Sky localization of burst sources with LIGO-Virgo network

(LV burst group activity)

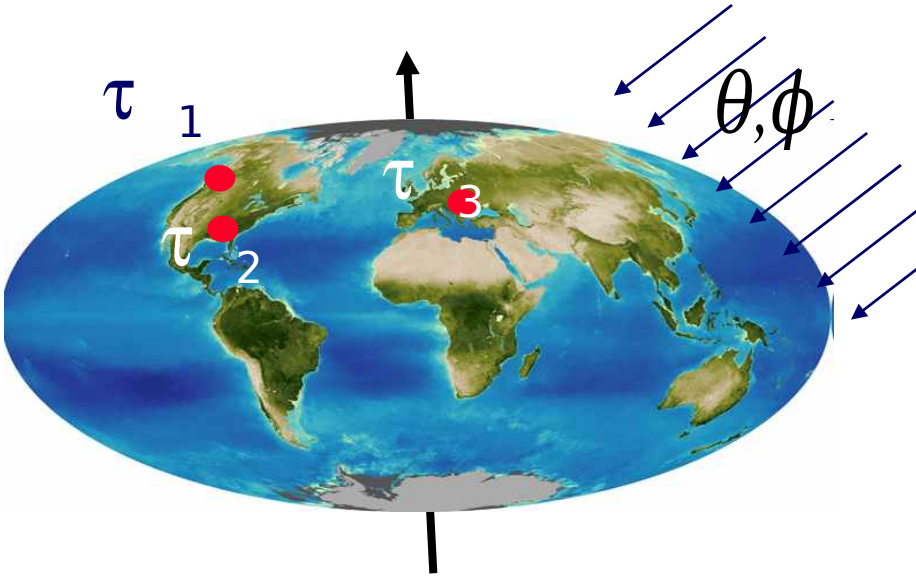
http://www.virgo.lnl.infn.it/Wiki/index.php/PRC
https://www.lsc-group.phys.uwm.edu/twiki/bin/view/Bursts/PosRec

Maria Pareja, Hannover-Golm Seminar, Sept. 1 2009

Reconstruction Method

three algorithms:

- triangulation
- Omega (Bayesian)
- coherent WaveBurst (max. likelihood)



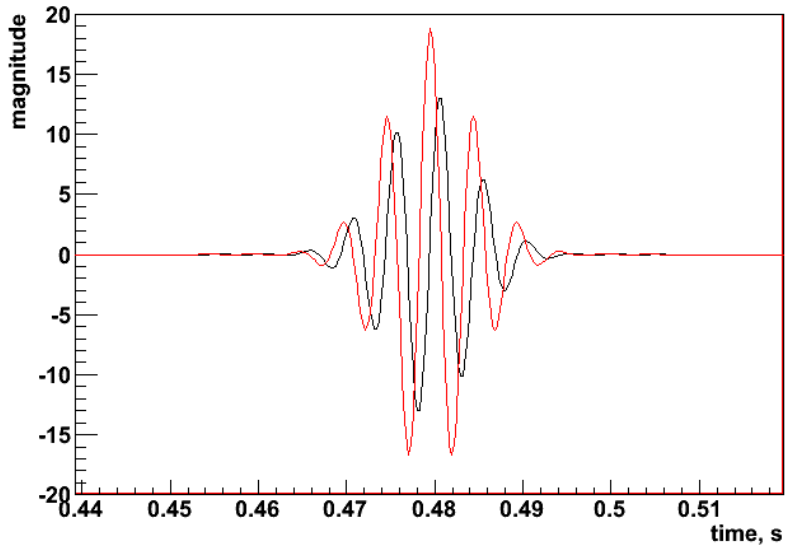
← based on **triangulation**

$(\tau_1, \tau_2, \tau_3, ..)$ need 3 or more det.sites

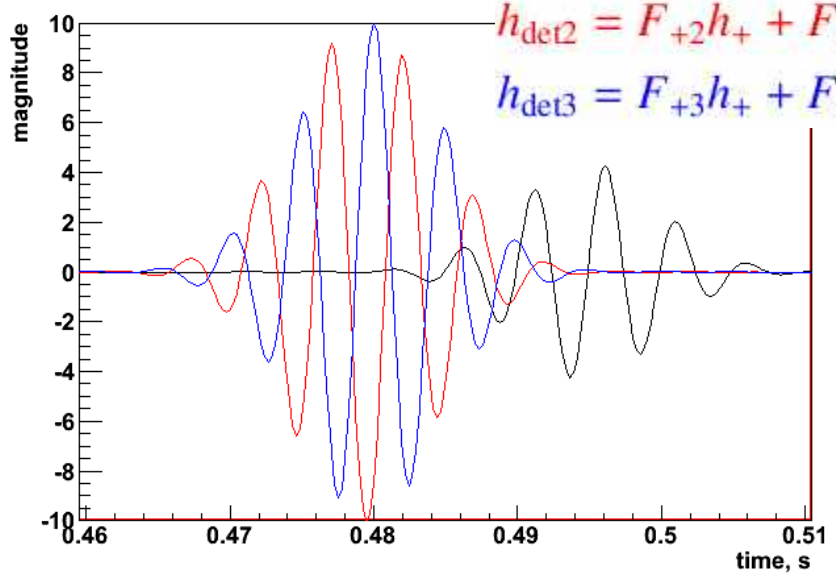
Position and *waveform* reconstr. → coupled

➢ **coherent network** approach

h_+ , h_x



$$h_{det1} = F_{+1}h_+ + F_{x1}h_x$$
$$h_{det2} = F_{+2}h_+ + F_{x2}h_x$$
$$h_{det3} = F_{+3}h_+ + F_{x3}h_x$$

