SPI background studies Application to the e^--e^+ annihilation

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1. Background modeling
   - Data and methods
   - Tracers

2. Applications
   - 511 keV
   - Positronium

Framework

- Purpose : to predict the background
  - between 506 and 516 keV for the line
  - in 7 energy bands between 200 and 545 keV for the positronium
  - for other lines (talk by Stéphane Schanne)

- Context :
  - high background variability (10-20%)
  - low astrophysical signal (2-4% of the background)

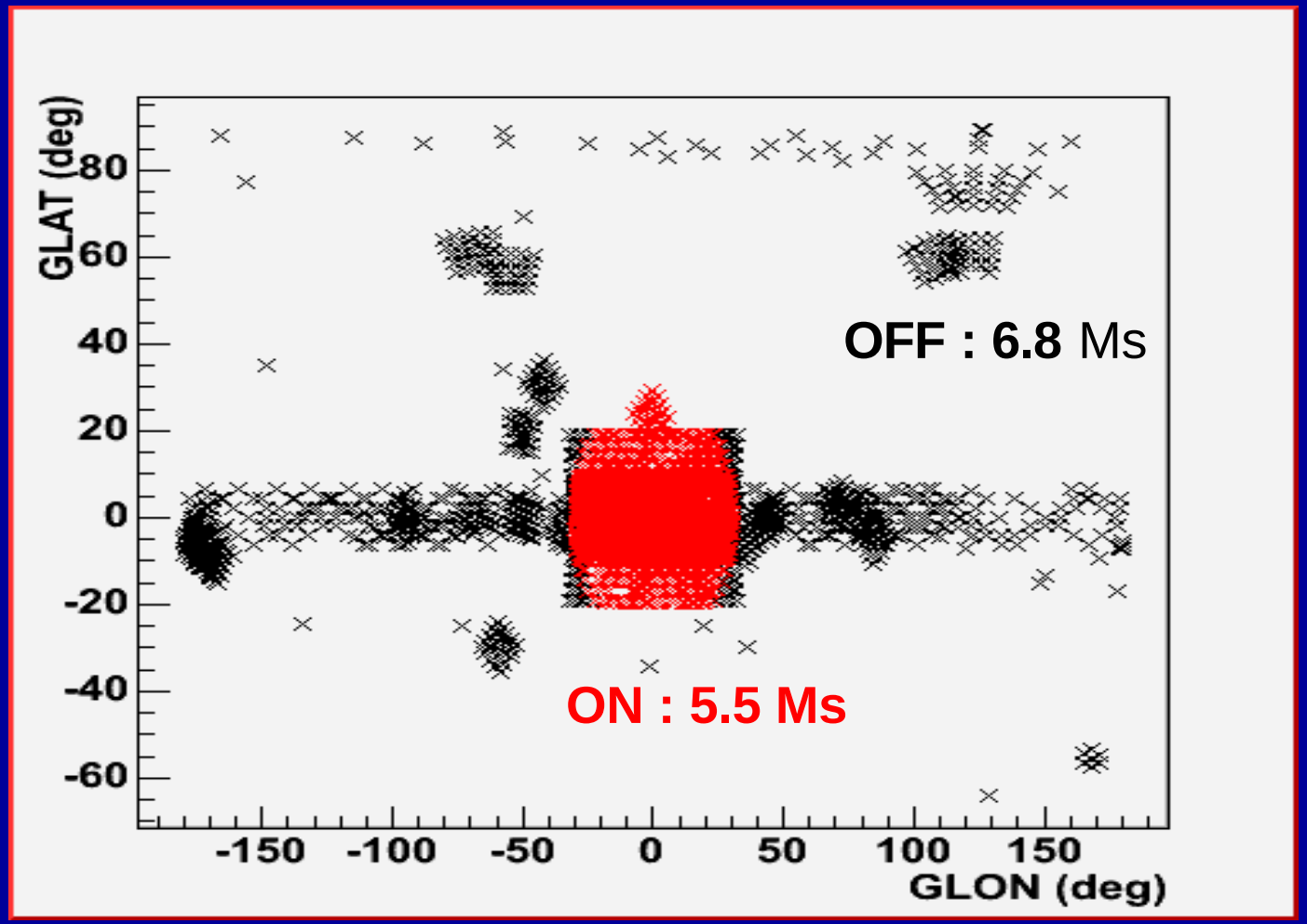
- « Light bucket » analysis : rates integrated over the camera
- Background continuum and background line components not split
- Learning with OFF data tracers, prediction of background for ON data

- Methods
  - linear combinations
  - non-linear combinations, neural network

Data

- Rev. 43-125
- Cleaning : exclusion of pointings with « abnormal » values of temperature, plastic scintillator rate, C line rate, protons rate and orbital phase near the radiation belts
- 2 data sets :
  - empty field ($\theta > 30°$) = 6.8 Ms
  - galactic center = 5.5 Ms

