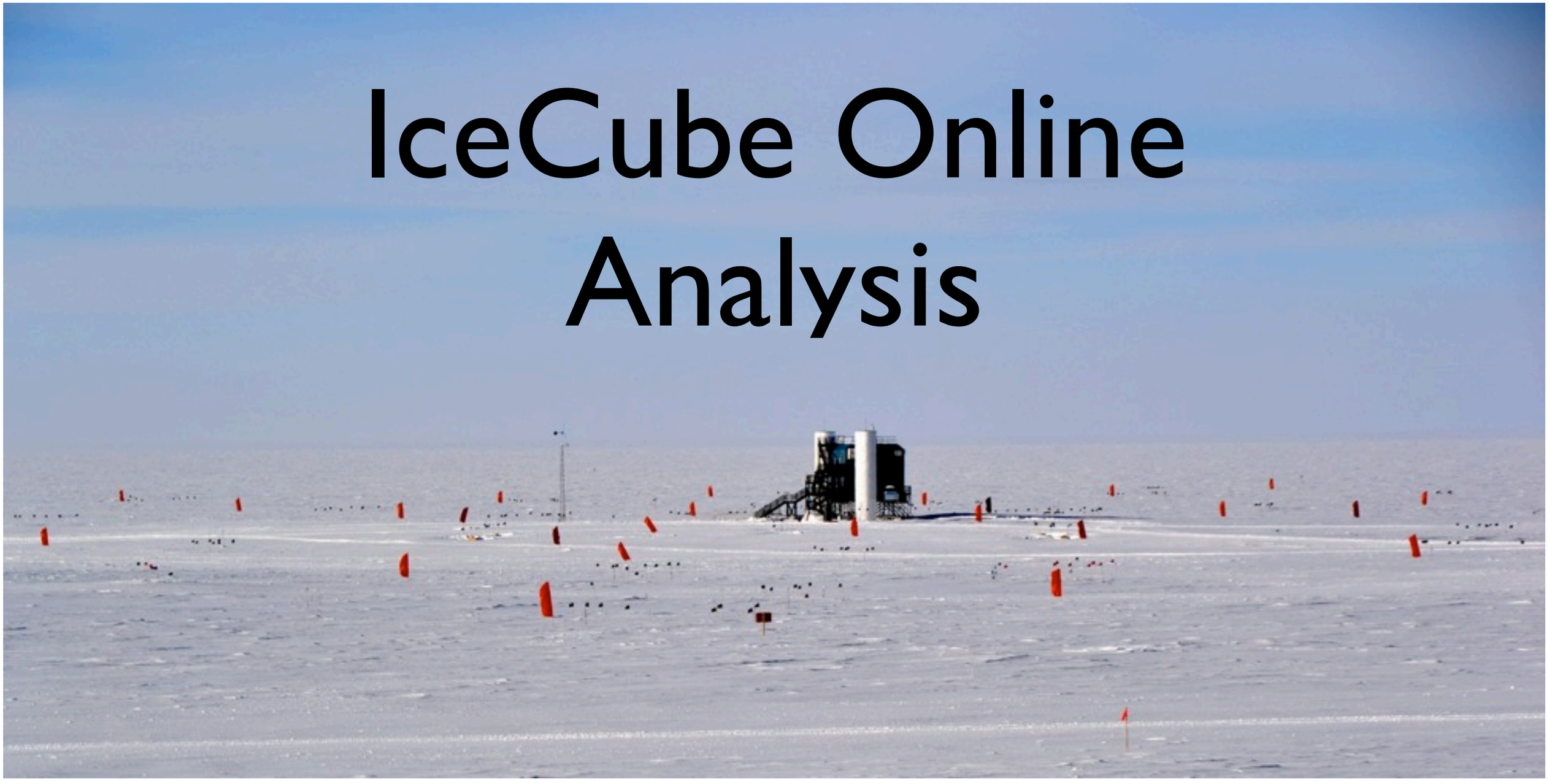
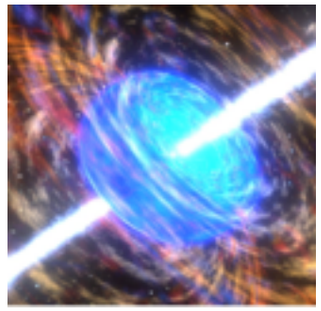
IceCube Online Analysis