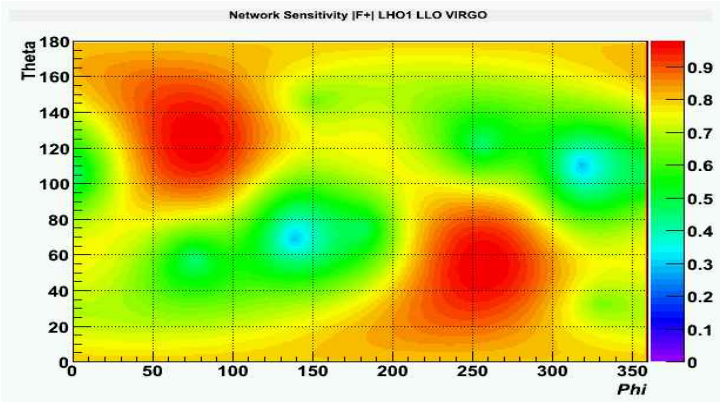


antenna patterns & noise

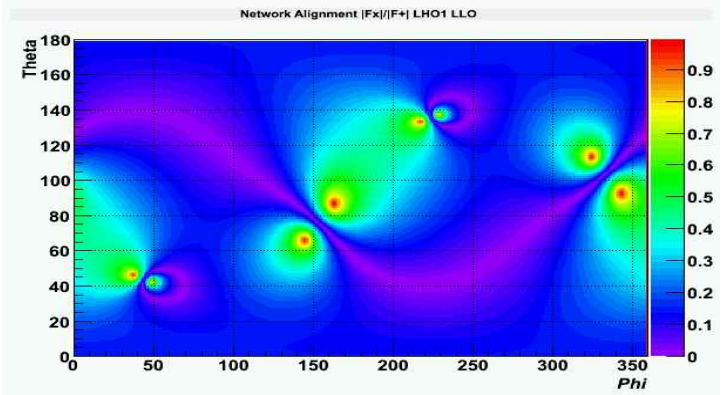
$$f_+ = \{\frac{F_{+1}}{\sigma_{+1}}, \ldots, \frac{F_{+K}}{\sigma_{+K}}\} \quad f_x = \{\frac{F_{x1}}{\sigma_{x1}}, \ldots, \frac{F_{xK}}{\sigma_{xK}}\}$$

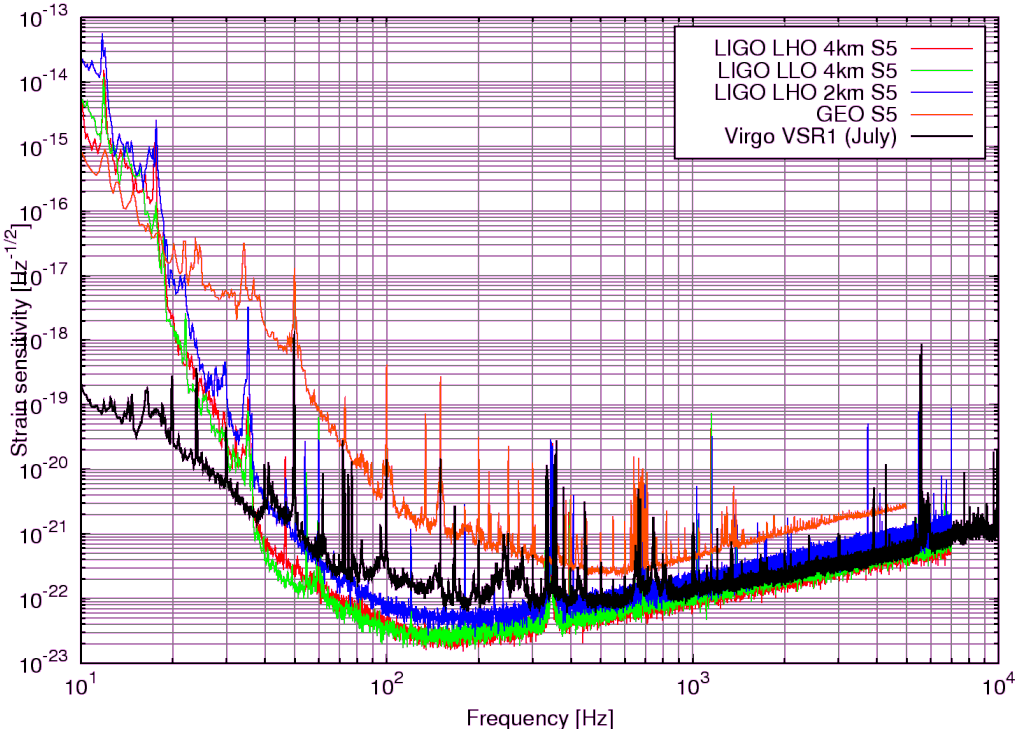
network SNR $\approx \sqrt{|f_+|^2 \langle h_+^2 \rangle + |f_\times|^2 \langle h_\times^2 \rangle}$

network sensitivity: $|f_+|^2 + |f_\times|^2$



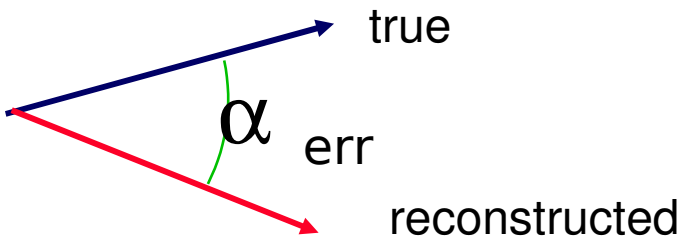
network alignment factor: $|f_\times|^2 / |f_+|^2$