Data


GLAT (deg)
80
60
40
20
0
-20
-40
-60
-150
-100
-50
0
50
100
150
GLON (deg)
OFF : 6.8 Ms
ON : 5.5 Ms

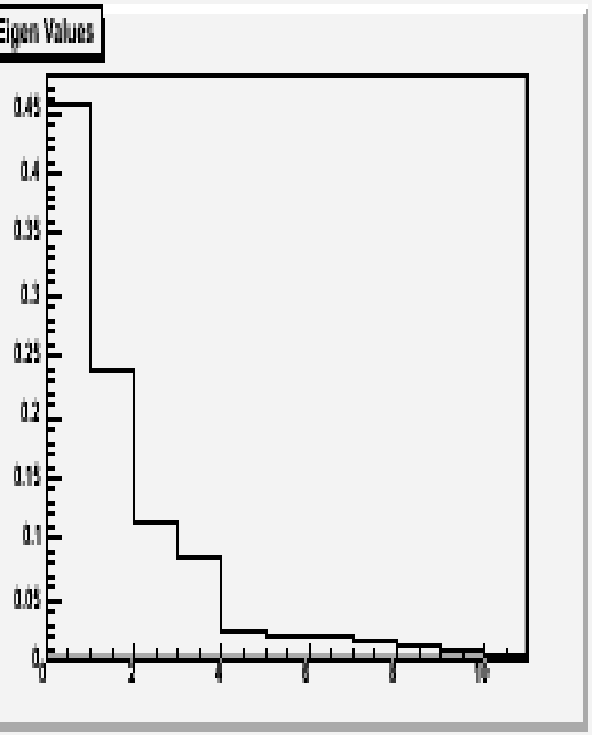
Tracers

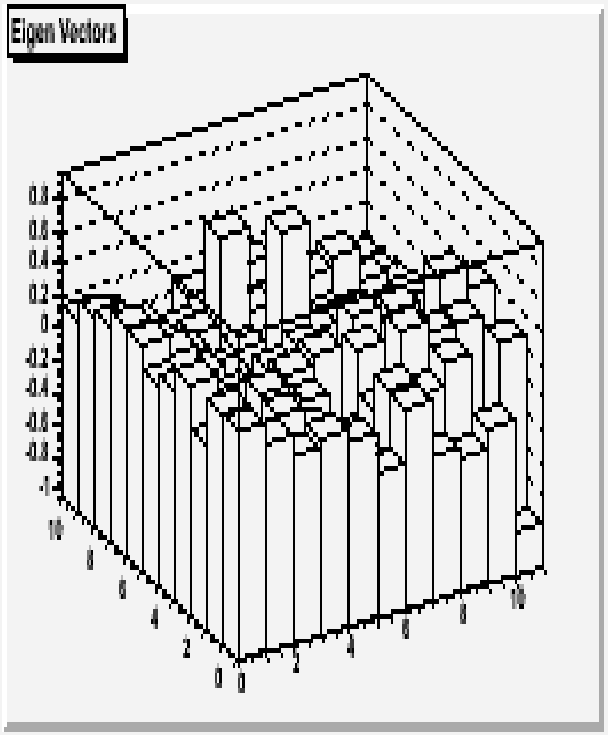
- House-Keeping data:
  - Ge saturating events (GEDSAT)
  - plastic scintillator (PSAC)
  - VETO…
- Irem : electrons, protons, ions
- broken multiple events @ 511 keV (brME)
- continuum band
- other lines : Zn, Co, CoK, Ga, Sc, Bi, Al, C, O
- cryostat temperatures
- revolution phase
- dead time

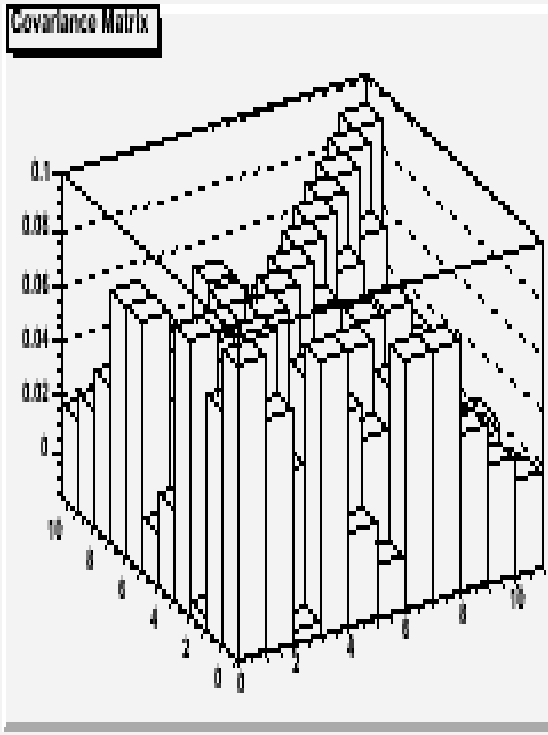
PCA

Principal Component Analysis of tracers :

