



**Faculty  
of Physics**

WARSAW UNIVERSITY OF TECHNOLOGY

# Software development for HBT analysis

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**Warsaw University  
of Technology**



# Outline

Femtoscopy

Motivation – problem of fitting

NicaCorrFit development

Plans

# Femtoscopy

Technique used to extract information about spatio-temporal structure of event

Base on two particle correlations

Correlation function defined as

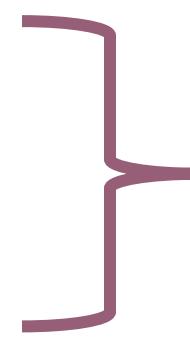
$$C(q) = \frac{P(p_1, p_2)}{P(p_1)P(p_2)}$$

where  $q = \sqrt{(p_1 - p_2)^2 - (E_1 - E_2)^2}$

# Femtoscopy

Typical analysis:

- Optimization of cuts
- Analysis of data
- Fit of experimental function with theoretical one
- Estimation of systematic uncertainties (requires more fits)



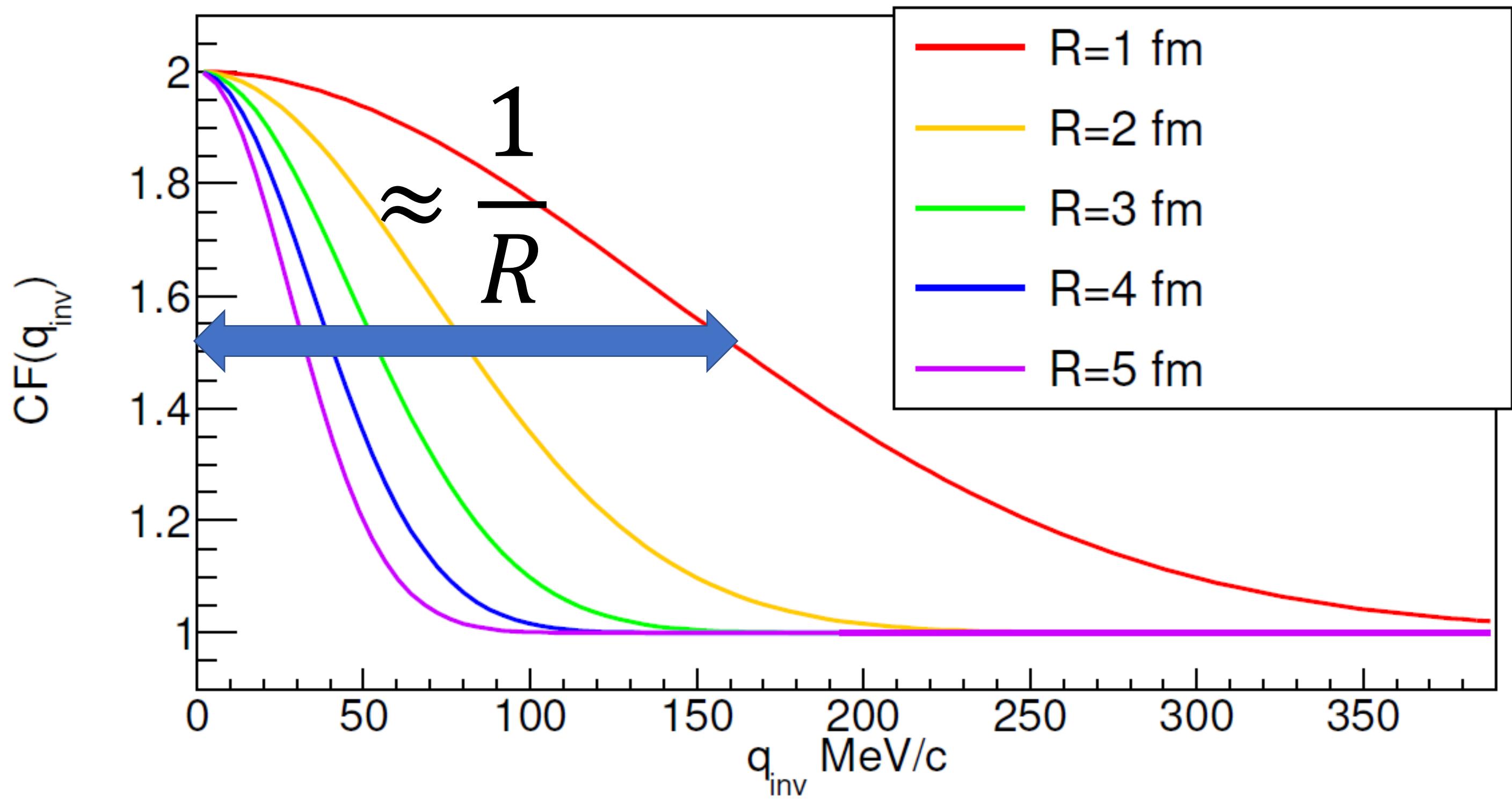
**MpdFemto** - Grigory Nigmatkulov & Pavel Batyuk

