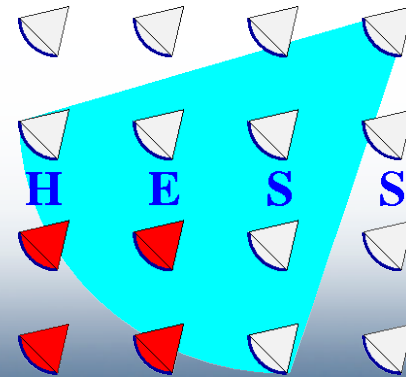


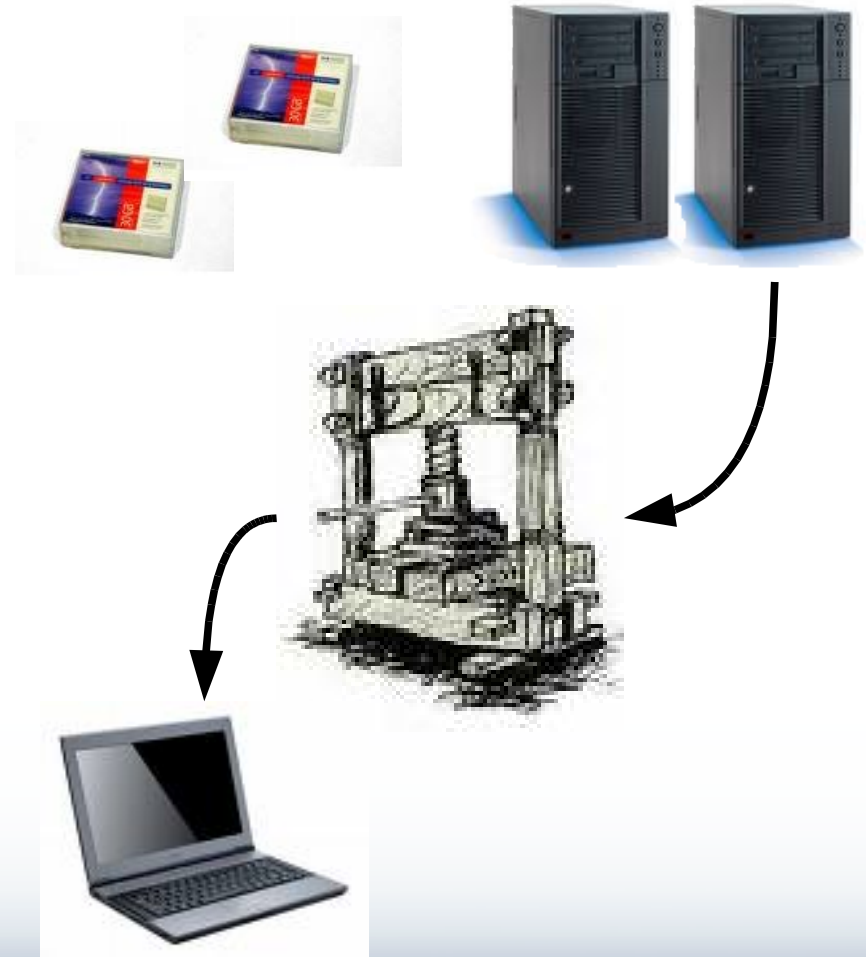
# Event-by-Event Analysis Using muDSTs

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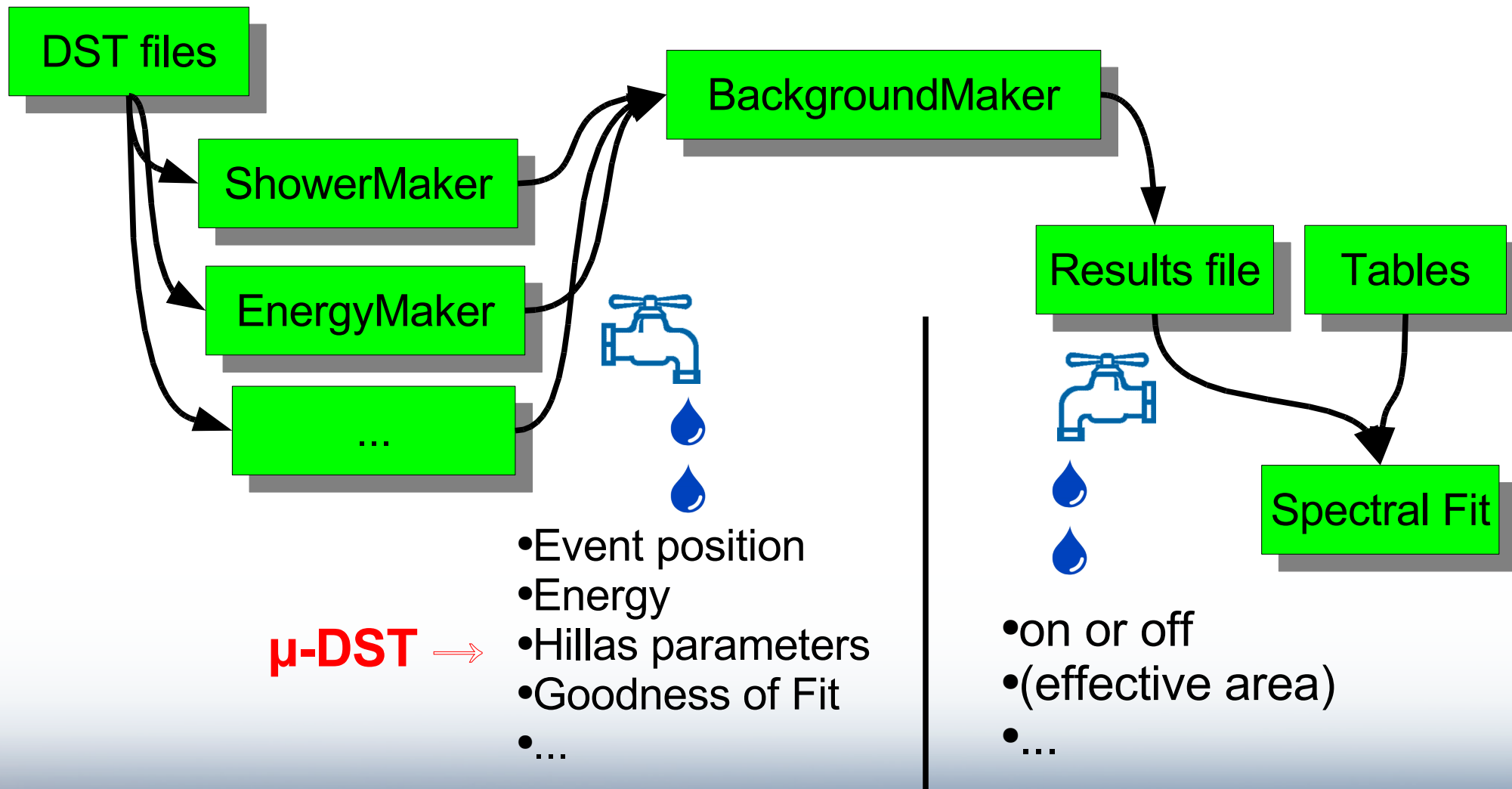


# Motivation

- each event comes with a lot of information
  - “raw” information: number of telescopes, Hillas parameters, telescope pointing, ...
  - reconstructed information: direction, energy, gamma or background, ...
  - several reconstruction algorithms
- compress the information, put it into small files
- → systematic studies, development of cuts and algorithms



# Tapping the Analysis Chain



# Time and Space

- DST files:

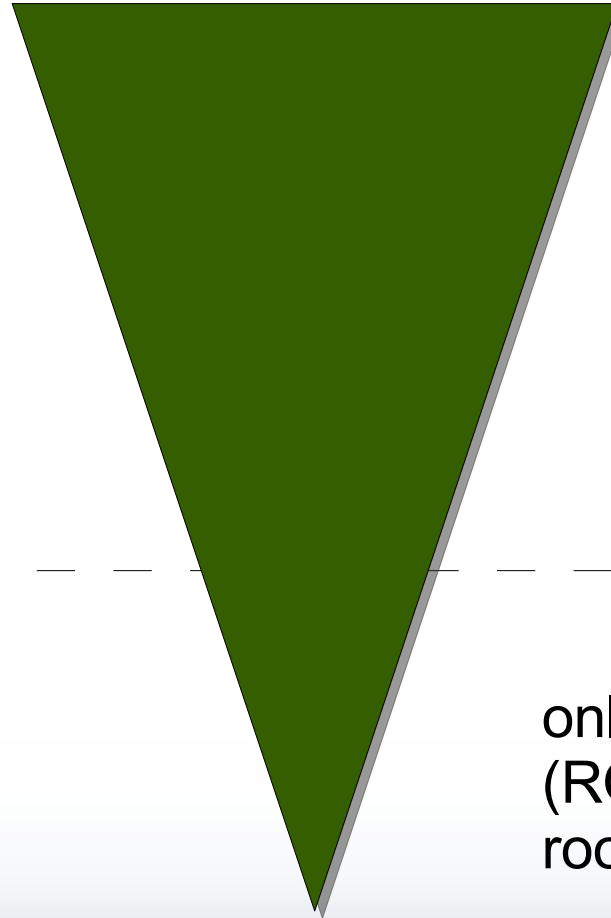
- size: 300 MB
- analysis time: ~ 5 min

- Results file:

- size: 13 MB
- analysis done

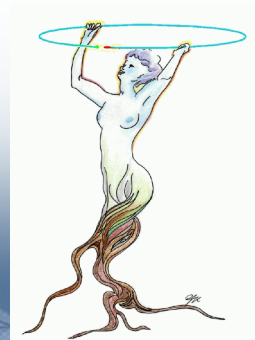
- muDST:

- size: 2 – 3 MB
- analysis: ~ 5 sec
- but: they need to be produced!!



H.E.S.S. analysis software needed

only standard software (ROOT) needed  
[root.cern.ch](http://root.cern.ch)



# What is in a muDST file?

- plain ROOT file
- contains Header
  - a TList of TNamed objects
  - run related information
- contains events tree
  - a TTree
- If you don't know TWhatever, don' worry about the details.

```
> root run018406.muDST.root
root [0] .ls
TFile**          run018406.muDST.root
  TFile*         run018406.muDST.root
    KEY: TList   Header;1           Doubly
    KEY: TTree   events;1           events
root [1] Header->Print()
OBJ: TNamed     RunNumber           18406
OBJ: TNamed     ObservationPosition_RA 83.6333
OBJ: TNamed     ObservationPosition_Dec 24.5144
OBJ: TNamed     TargetPosition_RA     83.6333
OBJ: TNamed     TargetPosition_Dec    22.0144
...
root [2]
```

# The Events Tree

- easy use: the TreeViewer, a graphical interface

```
root [2] events->StartViewer()
```

The screenshot shows the TreeViewer application window. The title bar reads "TreeViewer". The menu bar includes "File", "Edit", "Run", "Options", and "Help". Below the menu bar, there are input fields for "Command" and "Option", and a "Histogram" section with a dropdown menu set to "htemp" and checkboxes for "Hist", "Scan", and "Rec" (checked). The main area is divided into two panes: "Current Folder" on the left and "Current Tree : events" on the right. The "Current Folder" pane shows a tree structure with "TreeList" and "events" (highlighted). The "Current Tree : events" pane displays a list of variables, each with a green tree icon. The variables are arranged in four columns:

X: -empty-	GPStime_stamp_seconds	CombinedCut2	Hillas_CoG_x_3
Y: -empty-	GPStime_stamp_nanoseconds	Event_position_hillas_RA	Hillas_CoG_x_4
Z: -empty-	NomPointing_RA	MeanScaledSum	Event_number
-empty-	NomPointing_Dec	Event_position_hillas_Dec	Bunch_number
Scan box	NomPointing_ZA	ShowerDepth_hillas	Telescope_no
E( ) -empty-	Event_position_model_RA	ImpactParameter_hillas	Telescope_no_trigger
E( ) -empty-	Event_position_model_Dec	Energy_hillas	Tels_triggered
E( ) -empty-	Energy_model	Hillas_MSL	Tels_wData
E( ) -empty-	Depth_model	Hillas_MSW	OnOff
E( ) -empty-	dDepth_model	Hillas_CoG_y_2	
E( ) -empty-	MeanScaledGoodness	Hillas_CoG_x_1	
E( ) -empty-	Charge_1	Hillas_CoG_y_3	
E( ) -empty-	Charge_2	Hillas_CoG_y_1	
E( ) -empty-	Charge_3	Hillas_CoG_x_2	
E( ) -empty-	Charge_4	Hillas_CoG_y_4	

At the bottom of the window, there are "IList" and "OList" input fields, a status bar showing "First entry : 0 Last entry : 3957", and a "RESET" button.