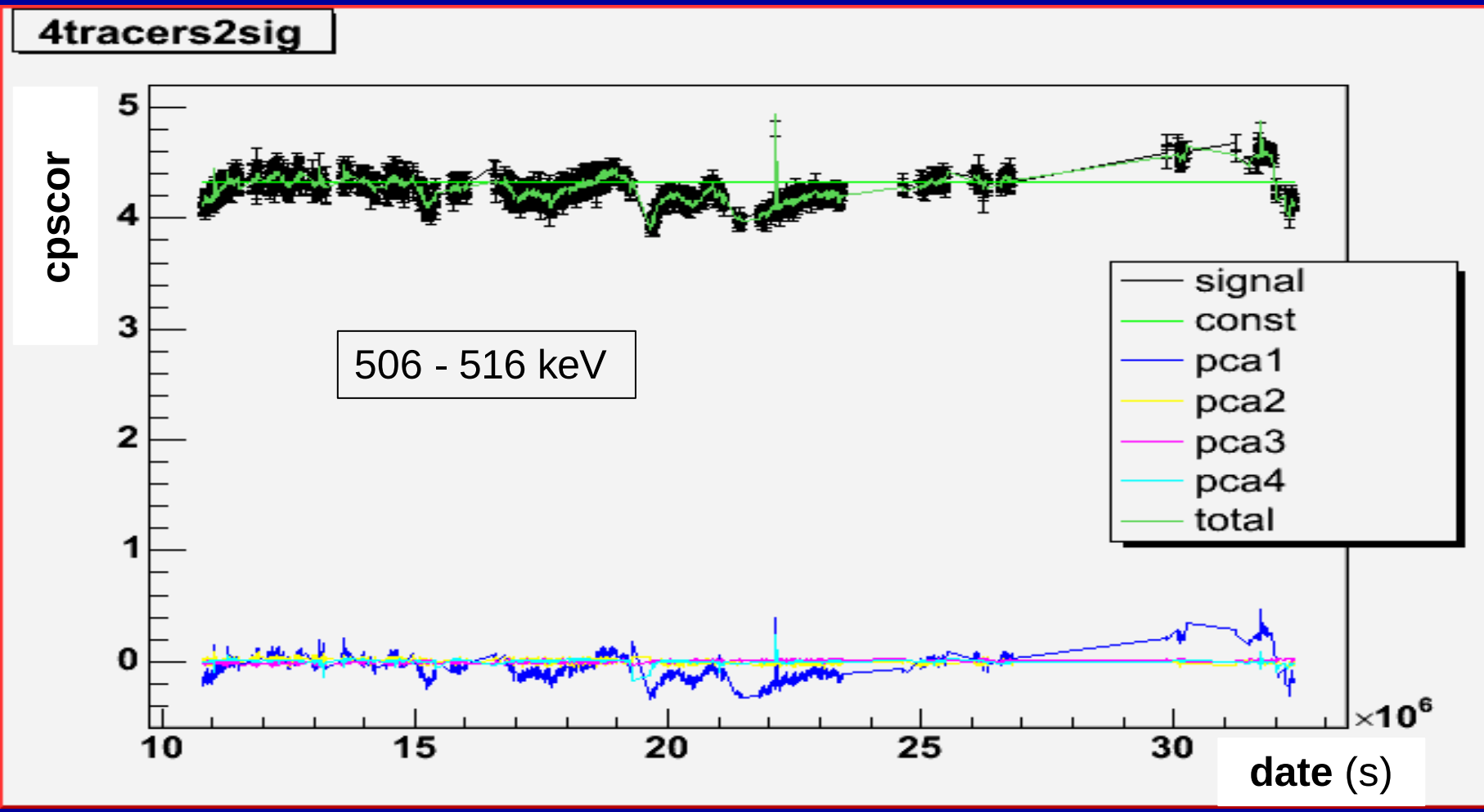
- new tracers centered and normalized
- selection of main components



