Tracking algorithms developments for SBS

Alessio Del Dotto (INFN Roma Tre), Cristiano Fanelli (INFN Roma)

SBS weekly meeting

2/4/2015

Outline

Simulated signal

Assumed rates: 20 kHz of good hits, 360 kHz/cm^2 of background hits

Event generation

- toy model: generation C++/ROOT
- realistic data: GEANT4 (old SBS simulator)

Occupancy in 10 cm^2

On the first plane plane around the signal

- 1 signal track
- 1 background track
- 1 photon hit per plane
- 100 ghost hits per plane (combinatorial fake due to the strip readout)

The tracking is based on a multi step approach:

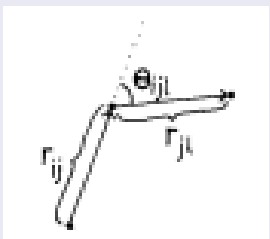
- charge and time correlation for clustering
- Neural network for hit association into tracks
- Kalman filter for precise track reconstruction

NN:Tracking algorithms in Mean Field Approximation

Energy function

- $E = d_G \sum_{ijl} \frac{(\cos\theta_{ijl})}{r_{ij}+r_{jl}} V_{ij} V_{jl} + \alpha \sum_{l \neq j} V_{ij} V_{il} + \alpha \sum_{k \neq i} V_{ij} V_{jl} + d_G \sum_{ijl} \frac{(\cos\theta_{ijl})}{r_{ij}+r_{jl}} \delta_{li} V_{ij}$

Geometric connection of the tracks



- only the forward connection is taken non null
- only the track within a cone of reference are put in connection

Mean Field Solution

- $V_{ij} = \frac{1}{2}\left[1 + \tanh\left(-\frac{\partial E}{\partial V_{ij}}\frac{1}{T}\right)\right]$

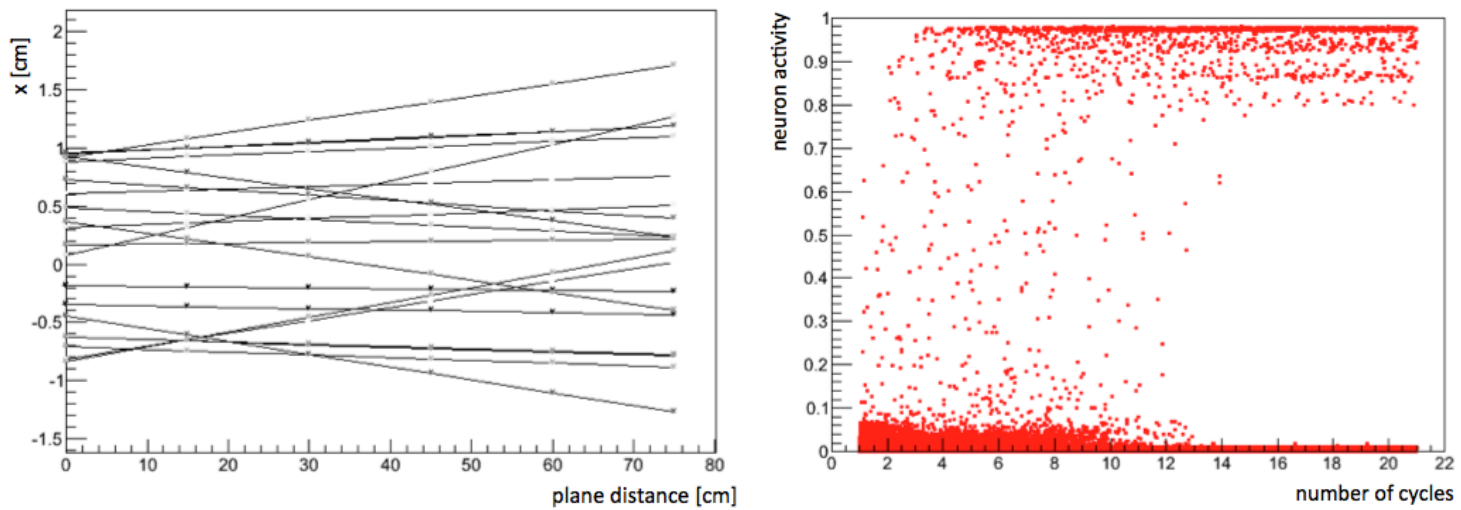
V are continuous value in $[0,1]$

Neural network work-flow

- random initialization of V_{ij}
- asynchronous updating cycle (one neuron at a time)
- stabilization of V_{ij} (convergence and parameters settings)
- conversion in binary map S_{ij}
- control with the true generated tracks

