Fireworks:

A Physics Event Display for CMS

Christopher Jones	*Cornell*
Bertrand Bellenot , Alja Mrak-Tadel, Matevz Tadel	*CERN*
Lothar Bauerdick	*FNAL*
Dmytro Kovalskyi	*UCSB*
Johannes Muelmenstaedt, Avi Yagil	*UCSD*

Overview

Requirements

Building Blocks

Interface

Views

Filtering

Requirements

When Viewing Data Only for Physics Content

Easy to use

First time users can easily be put off

Concentrate on only what you care about

Show only the data types requested

Show only the data items of interest

Pixel accurate representation may hamper physics

Distortion of space can be used to better use screen space

Placing objects in logical layers rather than exact x,y can aid comparison

Simple geometry avoids need for alignment info

Airplane test

Physicists want to be able to look at their data even away from a network

Building Block: EDM

CMS's New Event Data Model

Began in 2005 and now fully utilized

Strict separation of algorithm and data

- Code that is used to create data is in separate libraries from the data

Data objects serialized directly by ROOT

Tiered analysis strategies

- **Full framework**: can access all conditions information and use on grid
- **Lite framework**: helper classes and dictionaries for use in ROOT
- **Bare ROOT**: quickly look at simple data quantities

Fireworks is Built on the Lite Framework

Building Block: Eve

Eve is a New Package in ROOT

Used for constructing event displays

Originally developed for ALICE

Features

Optimized OpenGL rendering

3D, 2D and lego views

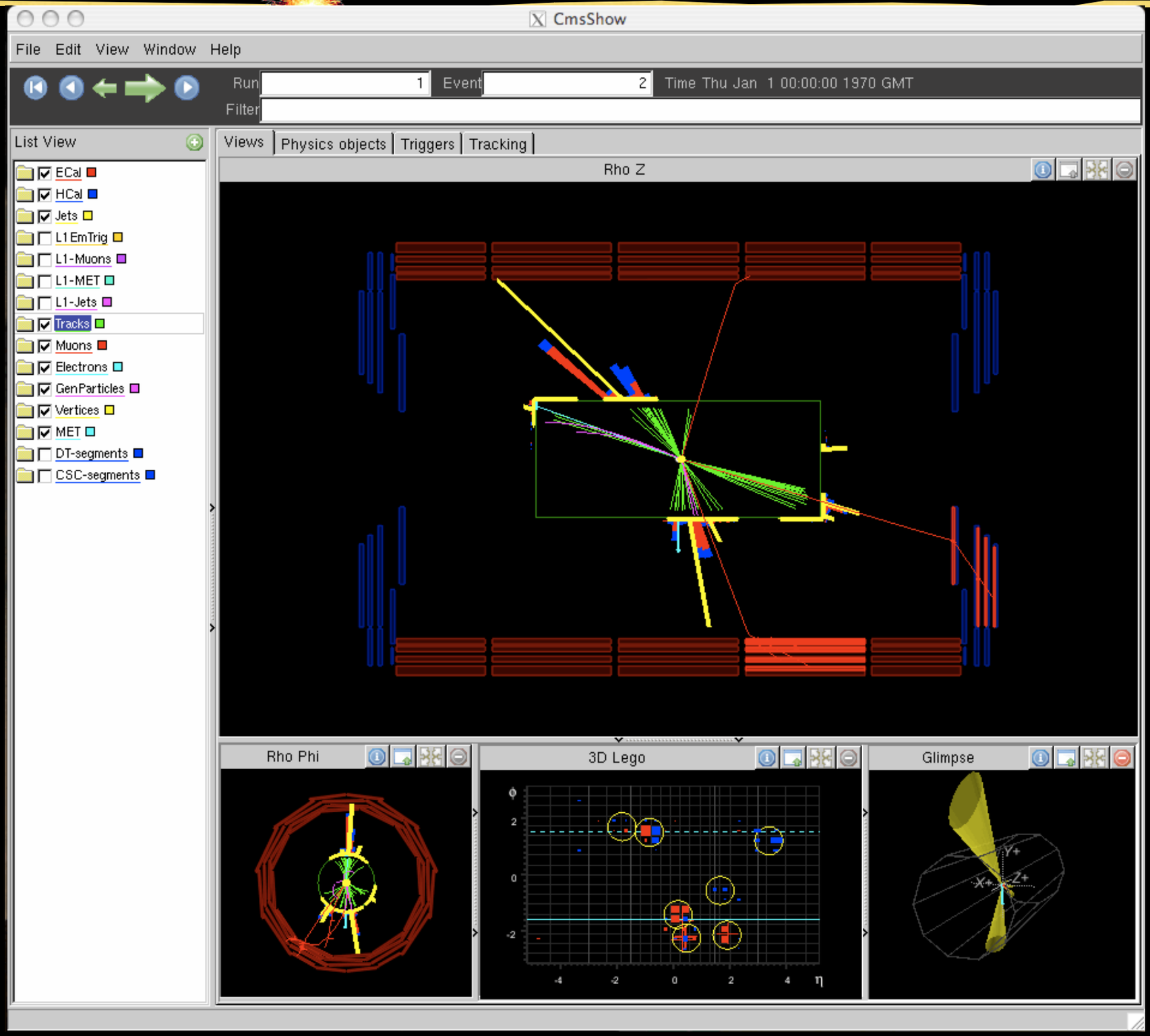
Real-time spatial distortions

E.g., fish-eye

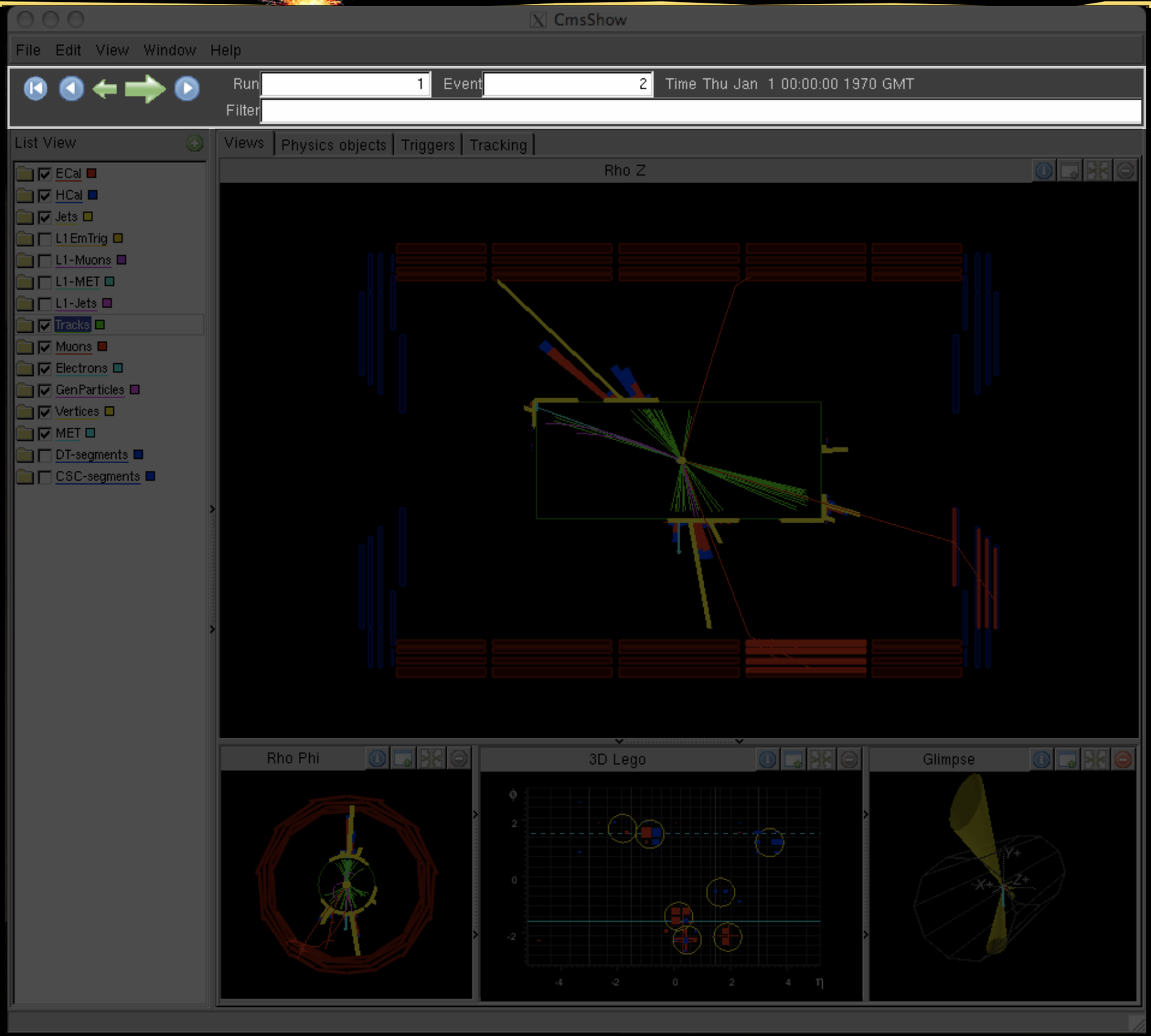
Individual object selection and highlighting