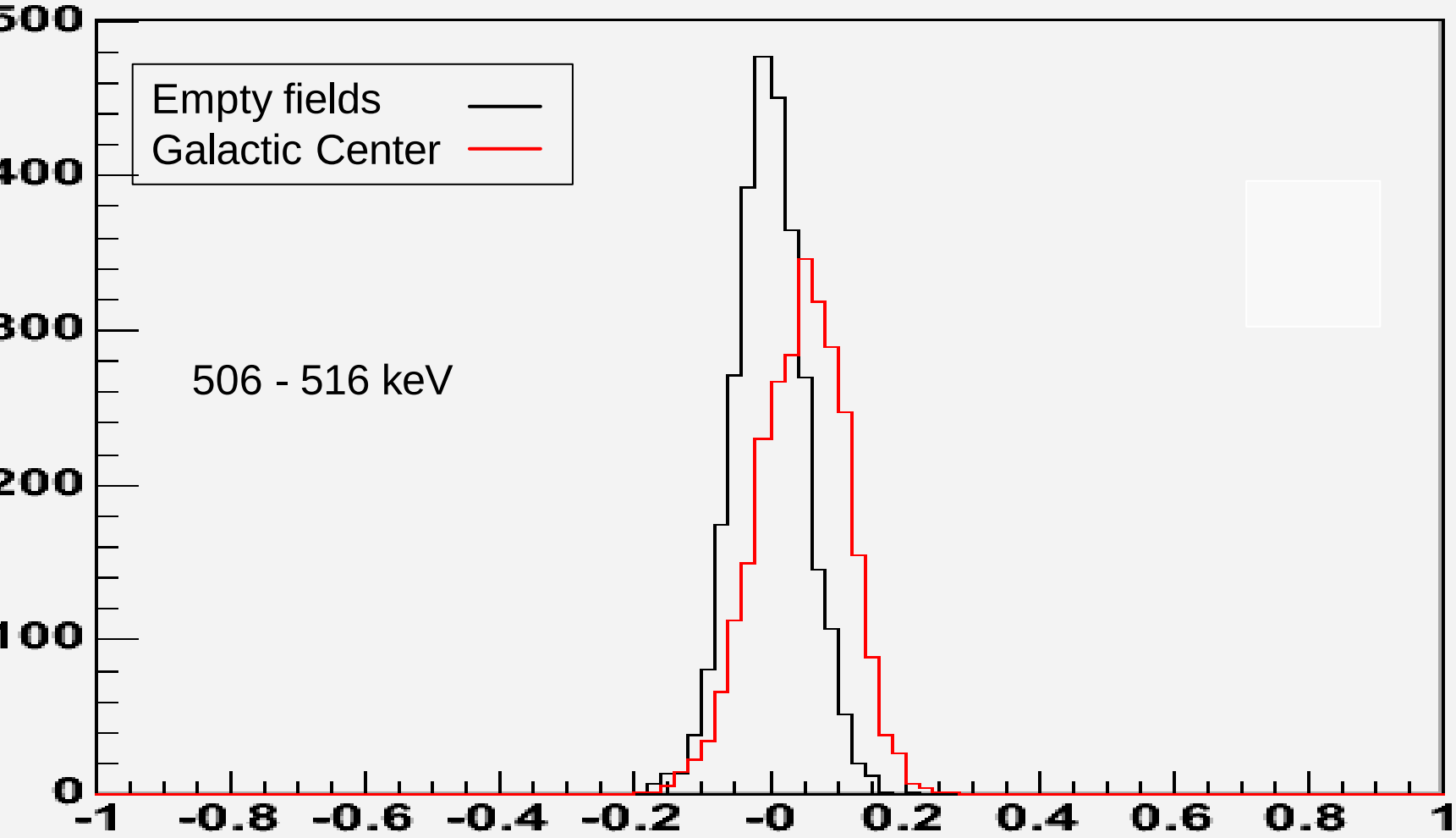




Linear combinations



Residual signal



Comparison of tracers

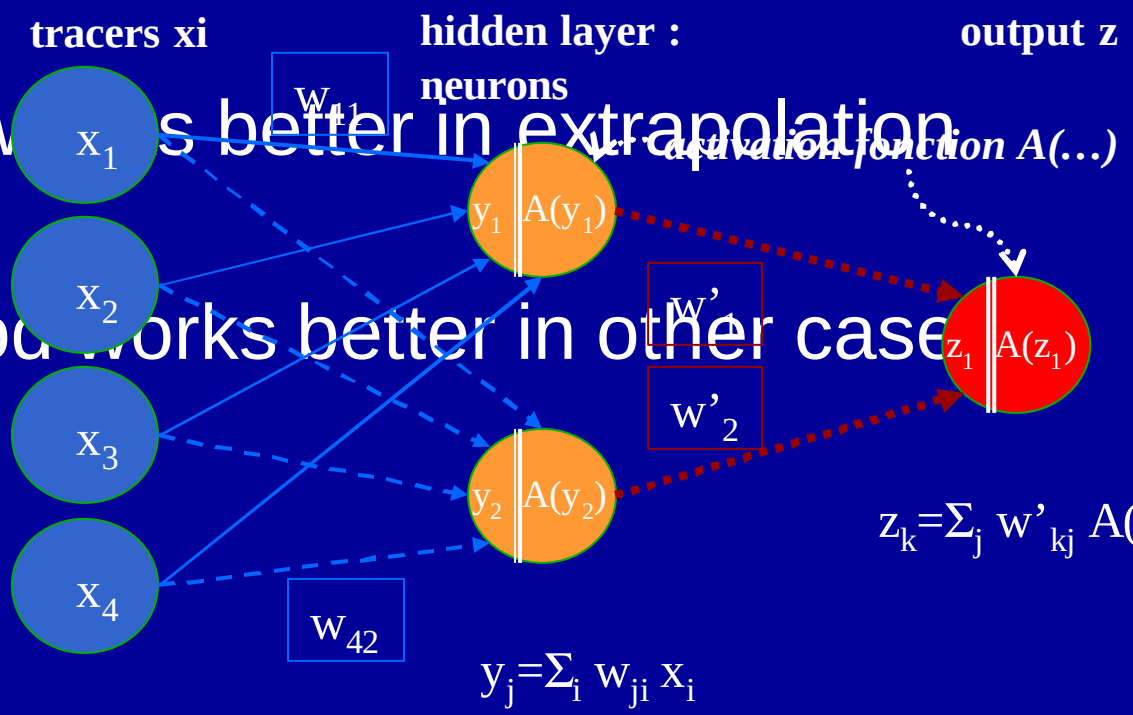
combination	χ^2_r
GEDSAT	1.532
GEDSAT + PSAC + Zn	1.485
GEDSAT + PSAC + Zn + brME	1.146
GEDSAT + PSAC + Zn + brME + Irem	1.142
GEDSAT + PSAC + Zn + brME + Irem + phase	1.139
GEDSAT + PSAC + Zn + brME + Irem + phase + T	1.137
GEDSAT + PSAC + Zn + brME + Irem + phase + T + dead time	1.134
GEDSAT + PSAC + Zn + brME + Irem + phase + T + dead time + lines	1.099