Erik Blaufuss - University of Maryland

MANTS - September 24, 2011



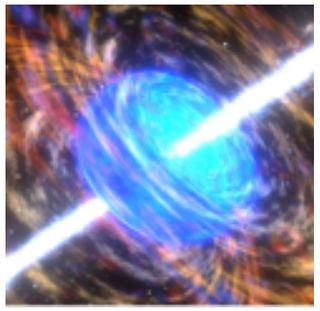
Online overview

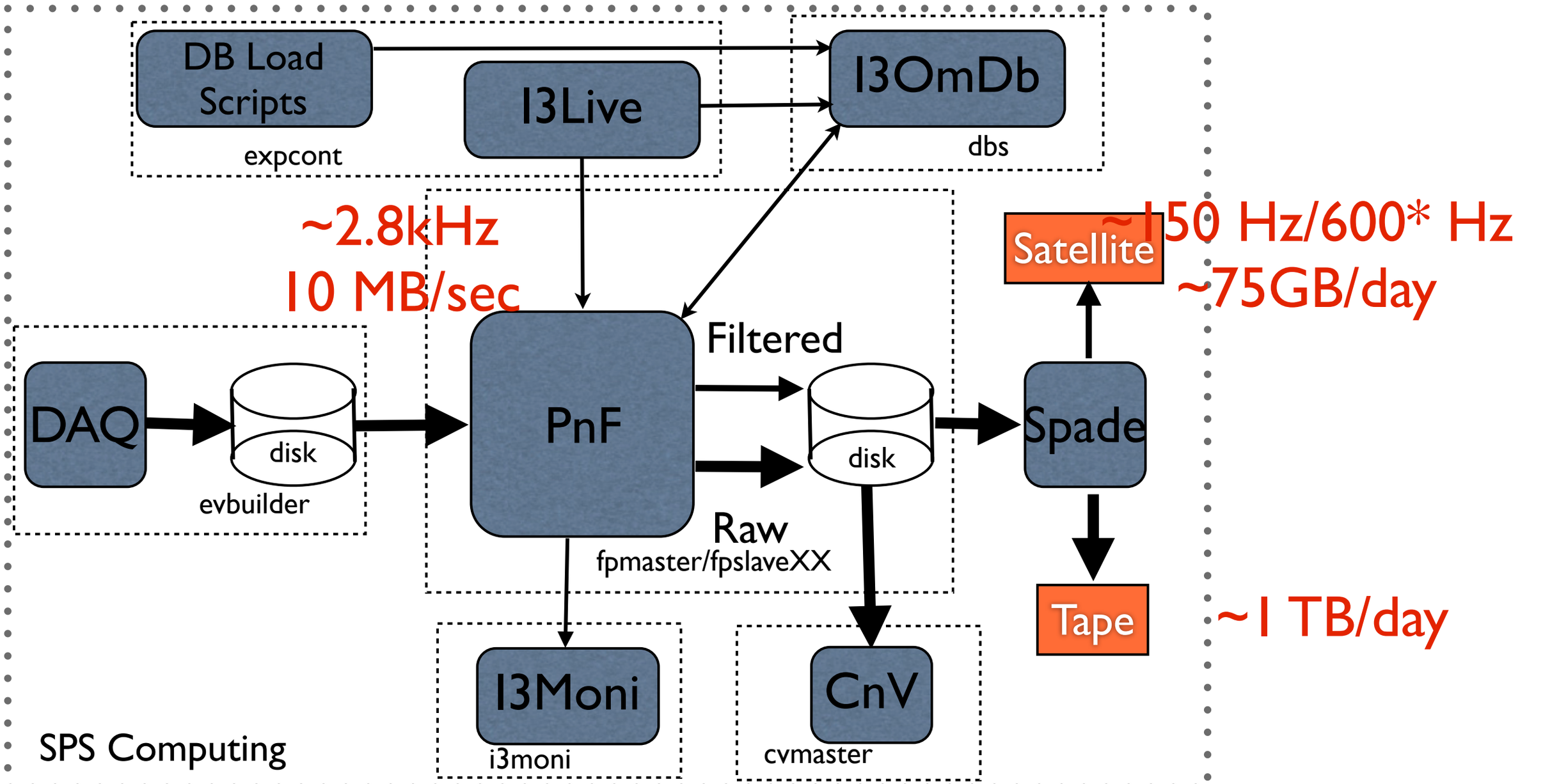
- Overview of IceCube online
  - What happens at South Pole
  - How do we communicate with systems there?
- Current and planned online analyses.
  - Optical FollowUp and Neutrino Target of Opportunity
  - “Real time” GRB neutrino searches
- Future plans

The challenges of data processing at South Pole

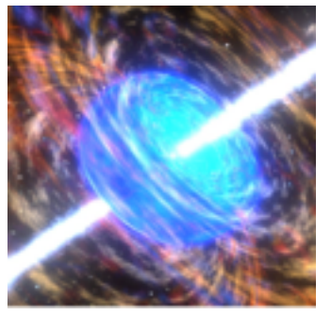
- Remote location of IceCube makes it difficult to get IceCube data out. We have two options:
  - Tape all events, and deal with them "next year"
  - Filter events in real-time, send a subset north immediately.
- We would like to start physics analysis of IceCube data as soon as possible.
  - Choose realtime filtering.
- Limited connectivity options
  - ~Dialup quality connection for a ~8 hours/day
  - TDRS bulk data transfer of 85 GB/day
- We'd also like to perform real time analysis, alert others in the event of interesting detections,
  - Realtime analysis of data is also very good for monitoring detector quality

PnF - Online filtering system





* including SuperDST only, no waveform data



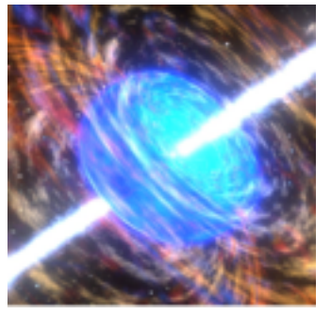
IC86 Filters

```
Rate for  SDST_MoonFilter_11 **sDST       is    0.00 Hz, with overlap    0.00 Hz (    0.00 pct)
Rate for  SlopFilterTime_11               is    0.45 Hz, with overlap    0.05 Hz (   11.79 pct)
Rate for  EHEFilter_11                    is    2.33 Hz, with overlap    2.24 Hz (   95.78 pct)
Rate for  SlopFilterTrig_11               is    0.81 Hz, with overlap    0.02 Hz (    1.91 pct)
Rate for  FilterMinBias_11                is    2.69 Hz, with overlap    0.09 Hz (    3.41 pct)
Rate for  DeepCoreFilter_11               is   26.86 Hz, with overlap    3.16 Hz (   11.78 pct)
Rate for  IceTopSTA3_InIceSMT_11          is    3.17 Hz, with overlap    1.42 Hz (   44.84 pct)
Rate for  MoonFilter_11                   is    0.00 Hz, with overlap    0.00 Hz (    0.00 pct)
Rate for  CascadeFilter_11                is   27.12 Hz, with overlap    8.07 Hz (   29.75 pct)
Rate for  SDST_GCMinBias_11 **sDST        is  270.16 Hz, with overlap   37.66 Hz (   13.94 pct)
Rate for  IceTopSTA3_11                   is    6.40 Hz, with overlap    1.67 Hz (   26.06 pct)
Rate for  SDST_GCNWStarting_11 **sDST     is  190.94 Hz, with overlap   33.70 Hz (   17.65 pct)
Rate for  SDST_SunFilter_11 **sDST        is    0.00 Hz, with overlap    0.00 Hz (    0.00 pct)
Rate for  IceTopSTA8_InIceSMT_11          is    0.43 Hz, with overlap    0.43 Hz (  100.00 pct)
Rate for  IceTop_InFill_STA3_11           is    1.01 Hz, with overlap    0.64 Hz (   63.30 pct)
Rate for  IceTopMuonCalibration_11        is    0.00 Hz, with overlap    0.00 Hz (    0.00 pct)
Rate for  SDST_MuonFilter_11 **sDST       is   40.43 Hz, with overlap   11.14 Hz (   27.55 pct)
Rate for  SDST_LowUp_11 **sDST            is   31.36 Hz, with overlap    8.66 Hz (   27.63 pct)
Rate for  GCLEStarting_11                 is    6.62 Hz, with overlap    1.84 Hz (   27.83 pct)
Rate for  SDST_VEF_11 **sDST              is    7.96 Hz, with overlap    1.94 Hz (   24.43 pct)
Rate for  InIceSMT_IceTopCoincidence_11   is    1.05 Hz, with overlap    0.11 Hz (   10.13 pct)
Rate for  SDST_GCHE_11 **sDST             is  104.38 Hz, with overlap   17.86 Hz (   17.11 pct)
Rate for  IceTopSTA8_11                   is    1.29 Hz, with overlap    0.83 Hz (   64.12 pct)
Rate for  MuonFilter_11                   is   30.25 Hz, with overlap   10.10 Hz (   33.40 pct)
Rate for  PhysicsMinBiasTrigger_11        is    1.28 Hz, with overlap    0.01 Hz (    0.69 pct)
```