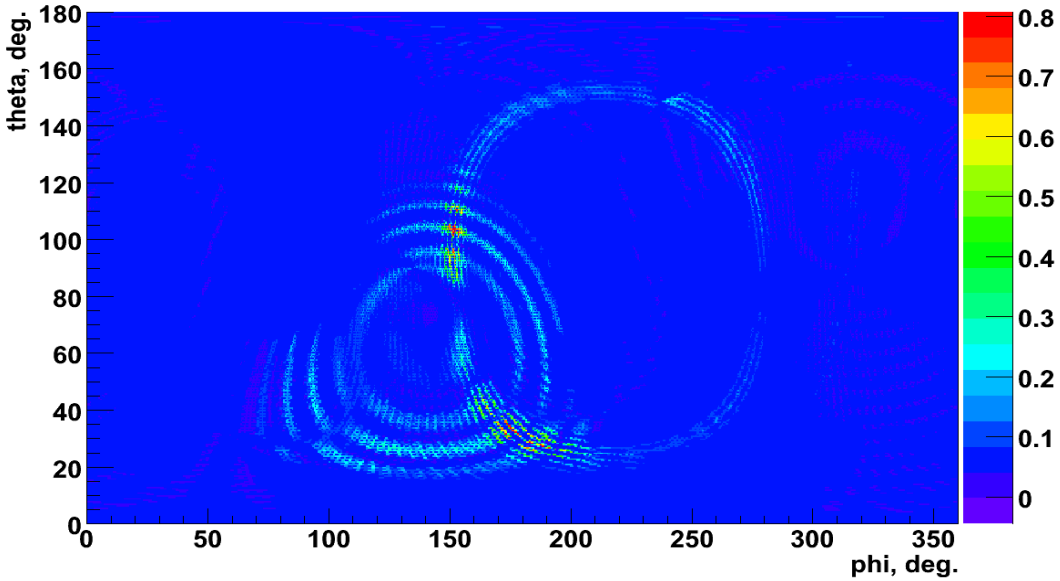


Error Angle

- **deviation from true source location**



- $\sqrt{erA50}$ **= effective error angle at 50% probability**

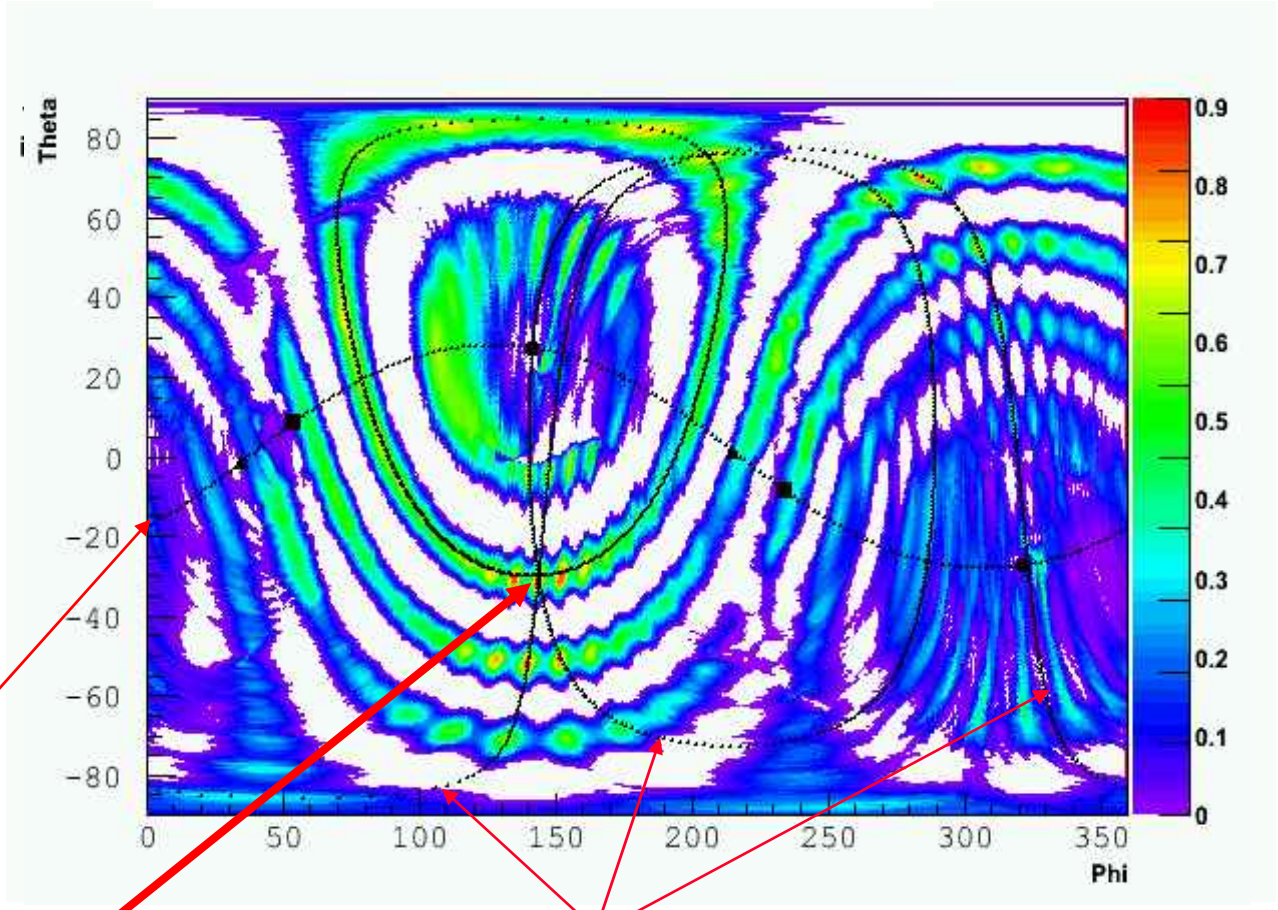


Likelihood sky map

Normalized Likelihood Sky Map

(a probability sky map)