Other methods

- Non- linear method : bayesian approach
- Neural network

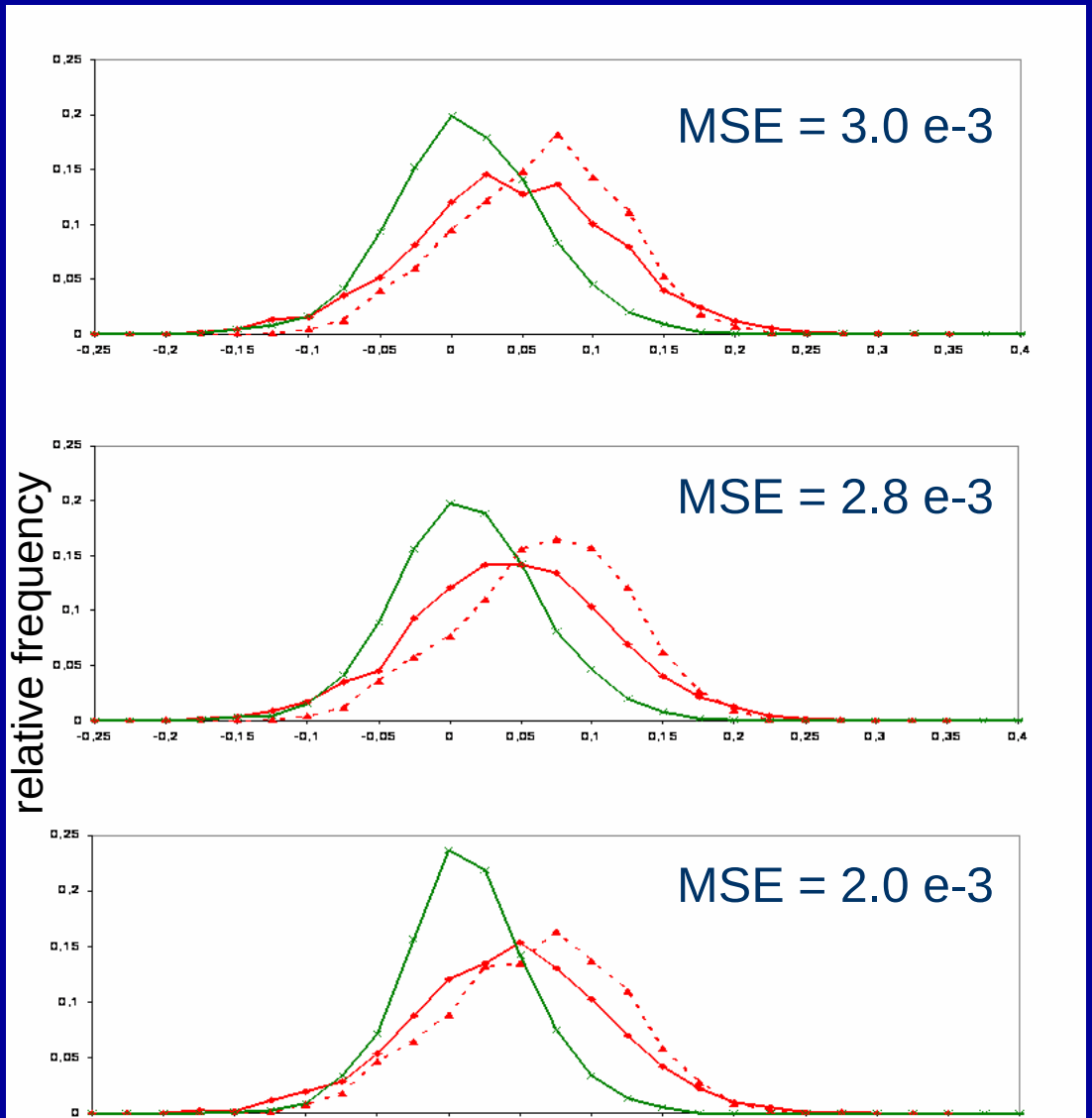
⇒neural network works better in extrapolation (solar flare)