# General Information

- Bunch\_number, Event\_number
- GPStime\_stamp\_seconds, GPStime\_stamp\_nanoseconds
- Telescope\_no, Telescope\_no\_trigger
- Tels\_triggered, Tels\_wData
  - bitmaps to identify the telescopes, e.g. tels 2+3+4:  $14 \quad \sum 2^{tel}$
- NomPointing\_RA, NomPointing\_Dec, NomPointing\_ZA



# Information from Model Analysis

- Event\_position\_model\_RA, Event\_position\_model\_Dec
- Energy\_model
- Depth\_model, dDepth\_model
- Charge\_1, Charge\_2, Charge\_3, Charge\_4
- MeanScaledGoodness, MeanScaledSum, CombinedCut2



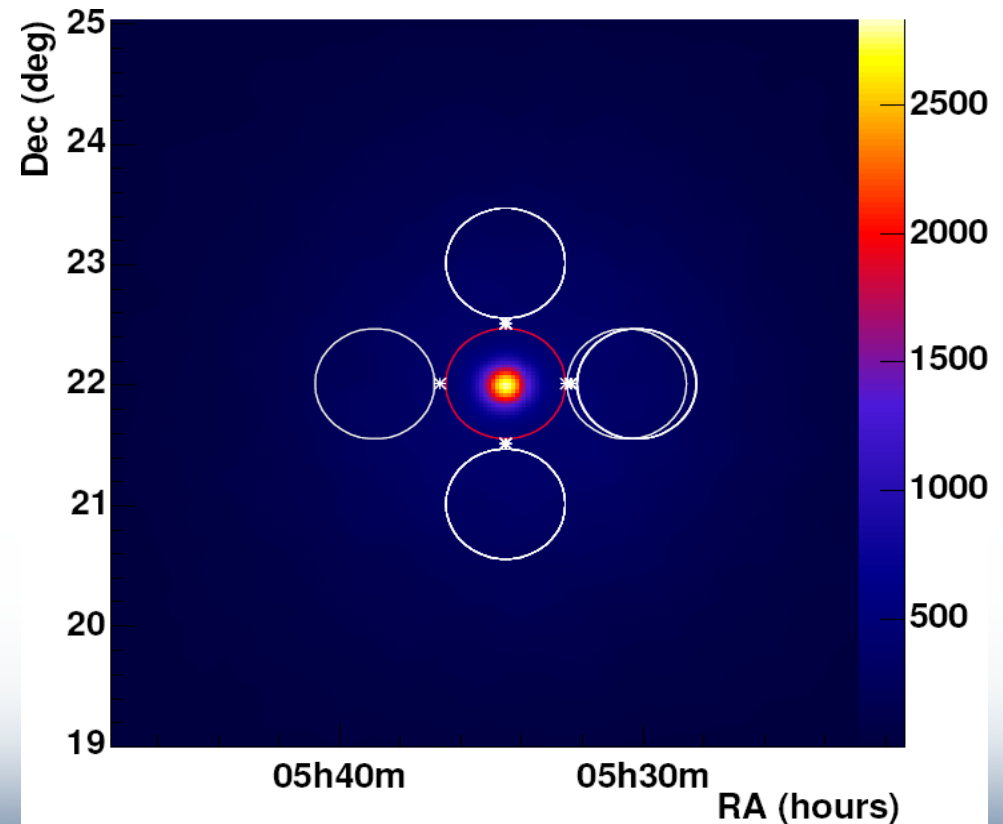


# Information from Hillas Analysis

- Event\_position\_hillas\_RA, Event\_position\_hillas\_Dec
- ShowerDepth\_hillas, ImpactParameter\_hillas
- Energy\_hillas
- Hillas\_MSL, Hillas\_MSX
- Hillas\_CoG\_x\_t, Hillas\_CoG\_y\_t      t = 1...4