- coherent network analysis -

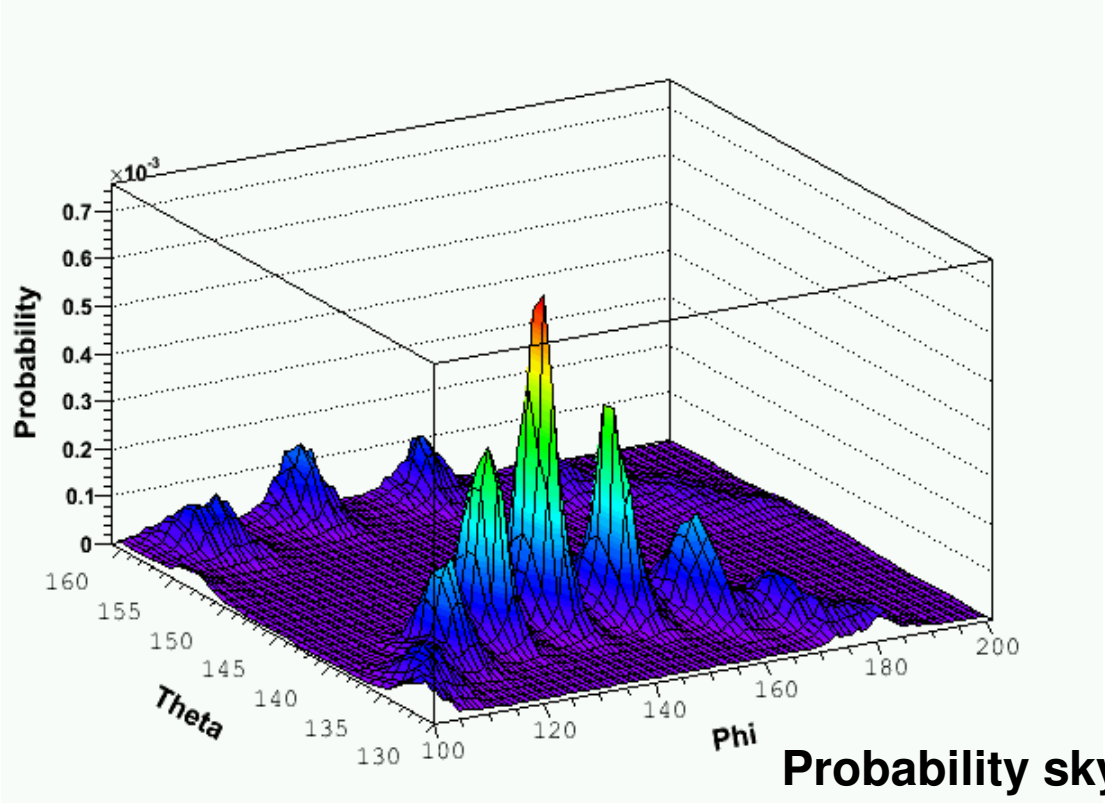


detector plane

source location

rings of **constant time-delay** for detector pairs

error region



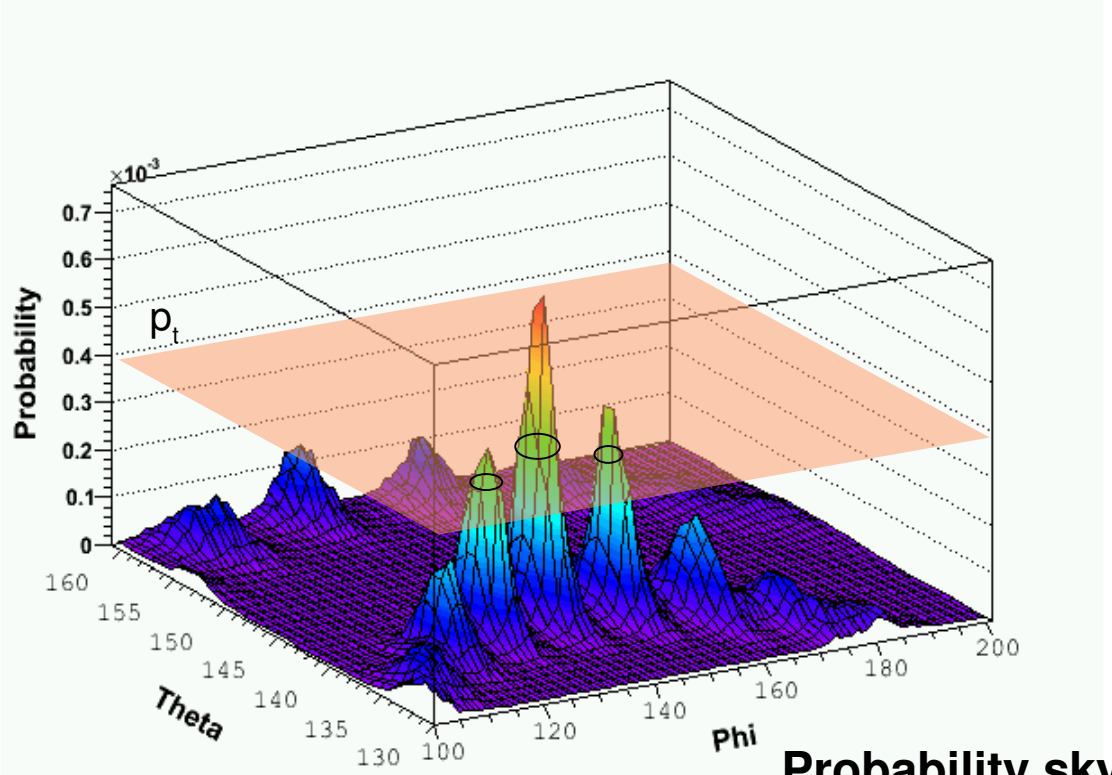
Probability sky map

error region

$$\int p(\theta,\phi)d\theta d\phi = P = 0.5$$

$\{(\theta,\phi) / p(\theta,\phi) > p_t\}$

$= 0.38 \times 10^3$



Probability sky map

error region

error region 50% probability is
the region for which the integrated nominal probability is 50%

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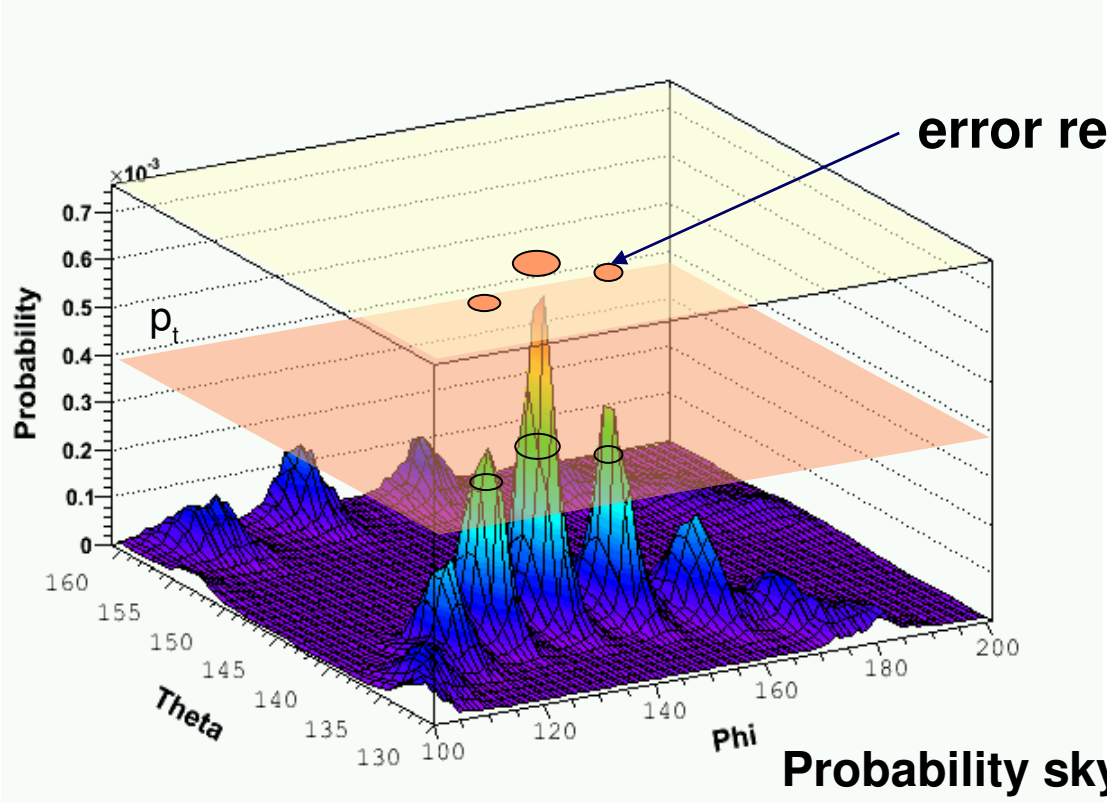