⇒bayesian method works better in other cases



Comparing methods

empty fields
GCDE 1
GCDE 2



linear method (neural network with no neuron)

+ 6 tracers

neural network

(1 hidden layer, 3 neuron

+ 5 tracers

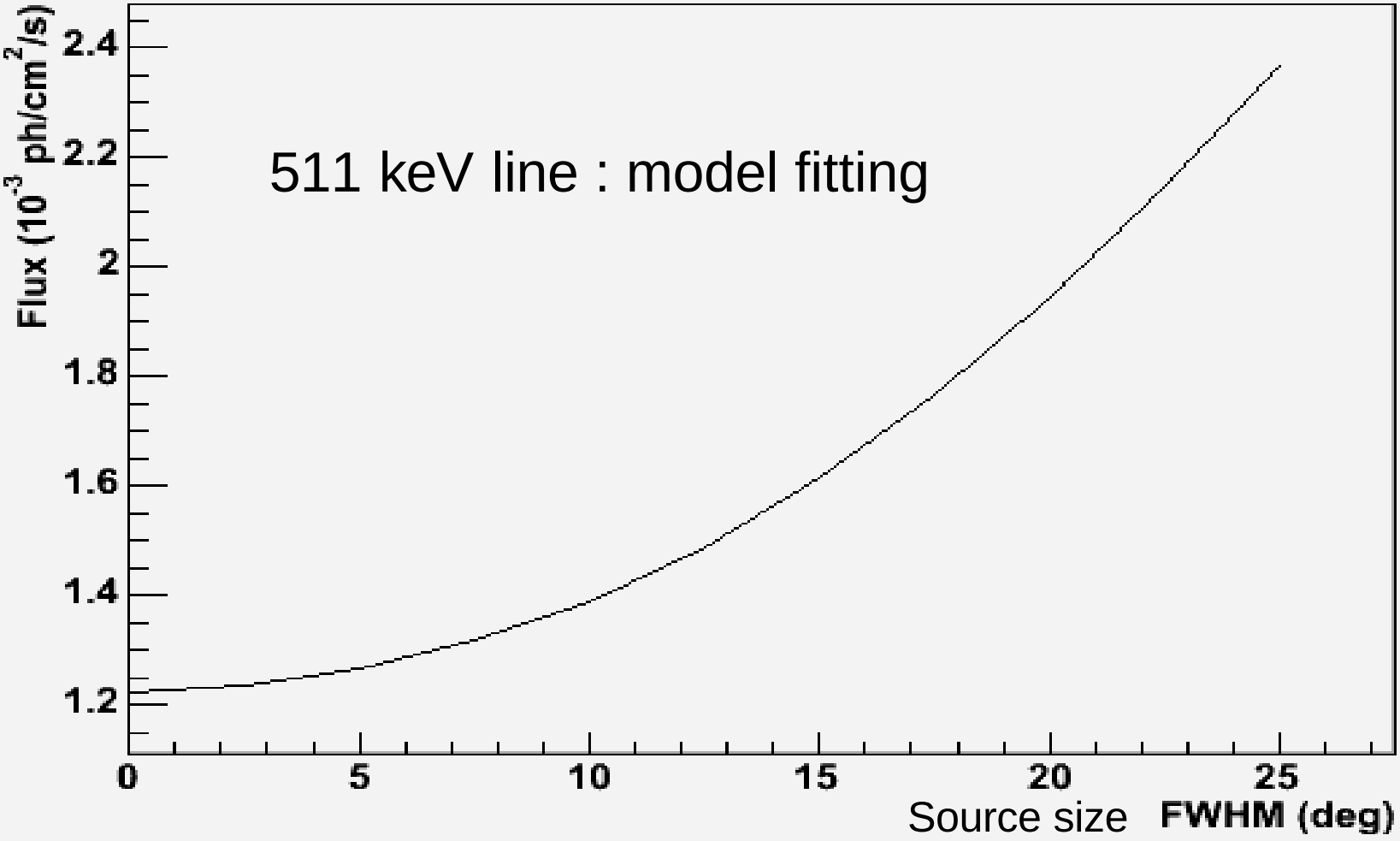
bayesian method

+ 11 tracers

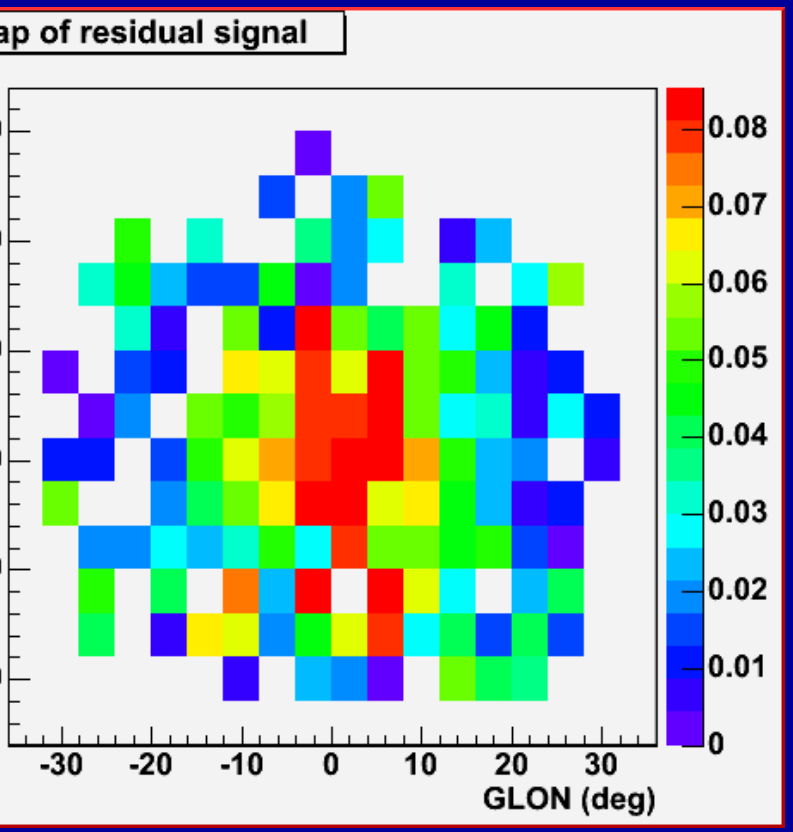
511 keV line : model fitting

- Background model from tracers
- Gaussian emission skymap