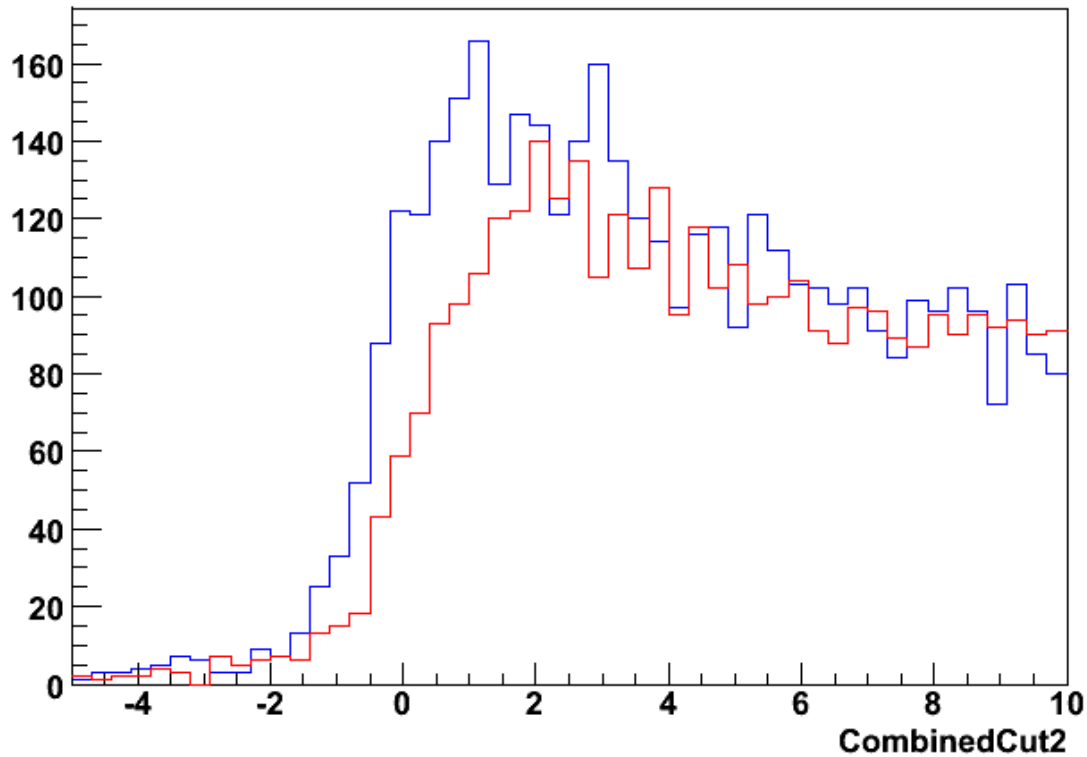
# Background Determination

- simplest method: one region reflected at camera centre
- in muDST:
  - OnOff = 1 (event in on source region)
  - OnOff = 2 (event in off source region)