NN: toy model test results

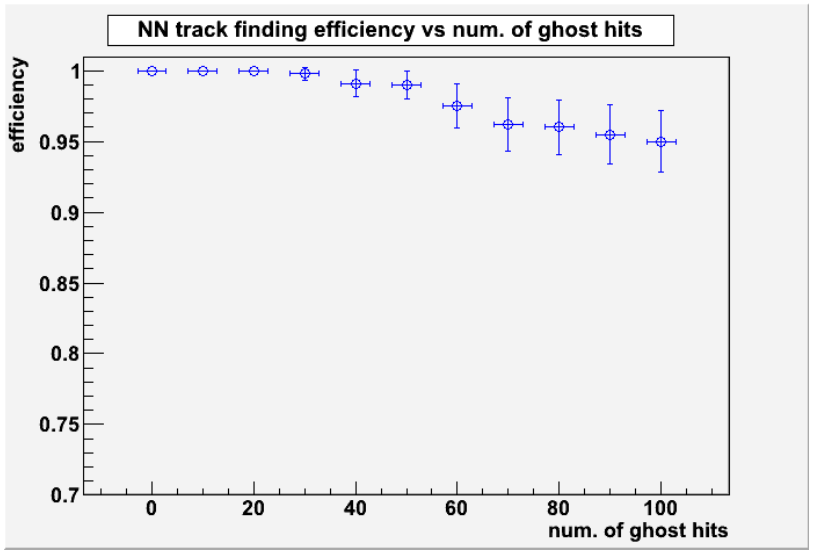
Consider 20 straight line tracks (10 from vertex) within a small cone 2×2 cm^2.

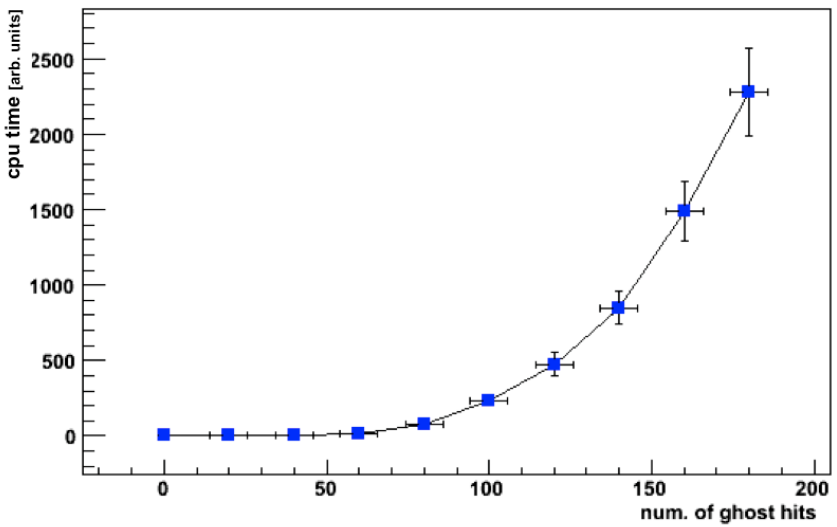


(left) Projection on the x-axis of the associated hits. (right) Neuron activity vs number of cycles, after 10 cycles neurons (connections) saturate to 1 (threshold 0.5).

NN efficiency in track association: results

Simulated data with detectors smearing and **without multiple scattering effects**

