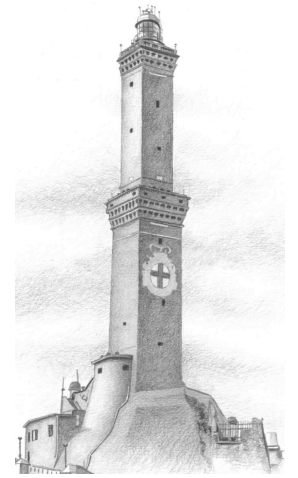




# An exact framework for Uncertainty Quantification in Monte Carlo simulation



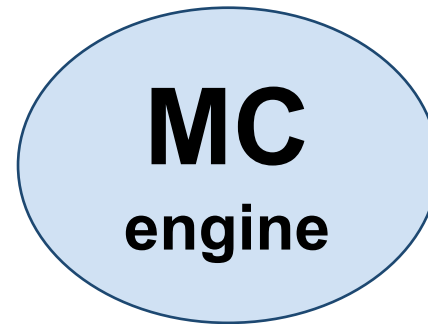
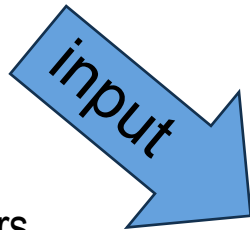
Paolo Saracco, Maria Grazia Pia  
*INFN Genova, Italy*

**CHEP 2013**  
Amsterdam, 14-18 October 2013

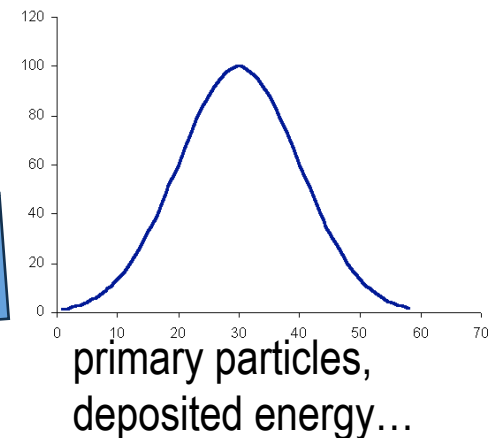
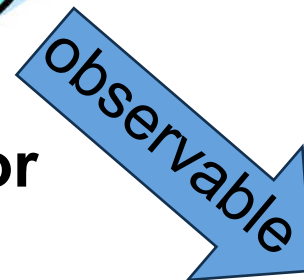


# Monte Carlo in HEP

cross sections,  
branching ratios,  
physics models,  
physics parameters..



**Event generator**  
*(Pythia, Herwig...)*  
**Particle transport**  
*(Geant4, MCNP, MARS...)*



How much can we trust the observables produced by MC?

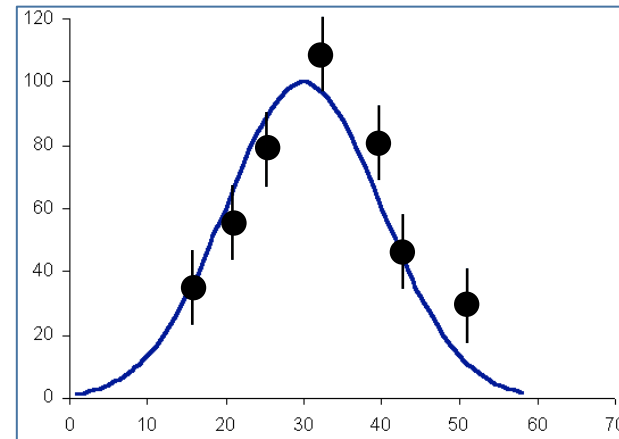
# Measure and compare

## Test beam



Courtesy CERN CDS, CERN-EX-0305054

## Measured and simulated observable



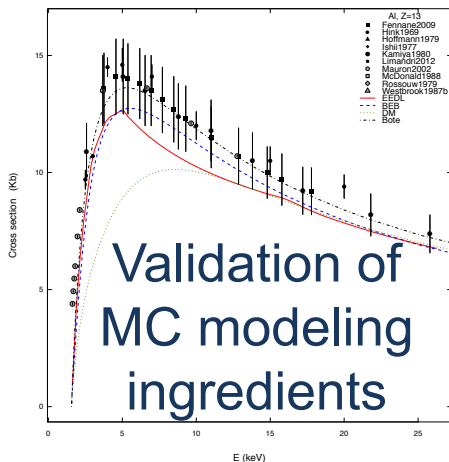
If the accuracy of observable **A** is assessed by comparison with experiment, **what about observable B?**

And what about the simulation of **detector concepts**, which do not exist yet?

And observables which cannot be measured in practice?