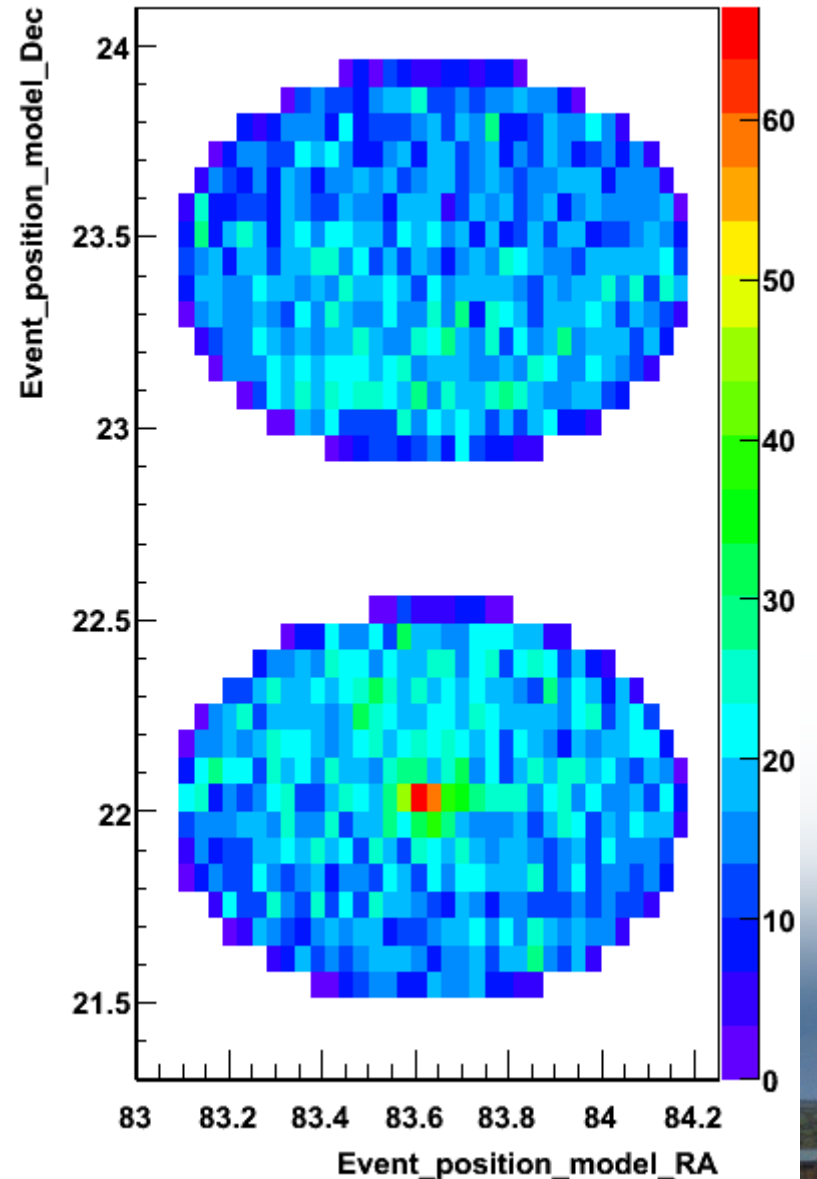


# Example Plots

- tutorials after coffee...



Event\_position\_model\_Dec: Event\_position\_model\_RA



# MuDST Production

- it is done during analysis
- predefined script for ParisAnalysis
- uses very loose cuts, keeps almost all events
- Lyon:  
\$HESSROOT/muDST/scripts/makeOnOffMuDST.C

```
root [2] makeOnOffMuDST(12345, ". /", 0.25)
```

run number

output directory, will produce  
a file ./run12345.muDST.root

squared radius of  
test region

# More ParisAnalysis Scripts

- you are not interested in On and Off, but just the data in the camera

```
root [2] makeMuDST(12345, "./")
```

- Simulation runs

```
root [2] makeMuMC(12345, "./", ...)
```

- if you have your analysis script, you can add

```
set_MuDST_inputFolder("event_on", "event_off");  
set_MuDST_outputFile(outputfile);
```
- you will get the same events in your Result and in the muDST
  - same preselection and number of background regions
  - event selection cut not applied

# Technical Details

- it is a Maker in the Sash frame
- `include <muDST/MuDSTMaker.hh>`
- `m = new MuDST::MuDSTMaker(onfolder, offfolder);`
- `m->InitBasic();`
- `m->InitModel();`
- `m->InitParisHillas();`
- `chain->UseMaker(m);`

# Technical Details

- it is a Maker in the Standard Model

it can be plugged into other analyses  
(e.g. HAP, to be done)

- `chain->UseMaker(m);`



# Dos and Don'ts

## What is it good for?

- all event information in one, simple file
- for systematic studies
- development of new cuts and algorithms