Probability sky map

erA50 = Area of $\{(\theta,\phi / p(\theta,\phi) > p_t\}$ (50% prob.)

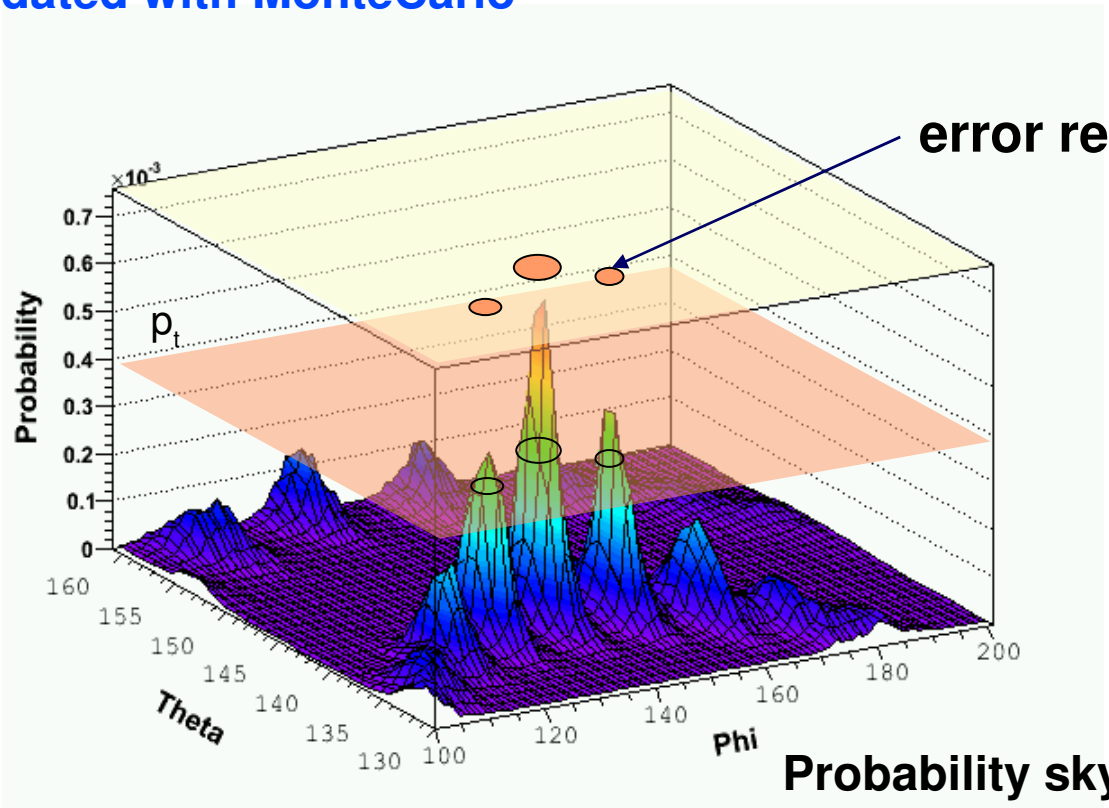
error region

error region 50% probability is
the region for which the integrated nominal probability is 50%

→ **has to be validated with MonteCarlo**

$$\int p(\theta,\phi)d\theta d\phi = P = 0.5$$

$\{(\theta,\phi) / p(\theta,\phi) > p_t\}$
$= 0.38 \times 10^3$



erA50 = Area of $\{(\theta,\phi) / p(\theta,\phi) > p_t\}$ (50% prob.)