Filters determined by physics working groups, tuned to match physics needs of each analysis

Reduce data to match BW

PnF - Online filtering system Internals



(~100) fpslaveXX

Client Pool 1

~1 sec

PFServer1

PF2Live

fpmaster

I3DAQDispatch

evbuilder

PFWriter
~20 sec

PFFiltDispatch
~1-2 min

PFServer2

PFDropBox

GCDDispatch

Client Pool 2

(~100) fpslaveXX

OpticalFollowup
GammaFollowup

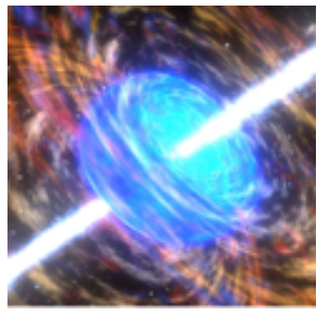
fpslave01

IceCube Teleport Service (Iridium)

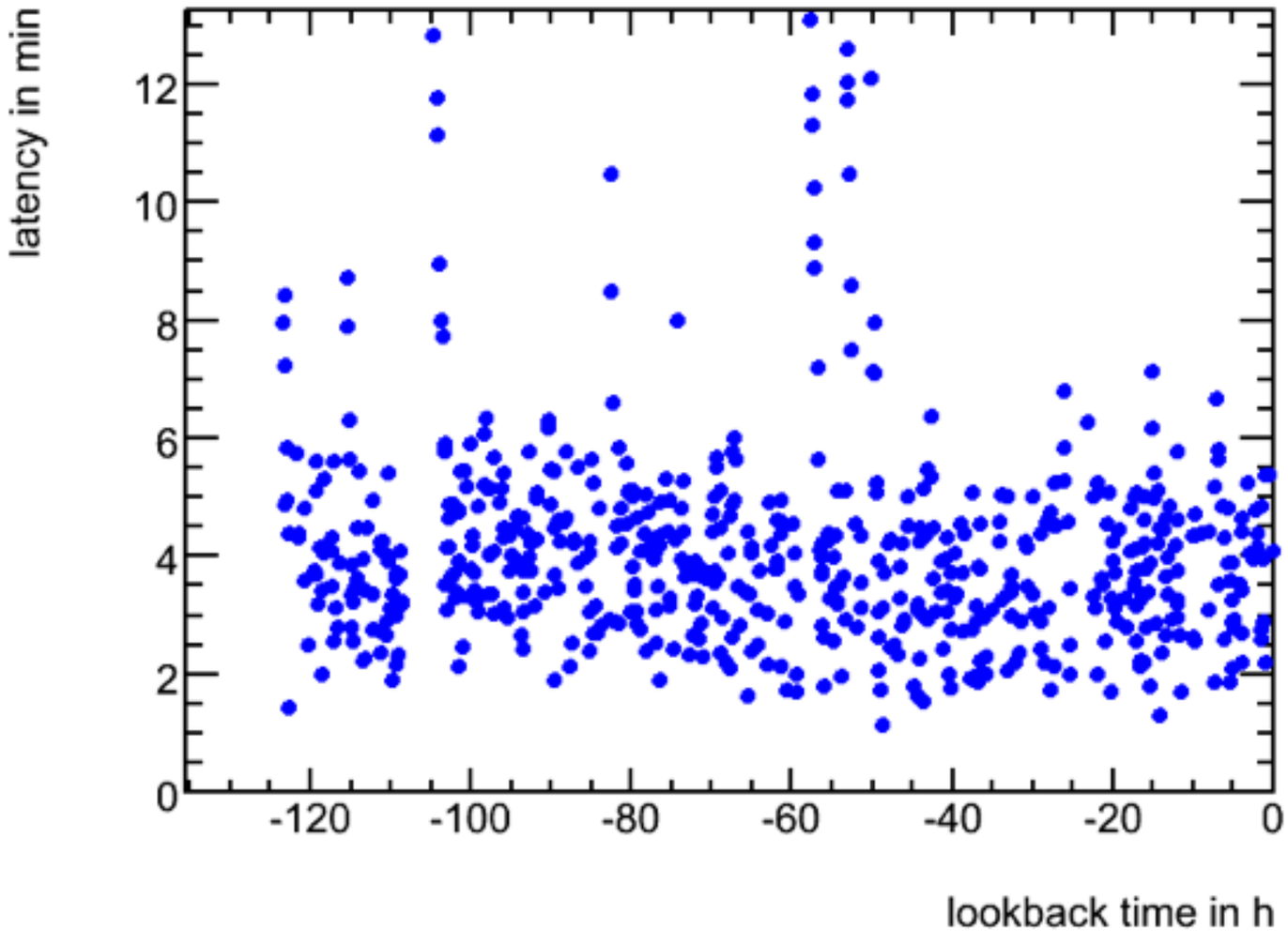
Telescopes
~3-4 min

Very short processing time in online filtering since IC79

PnF - Online filtering system Internals



(~100) fpslaveXX



I3DAQDispa

evbu

GCDDispat

(~100) fpslaveXX

fpslave01

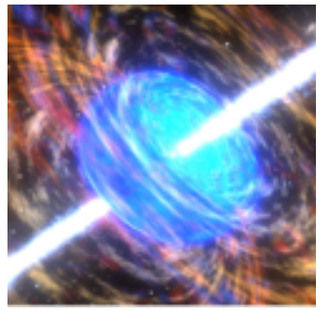
→ IceCube Teleport Service (Iridium)