**NicaFemto** – Daniel Wielanek

# Femtoscopy

Correlation function for  
nonidentical noninteracting bosons  
without spin

So called gaussian source:  
 $C(q) = N(1 + \lambda e^{-q^2 R^2})$

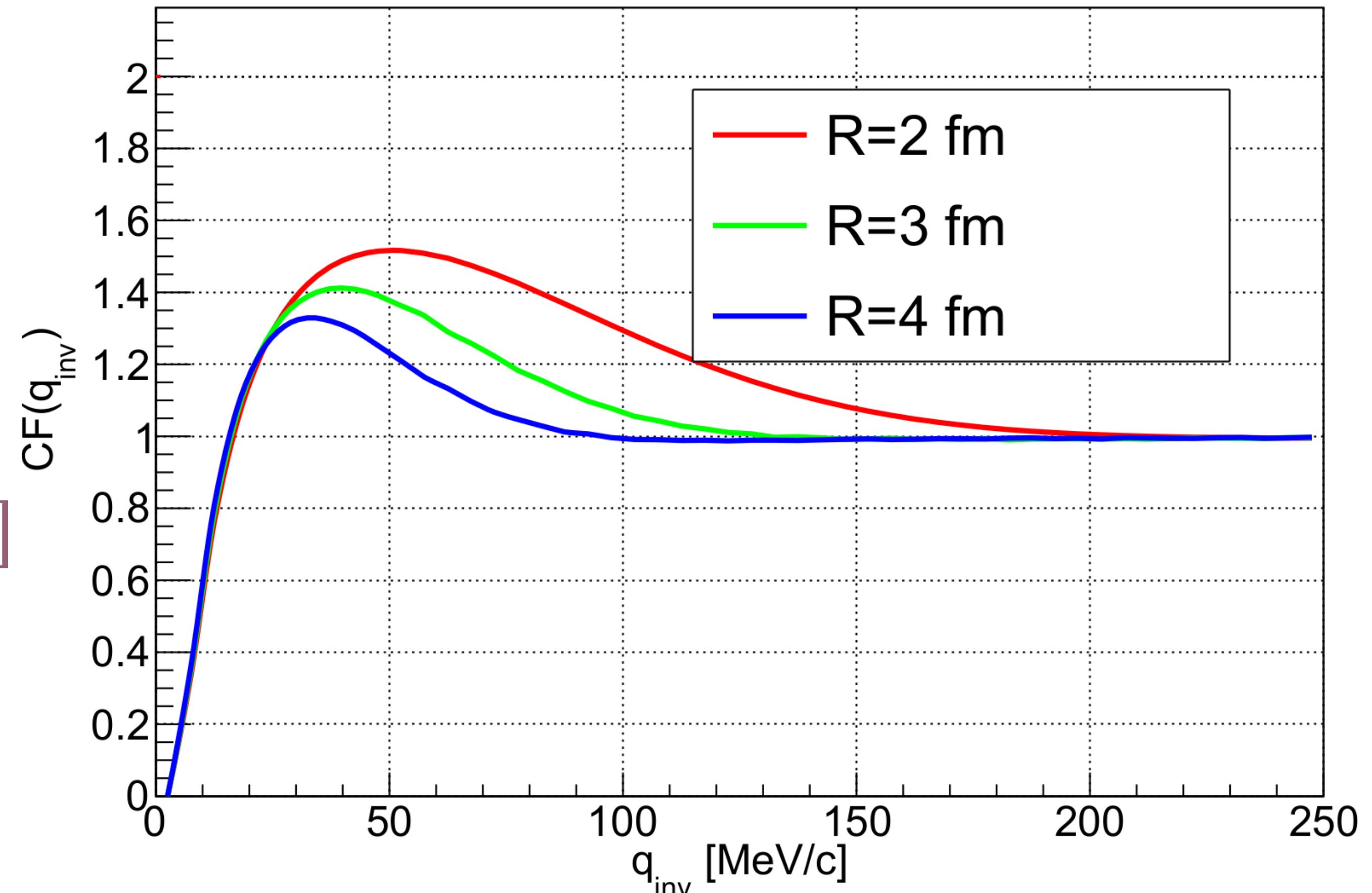


# Femtoscopy

Let's introduce two types of parameters:

1. Analytical – change of CF with change of parameter can be easily described e.g. normalization
2. Numerical – change of CF e.g R in K+K+ correlation

$$C(q) = N[1 + \lambda(C(q, R) - 1)]$$



# Femtoscopy

## Practical approaches

- Bowler-Sinyukov
- CorrFit (A. Kisiel)
- CATS (D.L. Mihaylov et. al)
- Manual generation of an group of CF and comparison with experimental one

# Fitting in NicaFemto - NicaCorrFit

Software for should contain 3 parts:

- Generator - class/function able to calculate the value of the theoretical CF
- Minimizer - software that finds the best fit
- Visualizer - software that show the quality of fit

# NicaCorrfit basics

Works similar to TF1, each fitted function is represented by class, user have to overwrite:

- CalculateCF(const Double\_t\* x, const Double\_t\* params) const
- RecalculateFunction() - called when parameters are changed (optional)

Some features of NicaFemto:

- Generator
  - Analytical
  - Map based
- Visualizer
  - Map of  $\chi^2$
  - GUI
- Minimizer
  - Base on ROOT minimizers
  - 3 minimized functions