  - centered at l,b = 0,0
  - various sizes (FWHM in °)
- Convolution
- Search for best scaling factor fitting background substracted data
  $\Rightarrow$ flux F(size of the source)

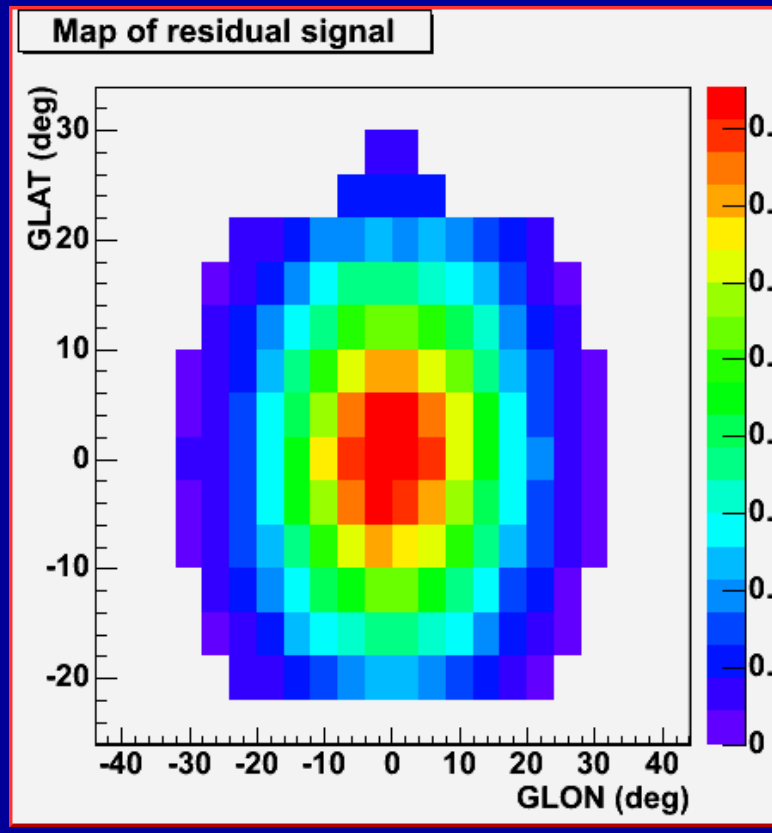
Link between the flux and the source size



511 keV line : flux and morphology



real data in the « light bucket » space



best model in the « light bucket » spa
(**convoluted** gaussian)