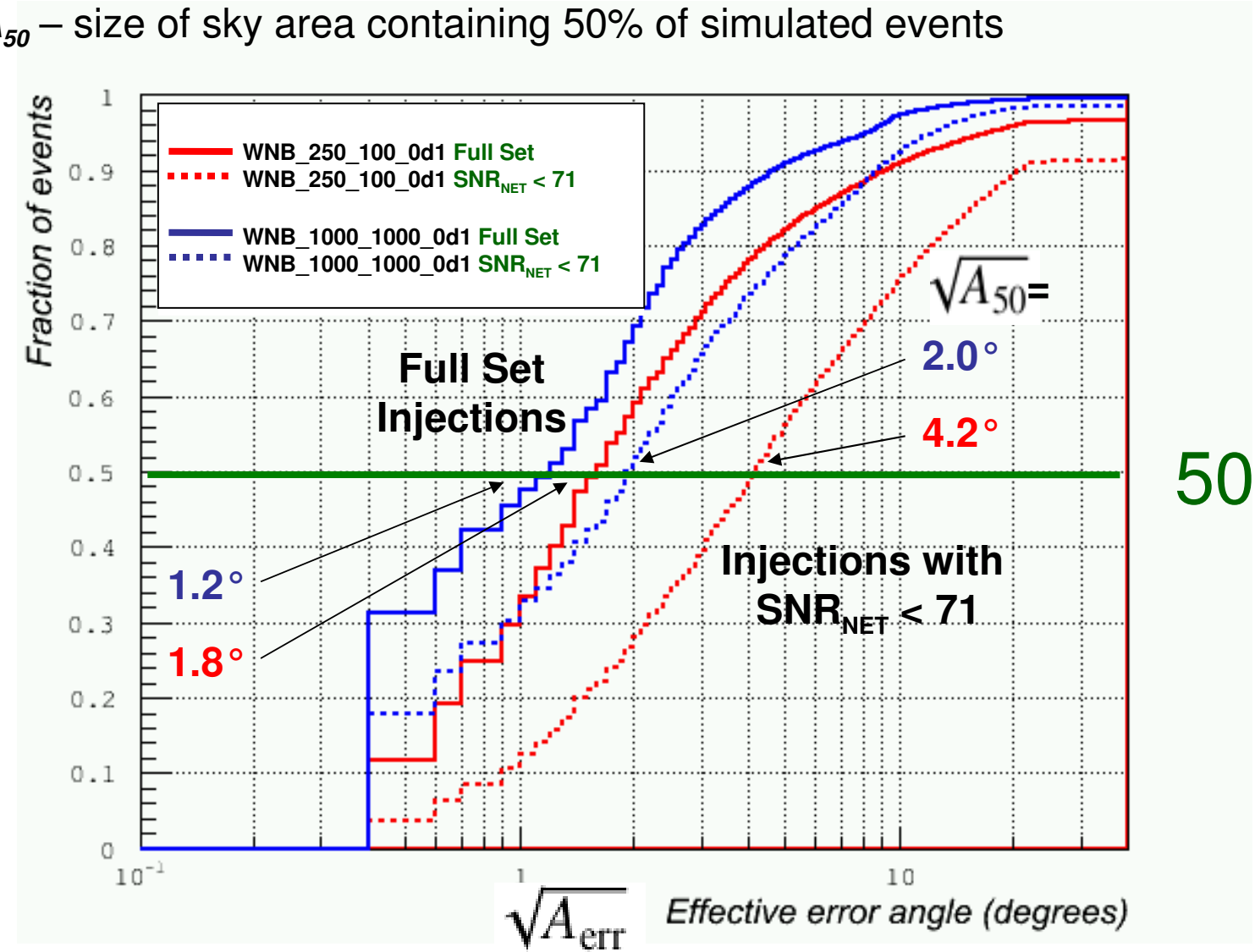
A_{err} = Area of $\{(\theta,\phi) / p(\theta,\phi) > p(source)\}$

Median Error Angle

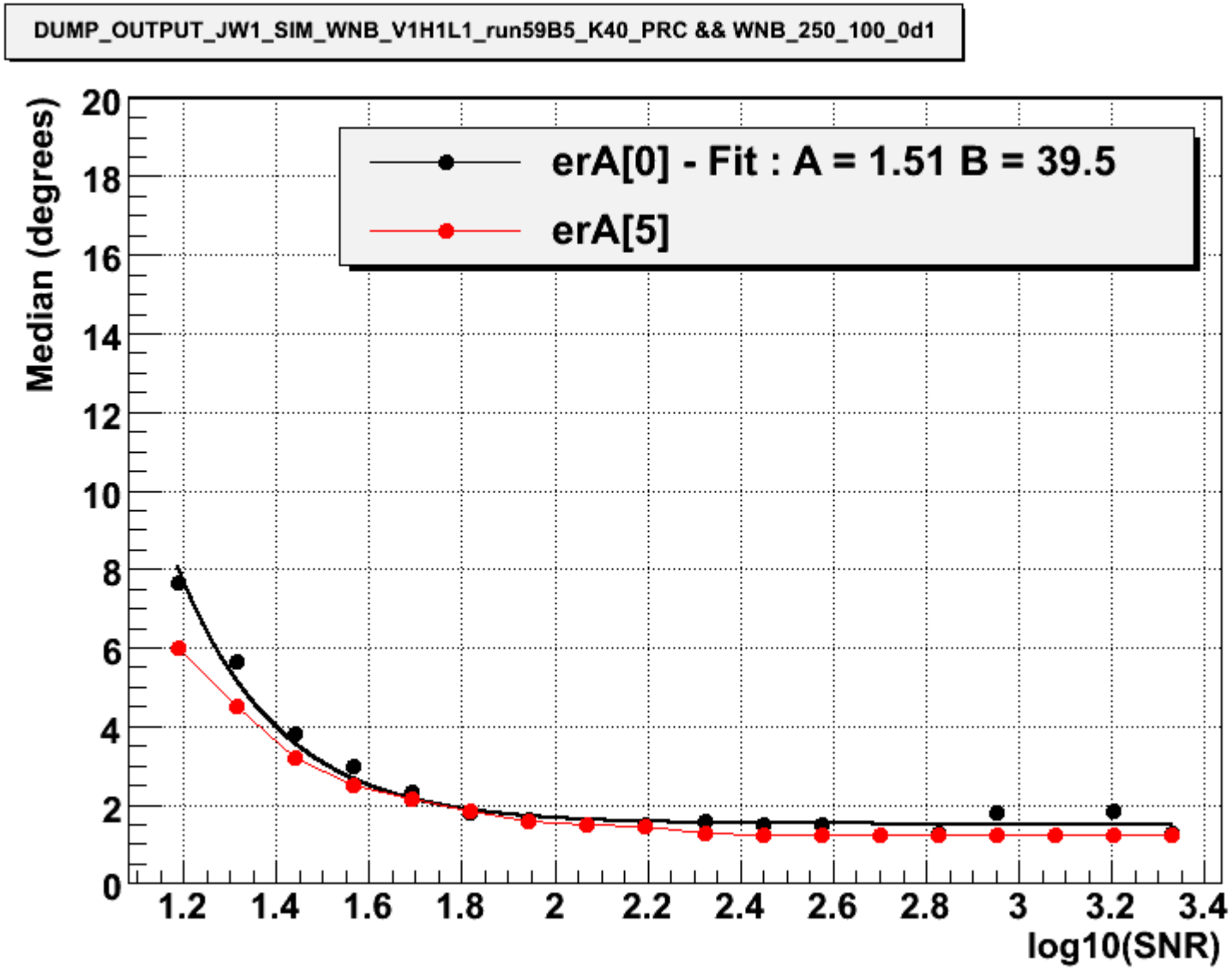
Cumulative distribution of the *effective error angle* $\sqrt{A_{err}}$ by MonteCarlo over all directions