Analytical + root minizer = TF1

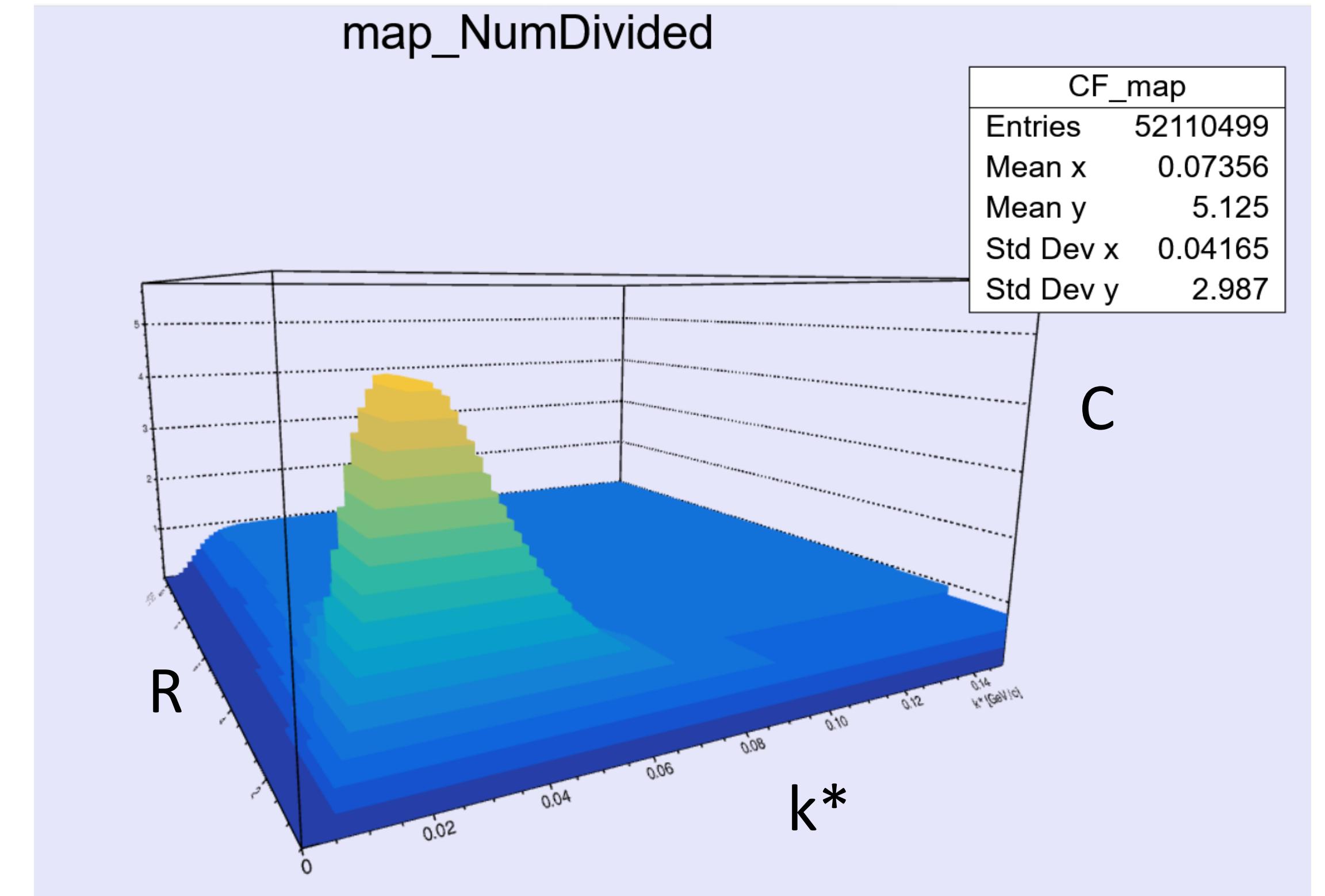
# Maps

Store CF as a function of  $k^*$  and R

- Interpolate values between bin centers
- Extremely fast fit on single PC
- Limited to only one numerical parameter