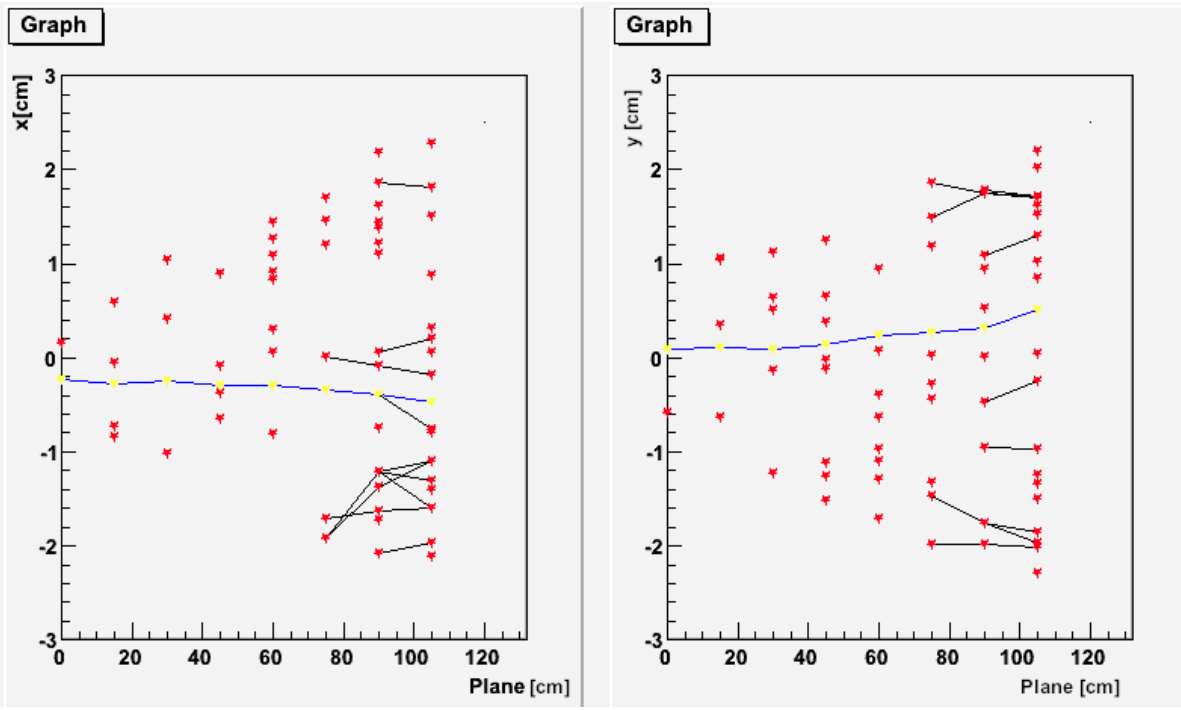




Six chamber planes: efficiency for a track is assumed 1 if at least 4 consecutive connections are on

NN: realistic simulated event

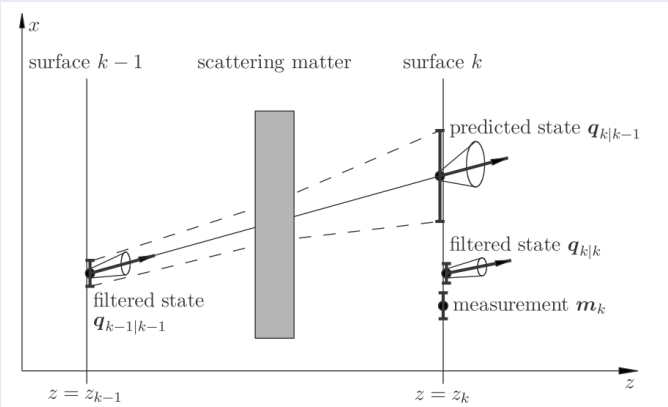
An example of reconstructed signal track for a typical event **with multiple scattering effects included** (GEANT4 SBS simulation). The two projections on x and y are shown.



Efficiency and optimization under study.

Particle filtering and smoothing

Kalman filter



Physical track: $\vec{x}_k = \mathbf{\Phi}_{k-1}\vec{x}_{k-1} + \vec{b}_{k-1}$
Measurement: $\vec{y}_k = \mathbf{C}_k\vec{x}_k + \vec{n}_k$

Filtering: each measurement is filtered from the noise, assuming a Gaussian uncorrelated noise; covariance matrix has been evaluated taking into account the propagation between planes.
Smoothing: the hits have been reweighed in the reverse direction, using the information from the last to the first.