↓

Telescopes
~3-4 min

Very short processing time in online filtering since IC79

“Online” L2



- A small fraction of the muon track candidates selected receive additional reconstructions in real time at South Pole

Up-Going Region ($\theta_{LLH} >= 80°$)

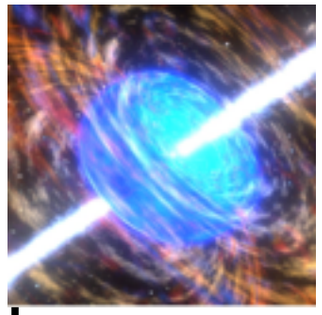
```
(PoleMuonLlhFit_logl/(NCh - 2) <= 7.3) || (NCh > 70)
|| (TMath::Power(PoleMuonLlhFit_LDirC/180.,2)
+ TMath::Power(PoleMuonLlhFit_NDirC/10.,2) >= 1)
```

Down-Going Region ($\theta_{LLH} < 80°$)

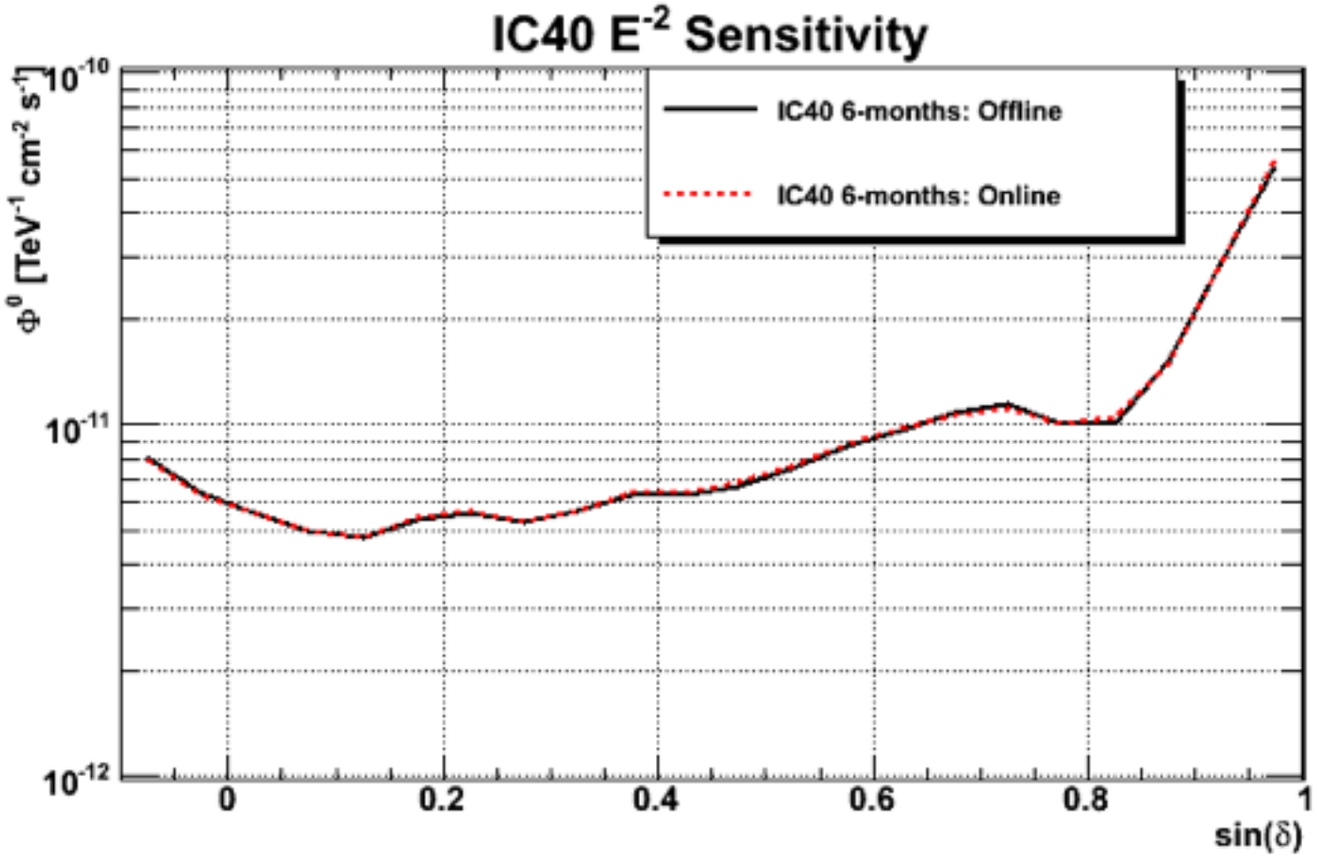
```
(((PoleMuonLlhFit_Zenith < 80 * TMath::Pi()/180)&&(
    PoleMuonLlhFit_Zenith >= 75*TMath::Pi()/180))
&& (TMath::Log10(QTot) > 1.95 || PoleMuonLlhFit_rlogl < 7.3))
||
((PoleMuonLlhFit_Zenith < 75 * TMath::Pi()/180)
&& (TMath::Log10(QTot) > 3.3 - 1.3 *TMath::Power(
    PoleMuonLlhFit_Zenith/1.309,6)))
```