How to deal with more parameters? How fit 3D CF?

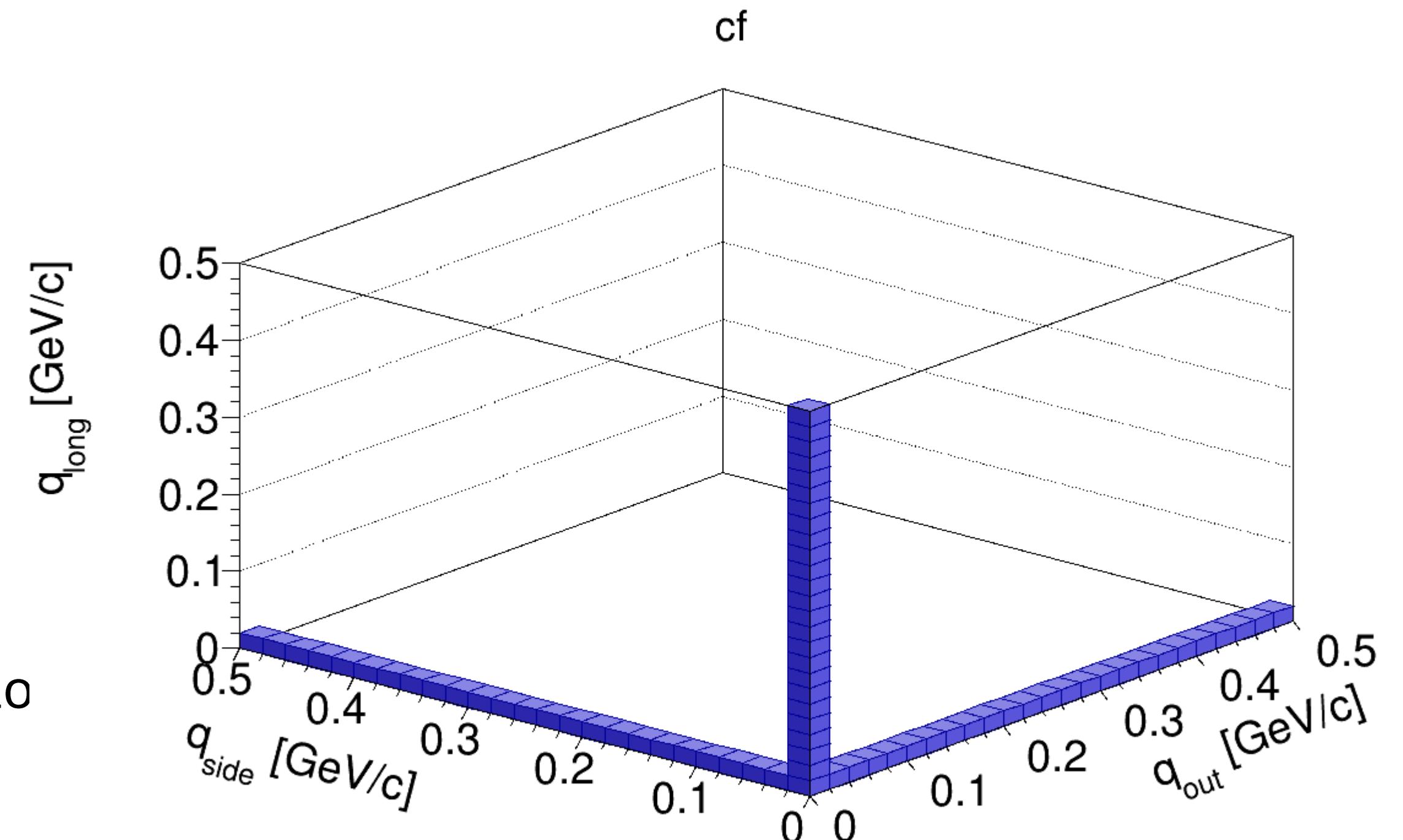
- 3DF: 50x50x50 bins + 3 parameters 10x10x10  
 $=125 \cdot 10^6$  cells \* size of float = 0.5MB, parabolic interpolation in 3D x27 =13.5 GB!