Matrices definition

$$\mathbf{x} = \begin{pmatrix} \text{x position} \\ \text{y position} \\ \text{x slope} \\ \text{y slope} \end{pmatrix} \qquad \mathbf{y} = \begin{pmatrix} \text{x measured coordinate} \\ \text{y measured coordinate} \end{pmatrix}$$

$$\hat{\mathbf{C}} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix}$$

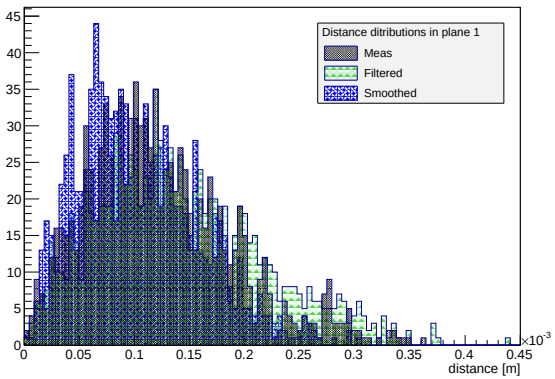
Evolution matrix and definition of the true-value initial covariance matrix

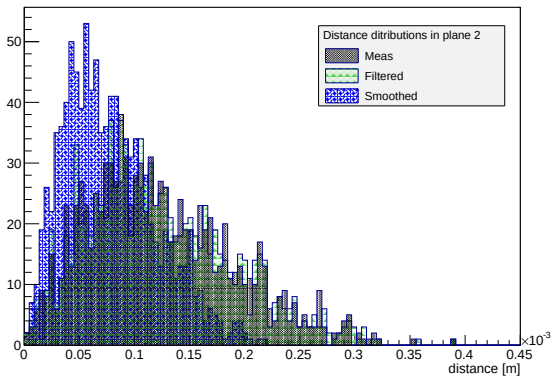
$$\hat{\mathbf{\Phi}} = \begin{pmatrix} 1 & 0 & \Delta z & 0 \\ 0 & 1 & 0 & \Delta z \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

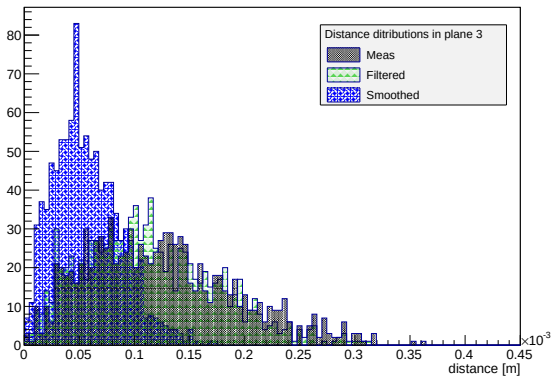
$$\hat{\mathbf{P}} = \begin{pmatrix} Var[x] & 0 & 0 & 0 \\ 0 & Var[y] & 0 & 0 \\ 0 & 0 & Var[\Delta x] & 0 \\ 0 & 0 & 0 & Var[\Delta y] \end{pmatrix}$$

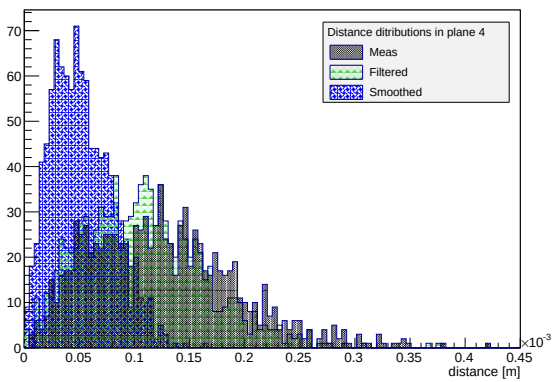
Kalman filter and smoothing: 6 chambers configuration

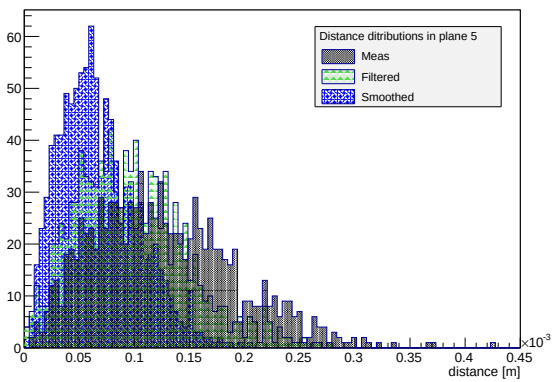
Simulated data **without multiple scattering**, spatial resolution of the detector $100\mu m$