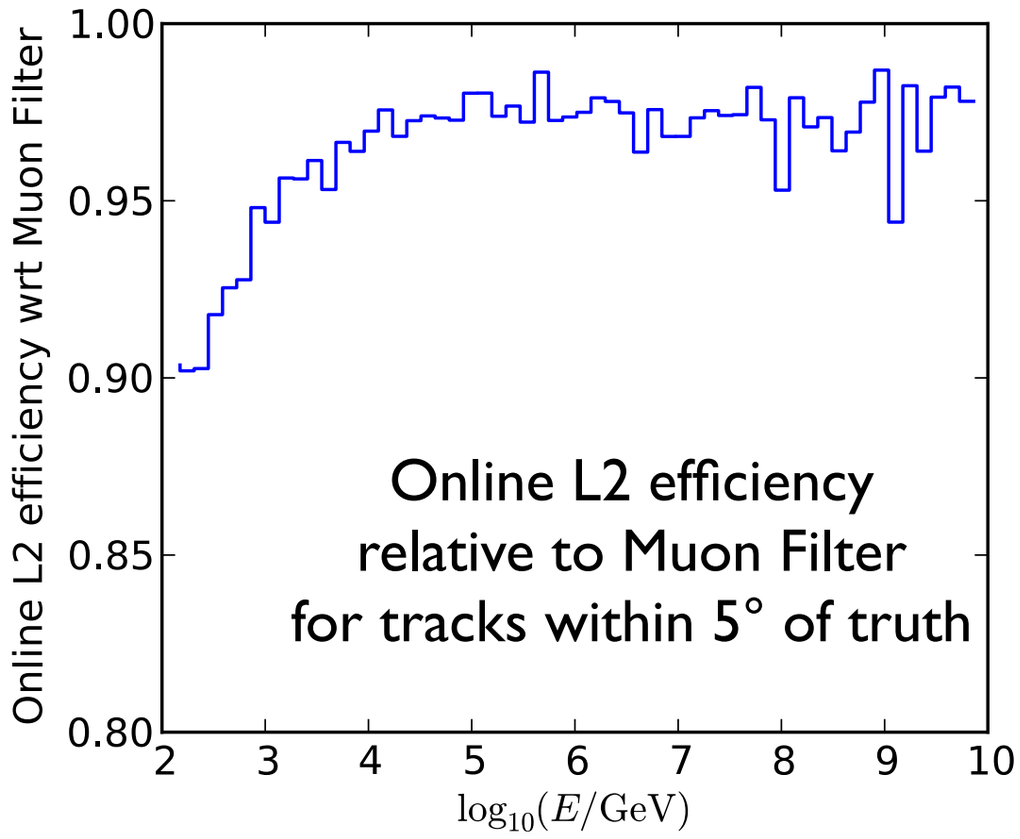
- L2 Reconstructions include:
  - Multiple iteration track LLH, MPE LLH
  - Cramer-Rao, Bayesian-prior LLH, Time/Geometry Split LLH recos
- This candidate selections, and the additional reconstructions are used by the real-time analysis clients.
  - Gamma-Ray Follow Up
  - Optical Follow Up

Online L2 selection is robust



- Cross check with 6 months of IC40 Point Source search sample
  - 0.44% event sample difference
- IC86 GRB neutrino search
  - Planning to use IC86 Online L2 as pre-selection





High-Energy Gamma-Ray Follow-Up Program

Online processing
at the South Pole (IC86)

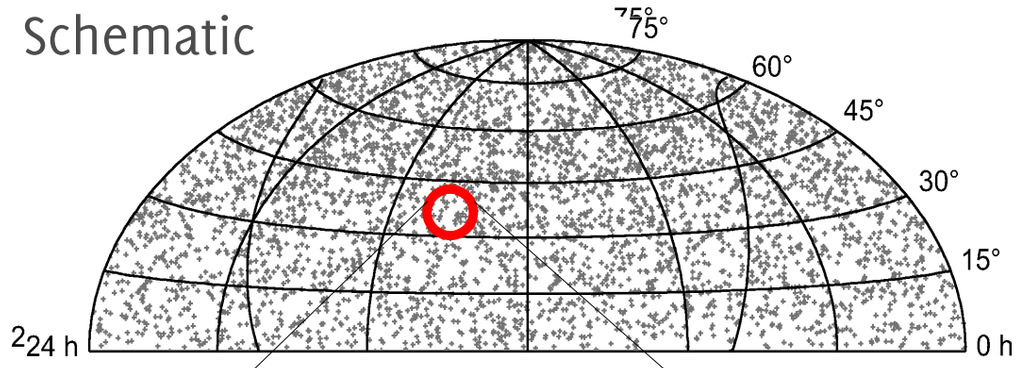
Trigger: ~2000 Hz

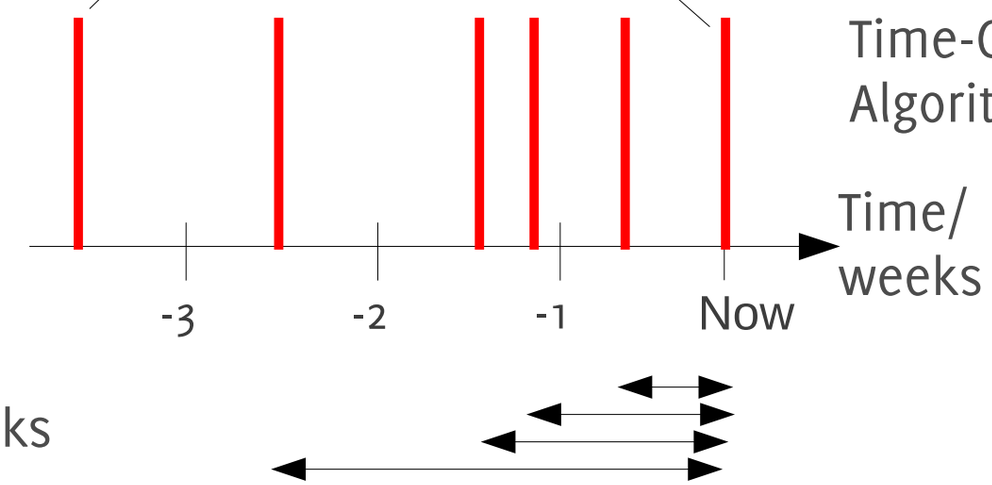
Level 1 Filter: ~35 Hz
Single iterations SPE Fit