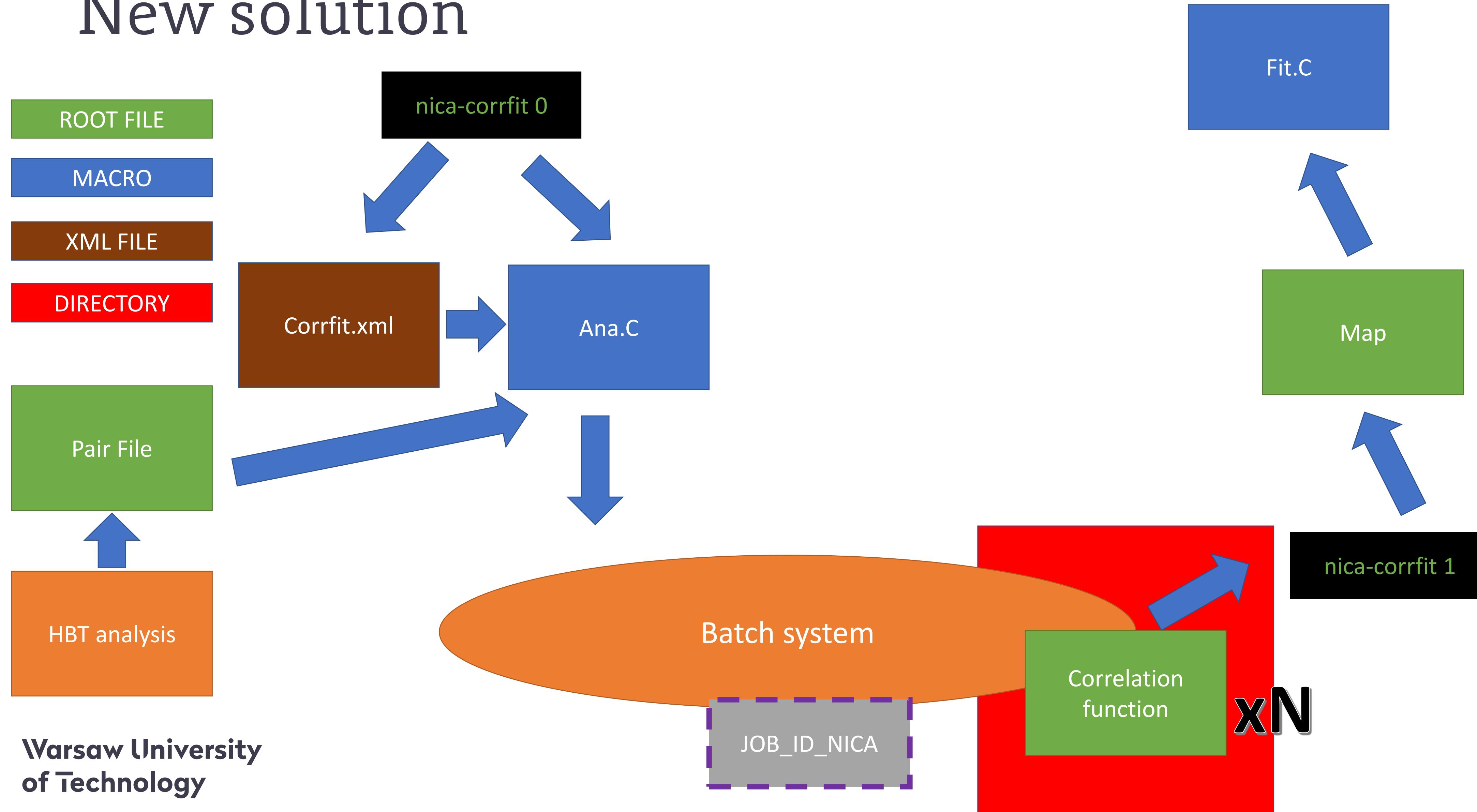
# New solution (Work In Progress)