characterizes overall reconstruction performance

- ***A*$_{50}$** – size of sky area containing 50% of simulated events

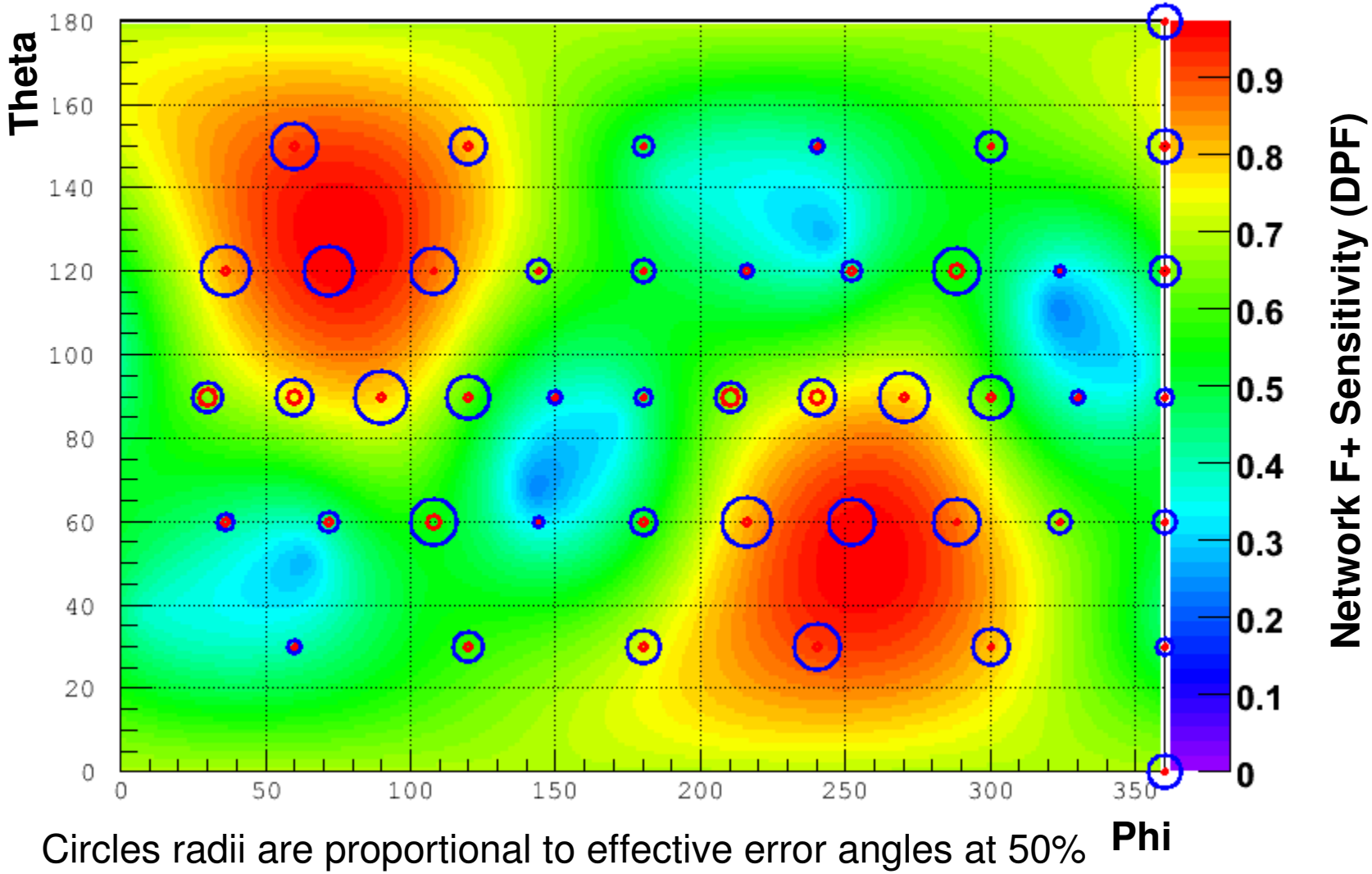


- extra slides -


DUMP_OUTPUT_JW1_SIM_WNB_V1H1L1_run59B5_K40_PRC && WNB_250_100_0d1
erA[0] - Fit : A = 1.51 B = 39.5
erA[5]
Median (degrees)
log10(SNR)
0
2
4
6
8
10
12
14
16
18
20
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4

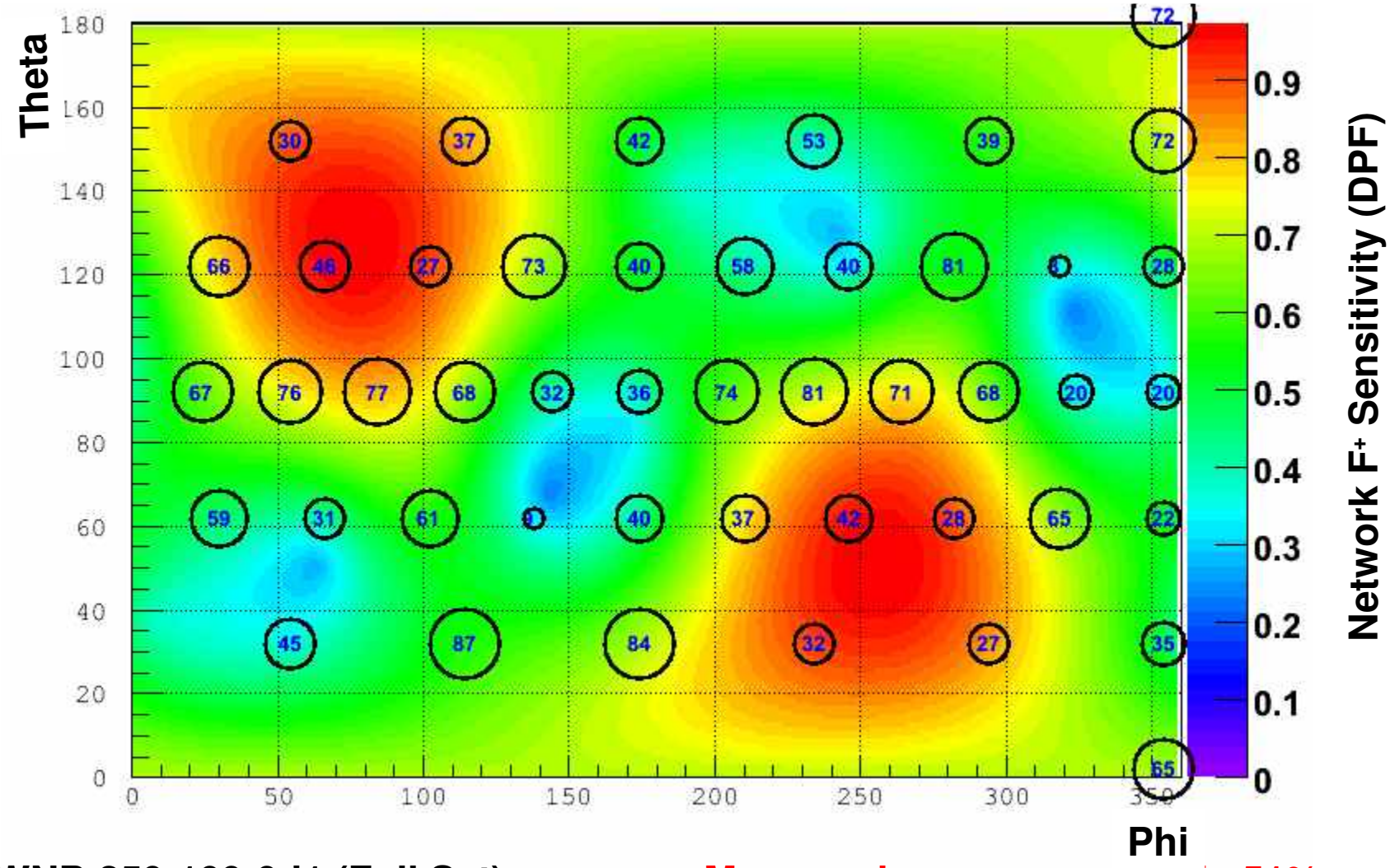
WNB 250-100-0.1s : Effective Error Angle @ 50%