FWHM ~ 20°

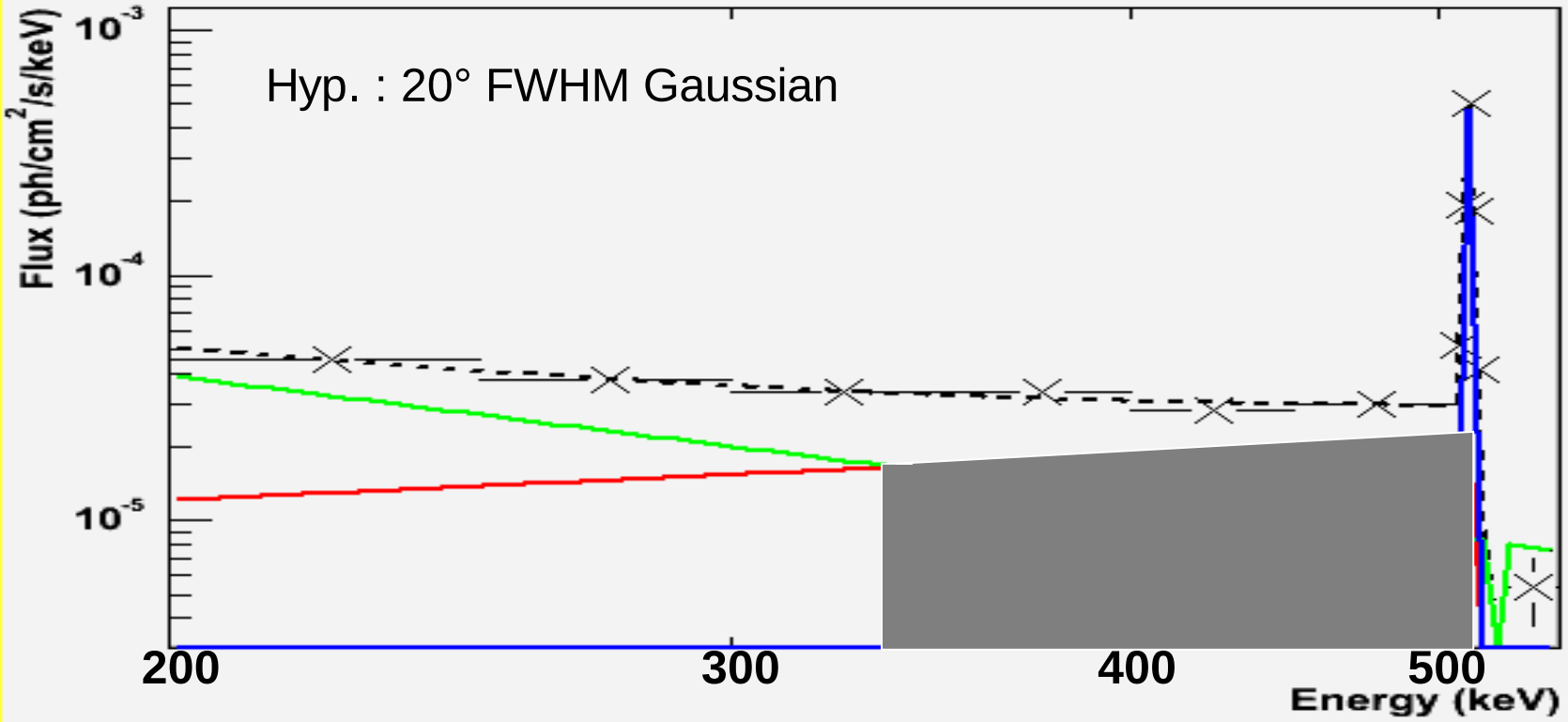
F ~ 1.94 10^{-3} ph/cm^2/s

Positronium

- Same approach as for the background in 7 energy bands:
  - 200 – 250 keV
  - 250 – 300 keV
  - 300 – 350 keV
  - 350 – 400 keV
  - 400 – 450 keV
  - 450 – 506 keV
  - 525 – 545 keV

- Fit of the residual spectrum between 200 and 545 keV by a three components model :
  - a power law
  - a gaussian line centered at 511 keV
  - a 3gamma continuum

Positronium



fPos ~ 90 %

Conclusion

- Preliminary results of these studies are promising but a lot of work remains :
- Further development of non-linear methods (neural network)
- Better quality criteria needed for comparing methods and combinations of tracers
- Estimation of the errors
- Single detector background model needed for “real” imaging
- Good tracers of detector ratios ?
- Grouping may be necessary
- More empty fields needed

Non-linear method

- « neural regression network»

$$\hat{y}(\vec{x}) = \frac{\sum_i y_i \exp(-D(\vec{x}, \vec{x}_i))}{\sum_i \exp(-D(\vec{x}, \vec{x}_i))} \text{ avec } \mathrm{D}(\vec{\mathrm{x}}, \vec{\mathrm{x}}_{\mathrm{i}}) = \sum_j \left(\frac{x_j - x_{i,j}}{s_j} \right)^2$$

- minimisation de S = $\sum (y - \hat{y}(\vec{x}))^2 / M$ → poids s_j