Storing calculated function as a tree!

- CONS
  - not automatic (like corrfit)
  - requires pair file
  - fits only one function at time
- PROS
  - works at any batch system
  - uses tree (limited RAM usage, ROOT compression)
  - final fit can be done on single PC
  - option of „manual fitting”
  - slice fit (performance!)
  - number of parameters – depends only on computing power



# New solution



```
1 <CorrfitConfig>
2   <Parameters>
3     <Param name="R_{out}" min="1" max="10" points="10"></Param>
4     <Param name="R_{side}" min="1" max="10" points="10"></Param>
5     <Param name="R_{long}" min="1" max="10" points="10"></Param>
6   </Parameters>
7   <!-- full path to file with pairs-->
8   <Pairfile>zz.root</Pairfile>
9   <!-- optional part, use to configure dump pair analysis-->
10  <DumpAnalysisConf>
11    <CorrelationFunction>
12      <Name>CF</Name>
13      <Frame>ENicaFemtoKinematics::kLCMS</Frame>
14      <Type>NicaFemto3DCF</Type>
15    <!-- optional part, used only for spherical harmonics-->
16      <L>3</L>
17      <Xaxis bins="100" min="0.0" max="1.0"></Xaxis>
18      <Yaxis bins="100" min="0.0" max="1.0"></Yaxis>
19      <Zaxis bins="100" min="0.0" max="1.0"></Zaxis>
20    </CorrelationFunction>
21    <FreezoutGenerator>NicaFemtoFreezoutGeneratorLCMS</FreezoutGenerator>
22    <SourceModel>NicaFemtoSourceModelGauss3D</SourceModel>
23    <MultiplyFactor>1</MultiplyFactor>
24    <UseMixed>kFALSE</UseMixed>
25    <IgnoreSign>kTRUE</IgnoreSign>
26    <WeightConf>
27      <Type>NicaFemtoWeightGeneratorLednický</Type>
28      <QuantumOn>kTRUE</QuantumOn>
29      <StronOn>kFALSE</StronOn>
30      <CoulombOn>kFALSE</CoulombOn>
31      <PairType>211;211</PairType>
32    </WeightConf>
33  </DumpAnalysisConf>
34</CorrfitConfig>
35 |
```