## Do not use

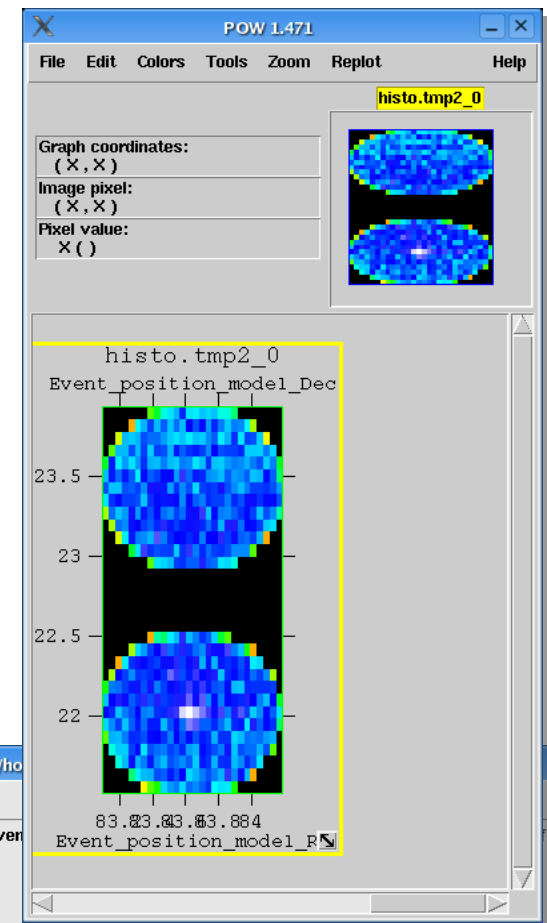
- to write a paper
- do not write long code for muDSTs
- it is not a starting point to get in touch with HESS analysis

your new algorithms and cuts  
should be put into a standard analysis chain



# Outlook

- what is missing
  - combination of different methods in one file
  - effective area per event
- muDST can be exported to FITS
- but not yet ready analysis
- (far) future:
  - spectral data in XSPEC
  - problem: effective areas



fv: Binary Table of run036012.fits[1] in /local/ho

File Edit Tools

CombinedCut2  Energy\_model  Event\_number  Event

Select  
 All  
Invert

1	2.266577148438E+01	8.908686637878E-01	61	2.322245869983E+01	8.327877761244E+01	2
2	4.405932426453E+00	5.287633538246E-01	67	2.318363498663E+01	8.391370632112E+01	2
3	8.016467094421E-01	3.510704994202E+00	82	2.180057422056E+01	8.321513327788E+01	1
4	2.428551864624E+01	3.534577131271E+00	96	2.327195525579E+01	8.375162541082E+01	2
5	3.667970657349E+01	6.741302013397E+00	237	2.203791000760E+01	8.350973526272E+01	1
6	9.343596458435E+00	5.528565645218E-01	270	2.297682463572E+01	8.364333162117E+01	2
7	1.060795402527E+01	8.841547012329E+00	273	2.344505773671E+01	8.410119909687E+01	2
8	4.409761905670E+00	3.702813386917E+00	281	2.175863440182E+01	8.370607303700E+01	1
9	1.339387059212E+00	2.691653251648E+00	299	2.322704518163E+01	8.367905330349E+01	2
10	3.190618038177E+00	5.578772544861E+00	348	2.318685027847E+01	8.379784373975E+01	2
11	1.114623737335E+01	5.892858028412E+00	368	2.329796218192E+01	8.394627474286E+01	2
12	1.187729740143E+01	9.176344275475E-01	400	2.183044161266E+01	8.381127960184E+01	1
13	7.171494483948E+00	1.646647691727E+00	411	2.370842621537E+01	8.389737528128E+01	2
14	1.254560756683E+01	1.140196084976E+00	423	2.376202093644E+01	8.398728260925E+01	2
15	2.502091598511E+01	2.983216941357E-01	432	2.168864020830E+01	8.393595562344E+01	1
16	8.939082622528E-01	4.352644443512E+00	443	2.160204960306E+01	8.388271511768E+01	1
17	1.833426284790E+01	6.145126819611E-01	448	2.367202118081E+01	8.320071463262E+01	2
18	6.757395267487E+00	1.273344230652E+01	464	2.369043887343E+01	8.345336072151E+01	2
19	1.001510429382E+01	3.265411257744E-01	489	2.219784065214E+01	8.334924650536E+01	1
20	1.077450561523E+01	6.548718810081E-01	500	2.190714007426E+01	8.402483598507E+01	1

Go to: Edit cell:

# Summary

- all event information in a single, small file
  - fast production of distribution plots
  - cut and algorithm development
  - only ROOT needed
- muDST production needs one full analysis
  - scripts implemented for ParisAnalysis
  - will be done for HAP
- Future
  - FITS files with event data
  - (spectral data for XSPEC)