Level 2 Filter: ~4 Hz
2-iteration SPE fit,
MPE fit, CramerRao

Neutrino selection:
~1.5 mHz

Schematic





Time-scale for
cluster search:
seconds to ~3 weeks

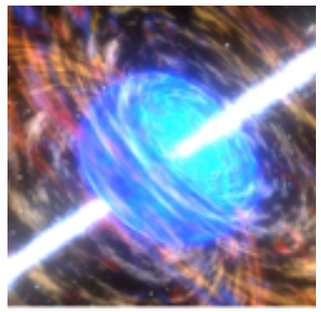
Detector stability
monitoring

+

Significance of current
neutrino cluster

→ Alert

Right now: Send alerts for 0.5 sigma clusters



Gamma-Ray Followup

- Monitor catalog of known HE Gamma ray sources
  - 22 cataloged sources for MAGIC
  - 22 + 56 potentially variable sources for VERITAS
- Set threshold to trigger ~1 followup/year
- Preparing final cuts selection to start sending alerts soon

Source name	RA	Declination
TeV J2032+4130	308.083	41.51

Table 1: Galactic source candidates for the IceCube-MA

Source name	RA	Declination	Redshift
PKS 2032+107	308.86	11.0	0.6
OX 169	325.87	17.72	0.21
3C 273	187.28	2.05	0.16

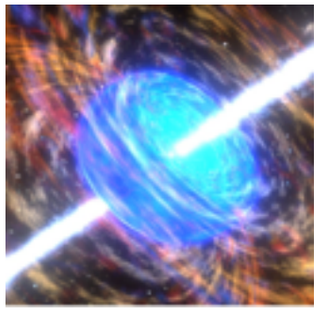
Table 1: FSQR source candidates for the IceCube-MAGIC N

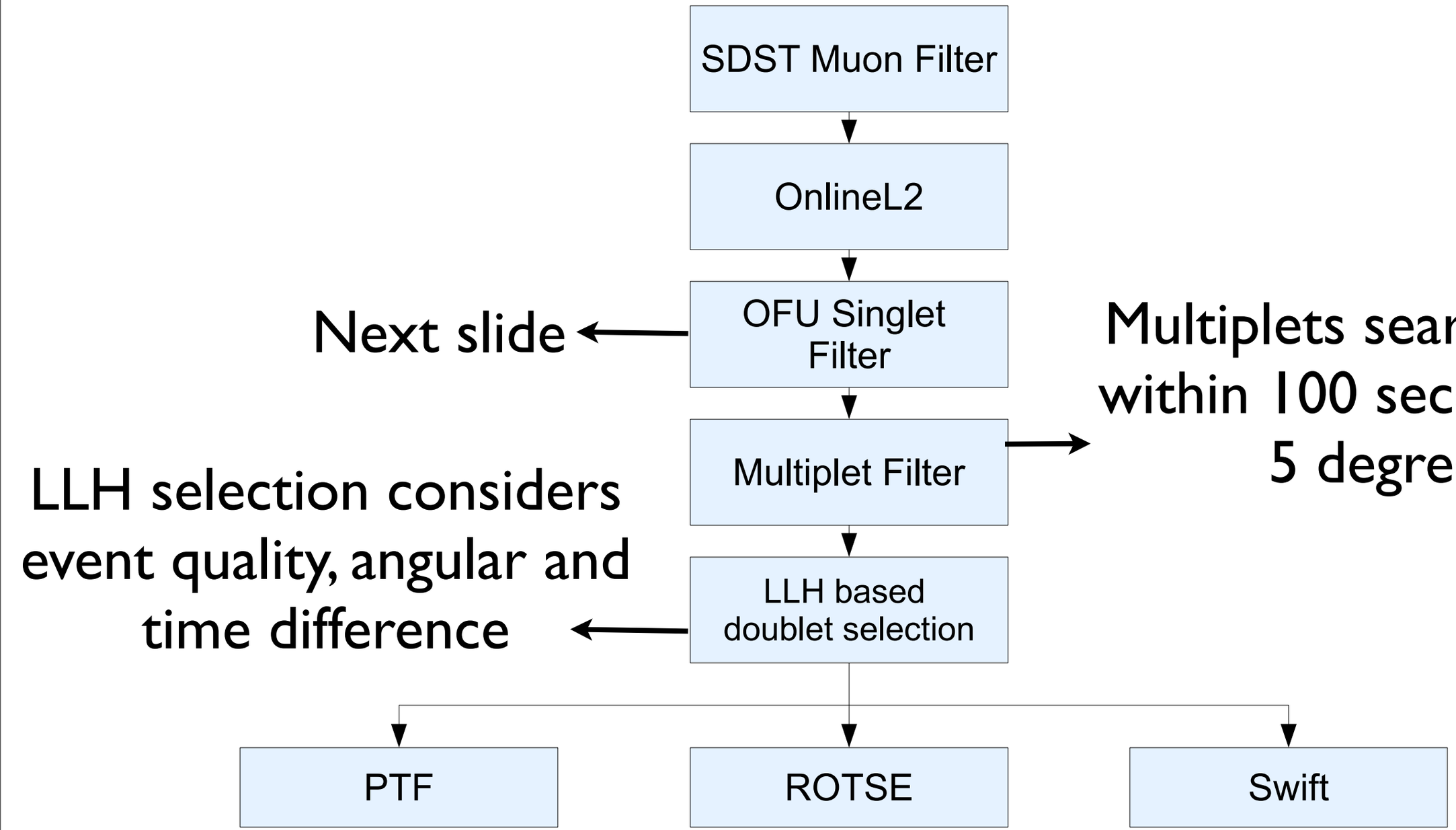
Selection thanks to A. Cruz

Source name	RA	Declination	Redshift
4C +09.57	267.89	9.63	0.32
PKS 0754+100	119.31	9.94	0.27
PG 1553+113	238.94	11.19	0.36
PKS 1717+177	259.81	17.76	0.14
OJ 287	133.71	20.11	0.31
PKS 1424+240	216.75	23.8	0.16
W Comae	185.39	28.25	0.1
B2 1215+30	184.45	30.12	0.1
B2 1218+30	185.34	30.14	0.18
Mkn 421	166.12	38.21	0.03
Mkn 501	253.49	39.75	0.03
1ES 2321+419	350.89	42.19	0.06
BL Lac	330.72	42.28	0.07
B3 0814+425	124.55	42.38	0.25
1ES 1011+496	153.79	49.45	0.2
CGRaBS J1058+5628	164.67	56.48	0.14
1ES 1959+650	300.02	65.13	0.05
S5 0716+71	110.48	71.34	0.3