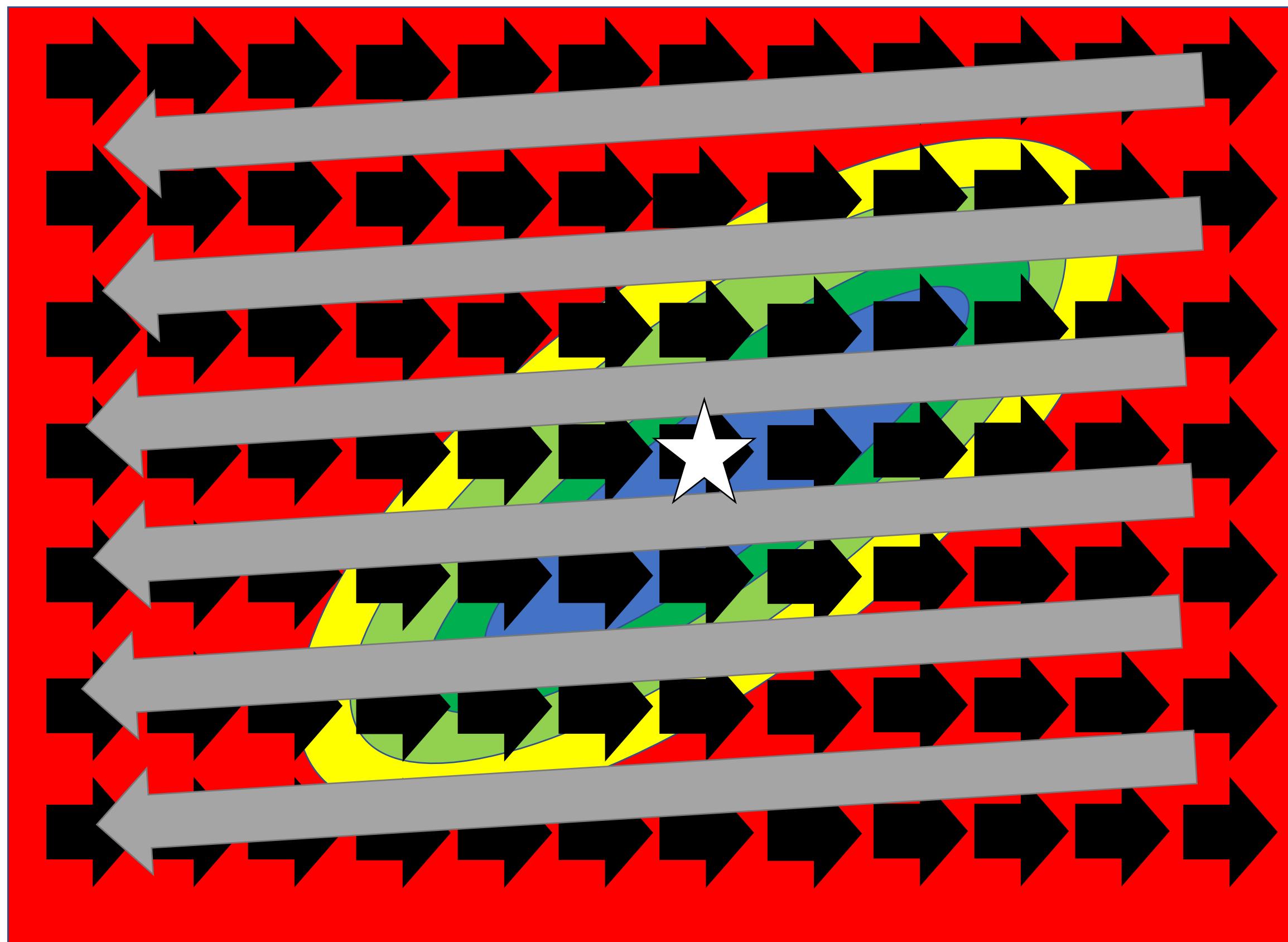
# New solution

GUI (finally!) for 3D correlation functions:

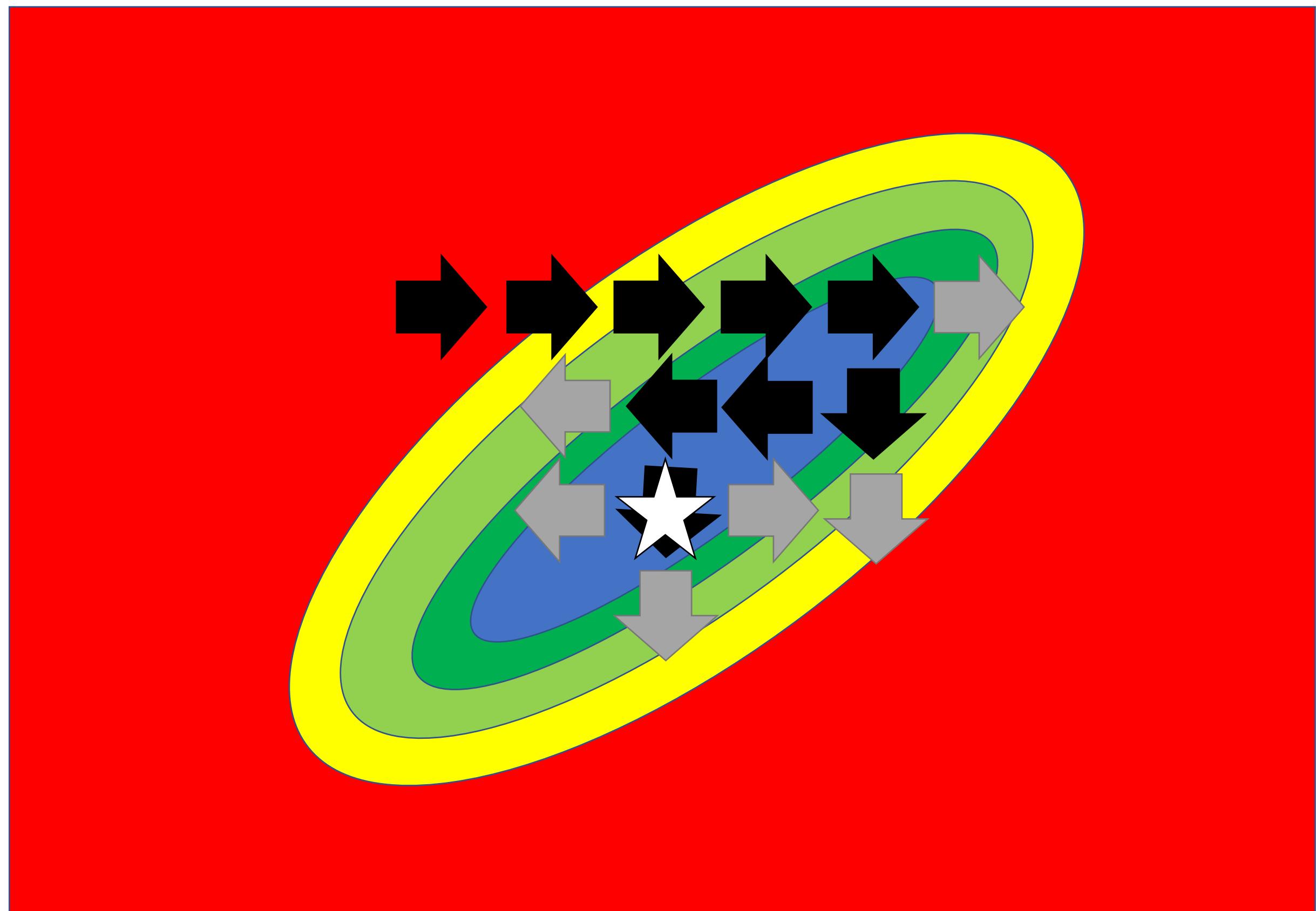
- Drawing the projections of CF
- Automatic update when user change parameter
- Discrete parameters are changed via list of available values
- Drawing of customizable chi<sup>2</sup> map possible

# New solution

# Nica Minimizer – towards „discretized fits”



# Minimizer – ant option



# Summary

Concept of 1D maps was tested and seems to be very good tool for BB correlation  
3D software is under development

- Map generator – draft stage
- GUI software – almost completed (requires some tuning)
- NicaMinimizer – early development stage

# Plans

Further development of CorrFit package

- Testing and development of minimization algorithm
- Full test of framework for pion, kaon and proton correlations
- Cleaning up the code, adding some missing things
- Testing of new concepts:
  - „pairs on the fly”
  - Some optimization of generator (?)
  - Interpolation in 3(6D) space(?)
  - Proof (?)
- Writing documentation/tutorials

Thank you for your attention

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# Backup slides

Maps of CF's

<http://femtocentrum.fizyka.pw.edu.pl/index.php/en/tables/maps-of-correlation-functions>