# Uncertainties

input  
with uncertainties

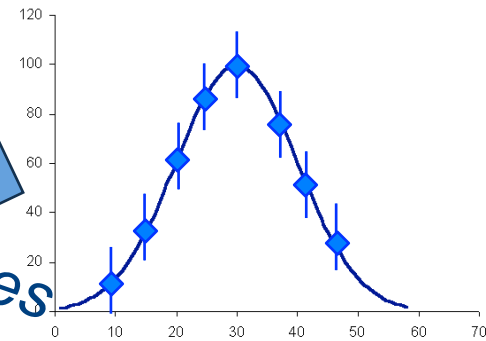


**Beware:** input uncertainties can be hidden in models and algorithms in the code



Monte Carlo method

observable  
with uncertainties



Uncertainties deriving from

- input uncertainties
- Monte Carlo algorithm
- simulation model

Uncertainty quantification is the ground for  
predictive Monte Carlo simulation

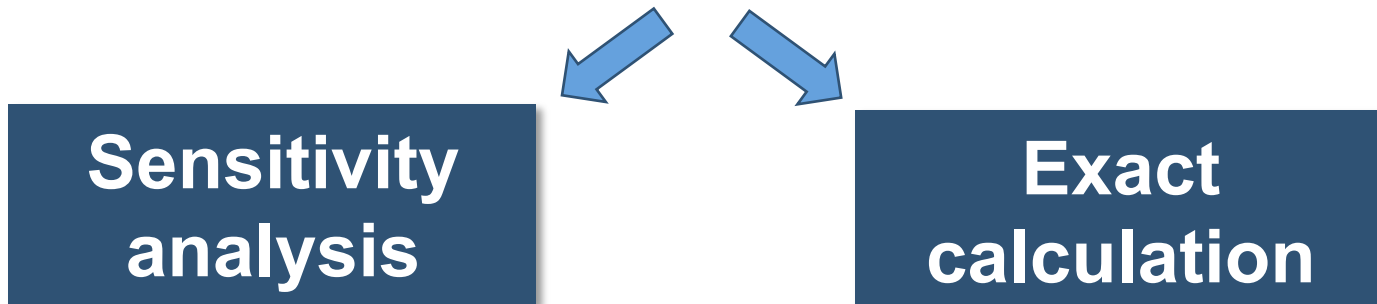
# Parameter uncertainties

They are the uncertainties of the “**ingredients**” of the simulation engine (*particle transport system, event generator*)



Can they be disentangled from statistical uncertainties associated with the Monte Carlo method?

Can we estimate their effect on the observables produced by the simulation?



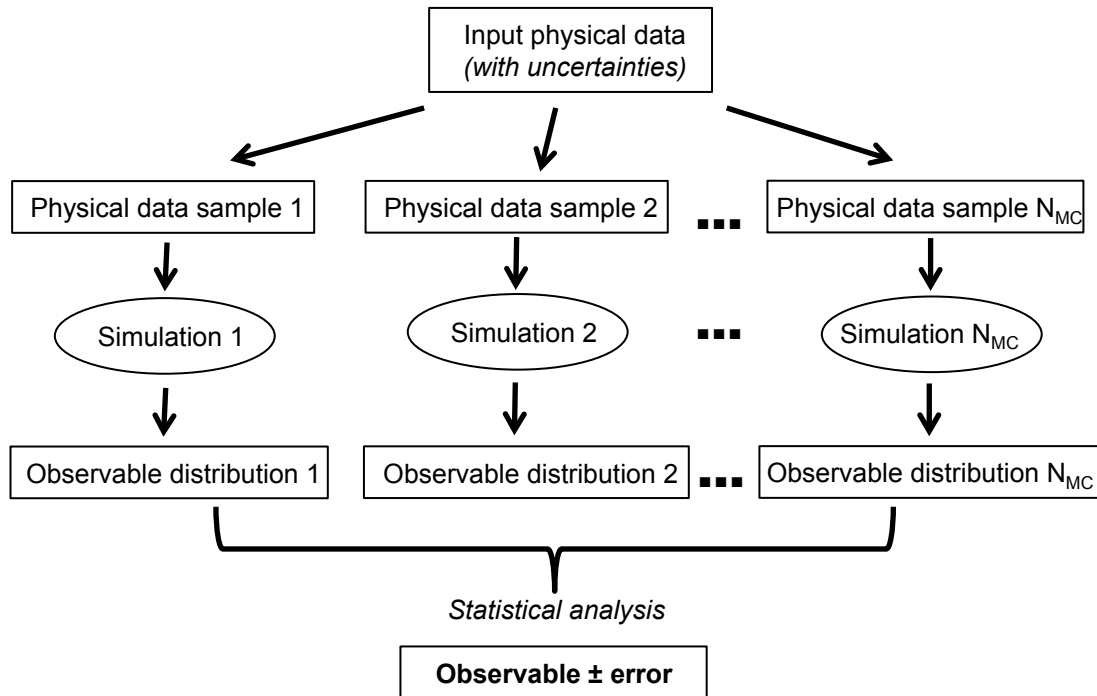


# Disentangling uncertainties

Algorithmic (statistical) and parameter uncertainties

# Sensitivity analysis

## Computational cost



- Mathematical methods
- Software toolkits (*DAKOTA, PSUADE..*)



# Uncertainty propagation

Spiegare il concetto



# Paolo's slides go here

# Current limitations

Bisogna spiegare quali siano le attuali limitazioni (concettuali e pratiche) del “nostro” UQ, e come intendiamo affrontarle



# Validation of physics ingredients

- The validation of the physics “ingredients” of Monte Carlo codes is a (*complex, slow*) still ongoing process
  - at least regarding Monte Carlo particle transport
- Quantitative estimates of input uncertainties (*cross sections, angular distributions, BR etc.*) are necessary for uncertainty propagation
  - A qualitative plot is not enough...
- Epistemic uncertainties are often embedded in the code, without being documented
  - See M. G. Pia, M. Begalli, A. Lechner, L. Quintieri, P. Saracco, **Physics-related epistemic uncertainties of proton depth dose simulation**, *IEEE Trans. Nucl. Sci.*, vol. 57, no. 5, pp. 2805-2830, 2010

# Conclusion and outlook

Collaborative contribution from HEP experiments is welcome!

## Collezione di immagini utili