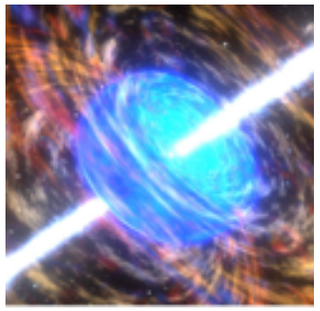
Table 1: BL Lac source candidates for the IceCube-MAGIC NToO

Optical FollowUp

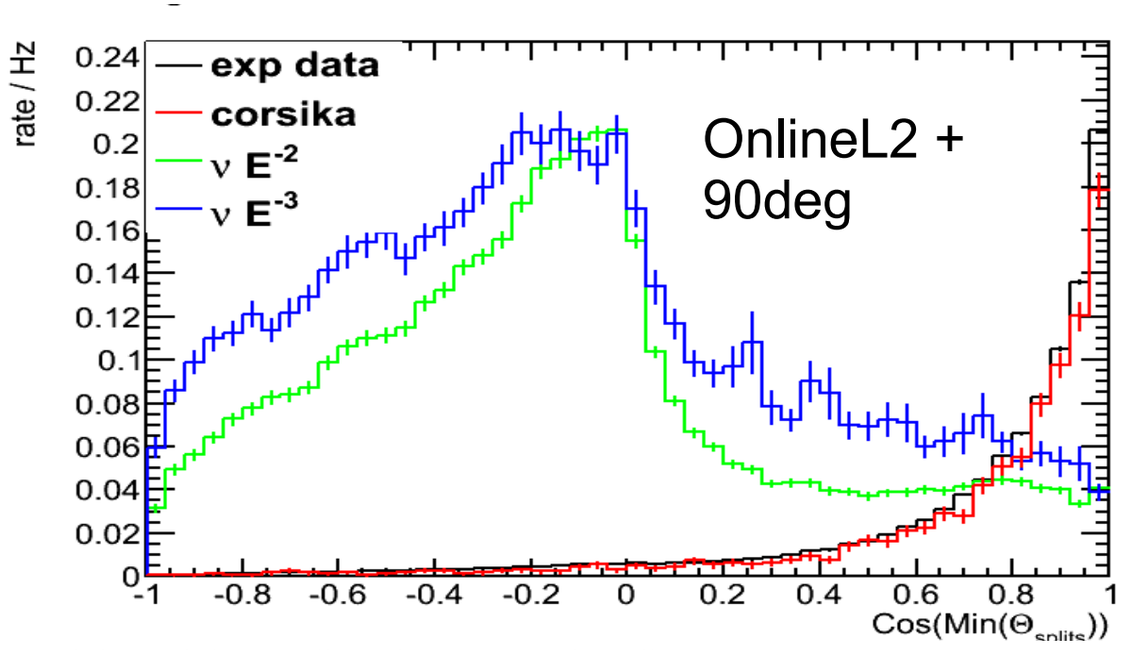


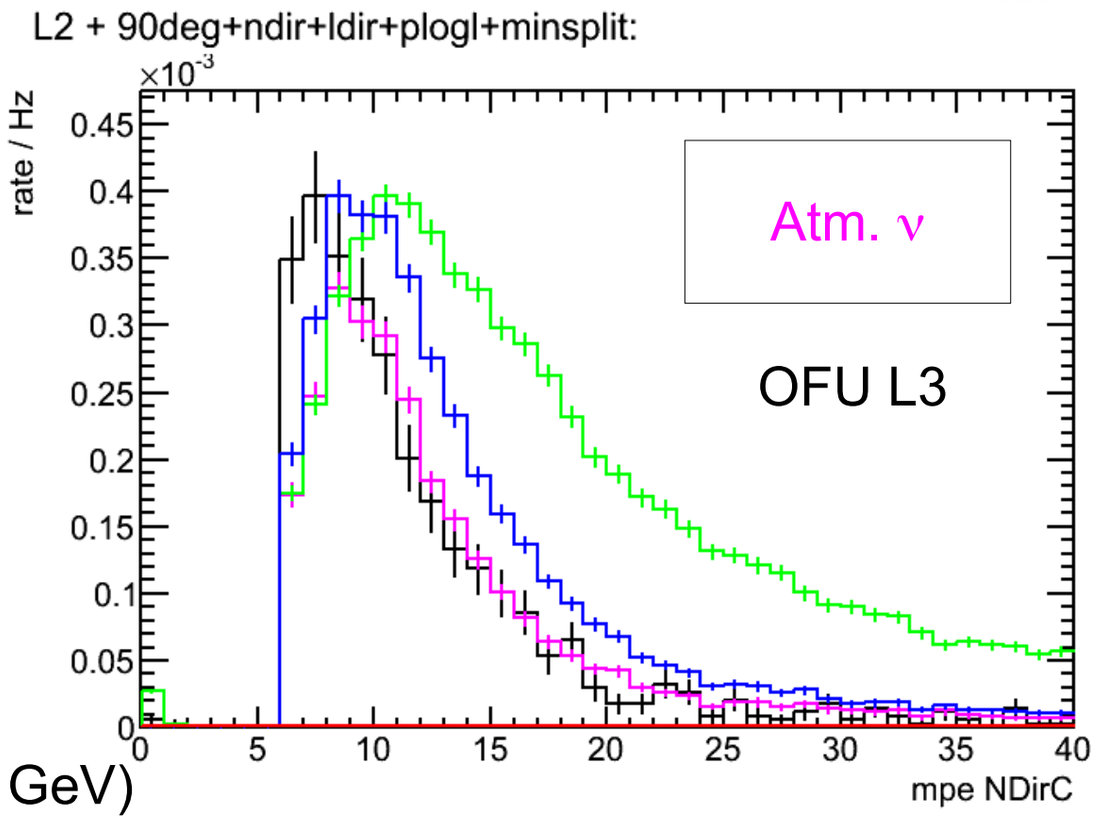


Optical followup event selection



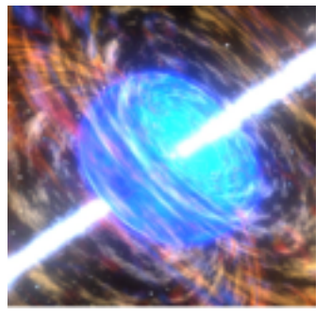
- New cut variable
  - Min($\Theta_{SplitFits}$)
- atm. ν 'purity': 85%
- Rate: 3 mHz (instead of 2 mHz)
- Number of doublets per year: ≈ 53
- Logic



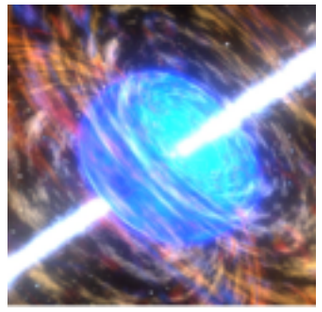


Zenith (MPE) ≥ 90 deg
and
llhlogl/(NCh-3.5) ≤ 8
and
Cos(Min($\Theta_{SplitFit}$))≤0.35
and
((NDir(MPE)≥6 & LDir(MPE)≥280) or muE≥1e6 GeV)

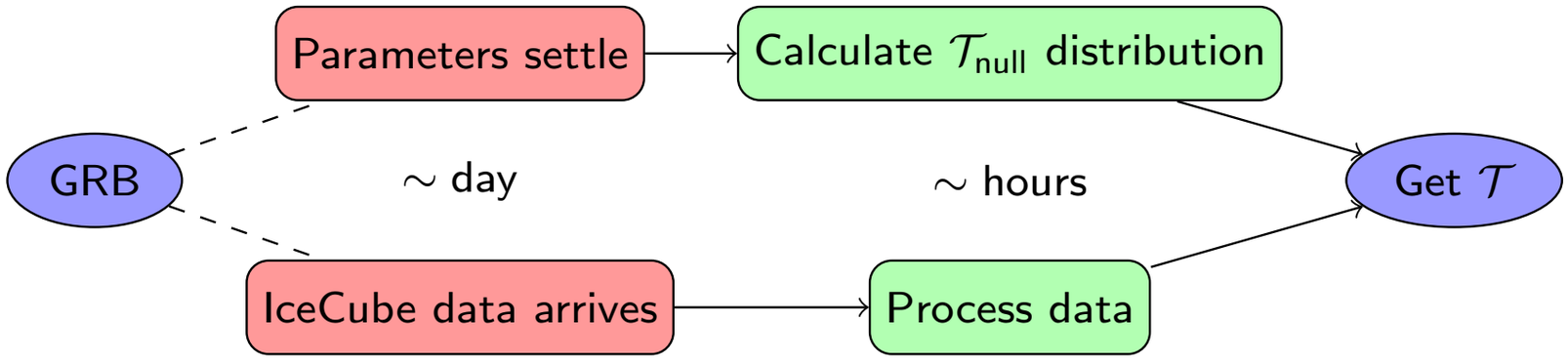
IC86 model dependent "real time" search



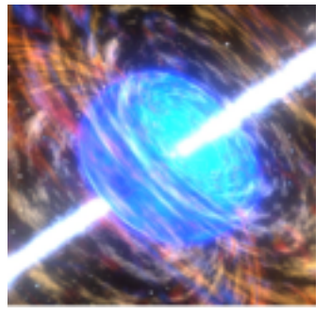
- With the completion of IceCube, we are planning to move our standard model dependent GRB search to a more real time result.
  - Within a 1-2 days, aim to have a completed on-time neutrino search for each GCN alert.
  - Follow up with circulars of our own in the event of detection
    - Or non-detection for the few "interesting" bursts a year.
- Model dependent searches are mature and robust
  - Very low expected background on-time and on-source in during gamma-ray T100.
  - Robust tools for achieving ~neutrino level samples with simple cuts or tools (BDT).
  - Optimizations *NOT* strongly dependent on modeled spectra.



IC86 real time search - How.



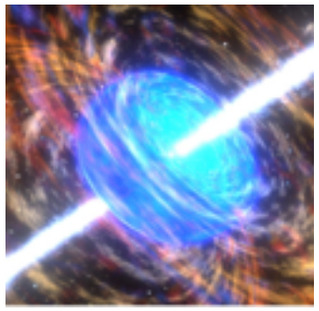
- Work performed in the North (not at South Pole)
- Within 1-2 days, have a result for each (real) GCN.
- Any case where $\tau > 0$, followup with GCN circular
  - Get followup observations underway.
- Stacked analysis to follow after some fixed time period
- Analysis in preparation, active in 2-3 months.
  - Perform search on all IC86 bursts to date once unblinded.



Online L2 future

- With next IC86 physics configuration, looking forward to expanding role of online L2
  - Robust, simple selections to get to ~few Hz rates
    - Aim to be basis for the mature searches: Point source, GRB, atmospheric neutrino searches
  - Addition of more realtime reconstructions
    - CPU capacity available online
  - Reduces physics working group wait for data samples for analysis
    - No L2 processing bottelnecks
- Still wider event selections for new and experimental analyses.
  - SuperDST data for large background samples, e.g Southern sky

IceCube Online analysis summary



- IceCube online event selections mature
  - Online L2 selections useful event selections
    - Online Optical/Gamma telescope alerts
    - Real-time analysis programs (GRBs first)
  - Online reconstructions as high of quality as those done offline
    - Looking to speed many analyses in future seasons
    - Online L2 sample ready for physics WG use in several mature analyses.
      - Avoid delays of mass data processing in North.