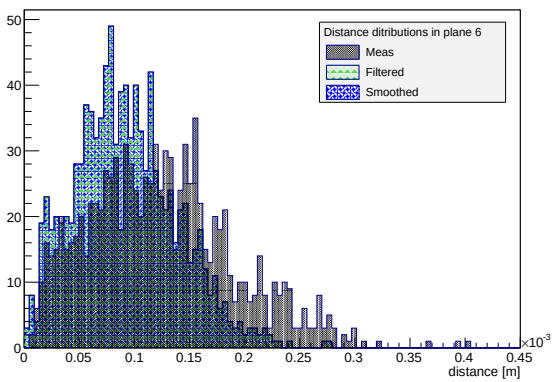








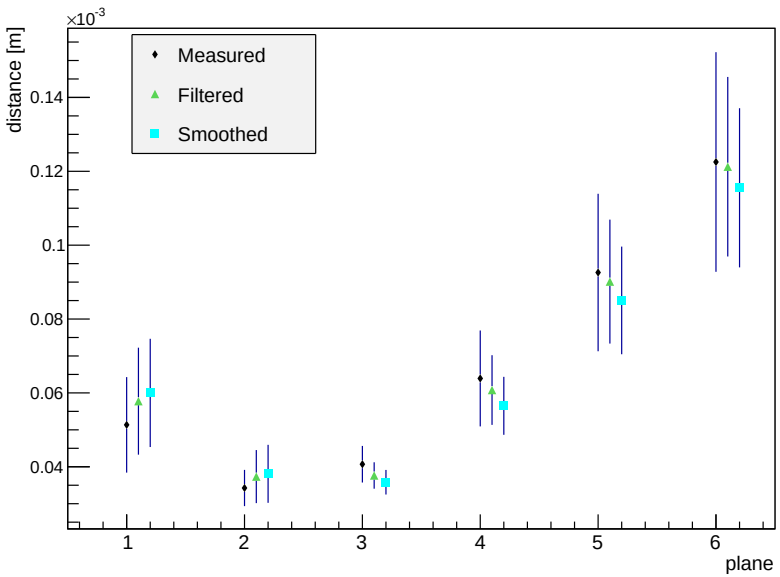


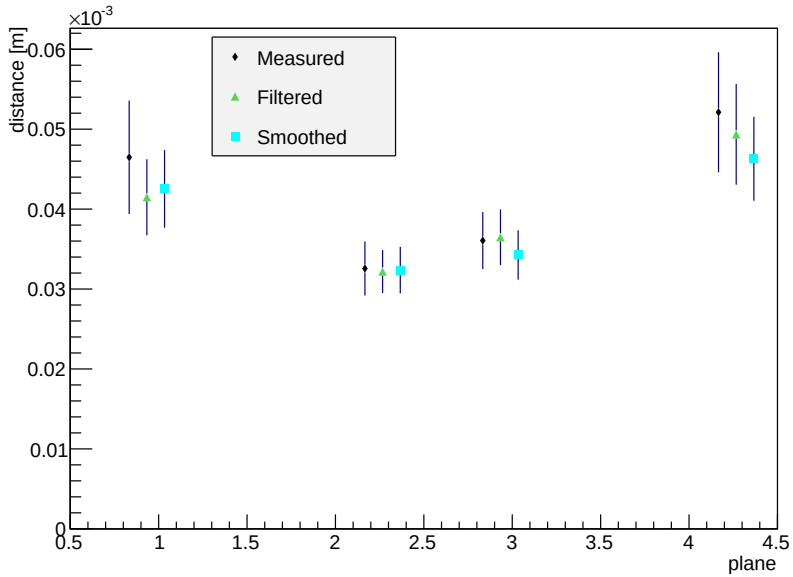


The filtering and smoothing procedure provides a significant improvement ($\sim 40\mu m$) in the spatial resolution in particular in the central planes

Kalman filter **with multiple scattering** effects

Simulated spatial resolution of the chambers σ =70 μm: key parameter is $\sigma_\theta = 30 \mu m$ the random displacement induced by multiple scattering from one chamber to another. Mean distances from the true hit are plotted for a sample of tracks; the bars are the RMS of the mean values.





Multiple scattering effects become dominant on the last planes → better to use 'first planes' only to filter the tracks

Code modular structure

Event generator

- Event: hit positions= x,y,z (plane); optional [x/y cluster size, cluster charge]

Association class

- input: event hits
- hits are associated using Neural Network
- output: list of associated hits (coordinates)

Reco class

- input:(associated) hits
- Tracks filtering and smoothing
- output: tracks parameters (intercept, slop) and covariance matrix

Work in progress

- Optimization of the NN on simulated GEANT4 data
- Test KF on real data (beam test)
- Code optimization