Red Circles : Full Set – Blue Circles : SNR_{NET}<71



Circles radii are proportional to effective error angles at 50%

Measured coverage of error regions @ 50% of Nominal Probability

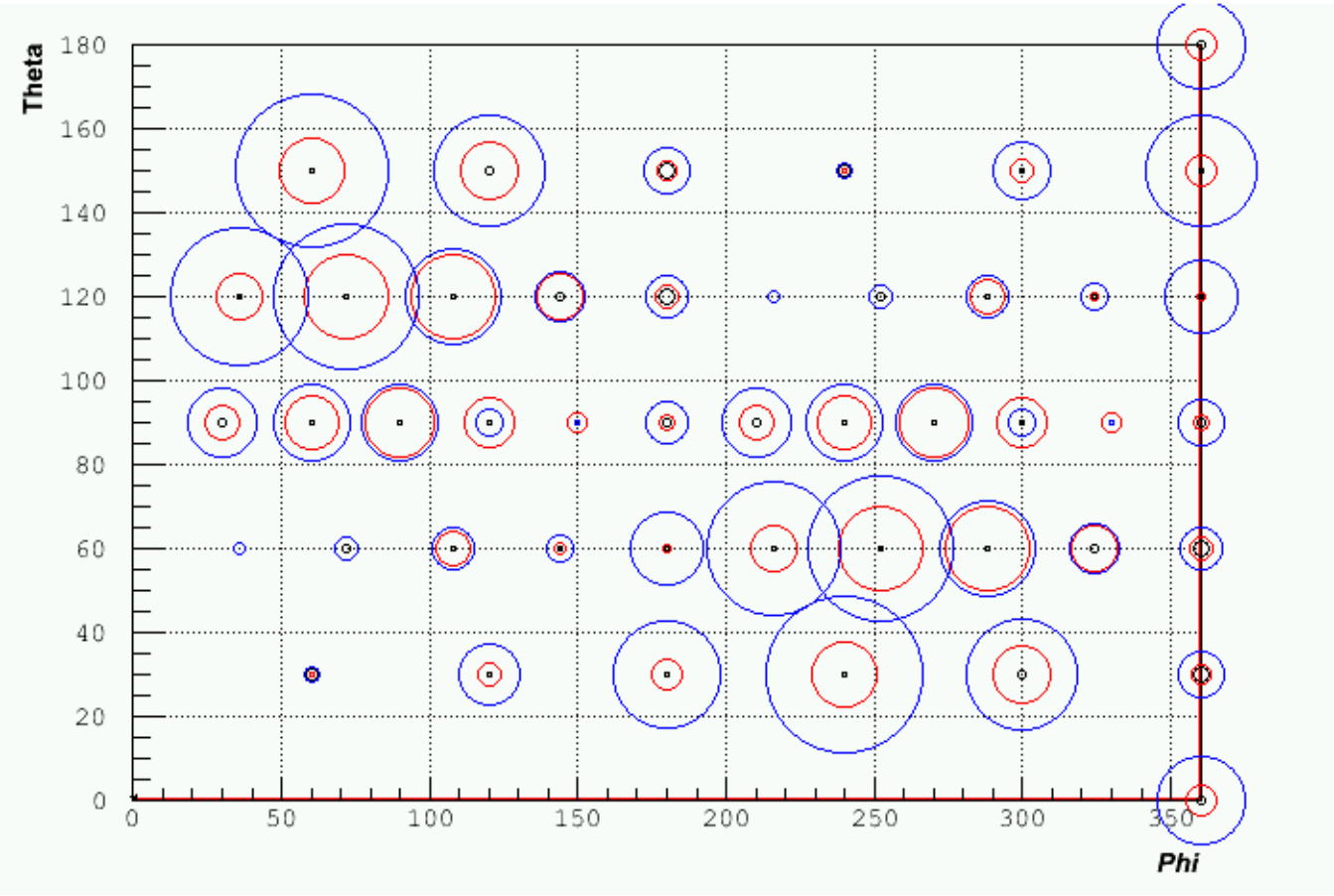


WNB 250-100-0d1 (Full Set)

Measured mean coverage is 51%

Relative contribution to SNR_net by each detector

WNB 250-100-0d1 waveforms with optimal polarization @ fixed injected hrss



Circles are proportional to the reconstructed SNR^2

V1 (black), L1 (red), H1 (blue)