Eve Developers are Fireworks Members

Interface


CmsShow
File Edit View Window Help
Run 1 Event 2 Time Thu Jan 1 00:00:00 1970 GMT
Filter
List View
ECal
HCal
Jets
L1EmTrig
L1-Muons
L1-MET
L1-Jets
Tracks
Muons
Electrons
GenParticles
Vertices
MET
DT-segments
CSC-segments
Views
Physics objects
Triggers
Tracking
Rho Z
Rho Phi
3D Lego
Glimpse

Interface


CmsShow
File Edit View Window Help
Run 1 Event 2 Time Thu Jan 1 00:00:00 1970 GMT
Filter
List View
ECal
HCal
Jets
L1EmTrig
L1-Muons
L1-MET
L1-Jets
Tracks
Muons
Electrons
GenParticles
Vertices
MET
DT-segments
CSC-segments
Views
Physics objects
Triggers
Tracking
Rho Z
Rho Phi
3D Lego
Glimpse

Interface

Event Controls

Easy access for most common actions

Single step forward and back

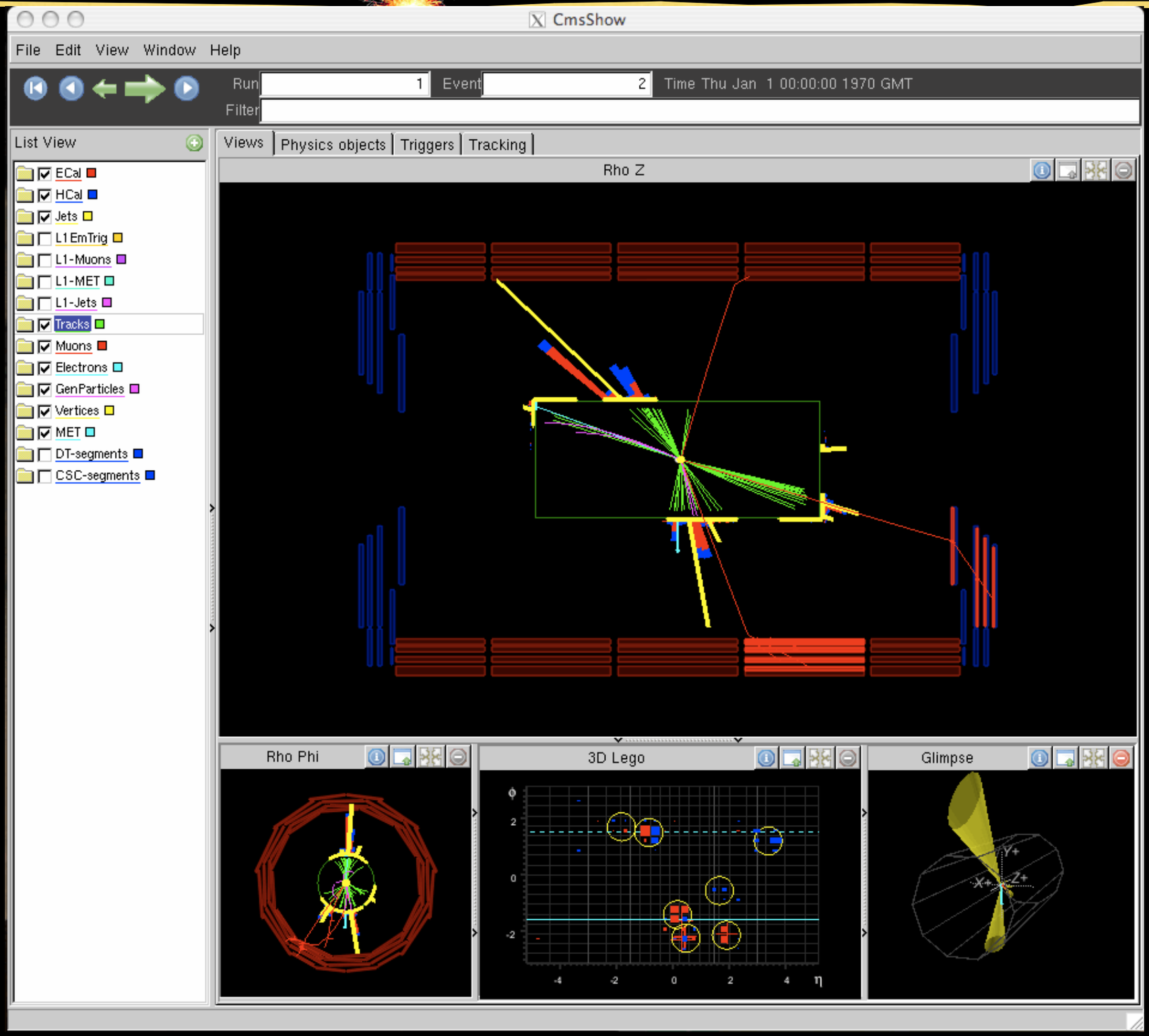
Play forward and back

Go to first event

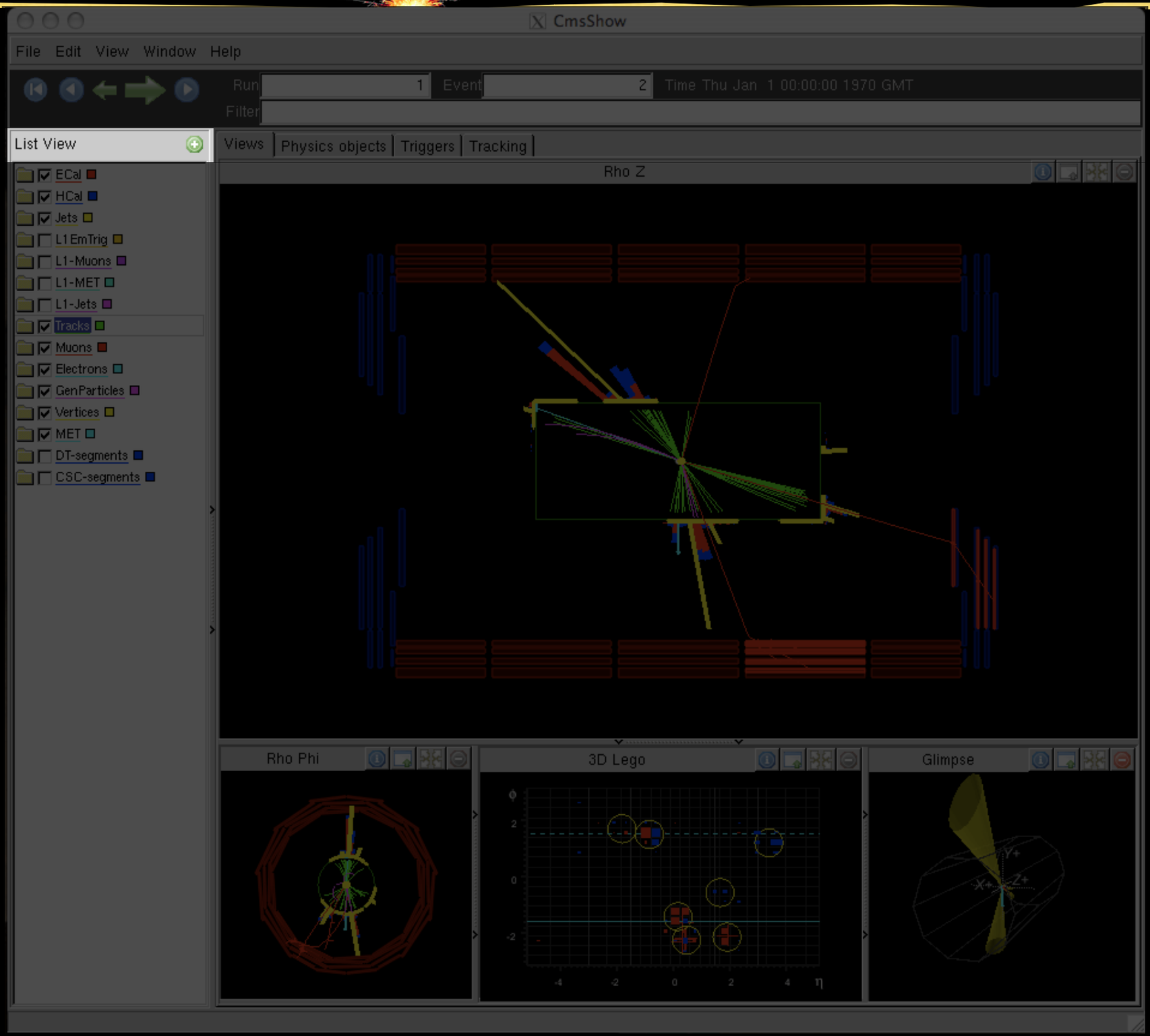
Jump to Run/Event

Filter events

Interface


CmsShow
File Edit View Window Help
Run 1 Event 2 Time Thu Jan 1 00:00:00 1970 GMT
Filter
List View
ECal
HCal
Jets
L1EmTrig
L1-Muons
L1-MET
L1-Jets
Tracks
Muons
Electrons
GenParticles
Vertices
MET
DT-segments
CSC-segments
Views
Physics objects
Triggers
Tracking
Rho Z
Rho Phi
3D Lego
Glimpse

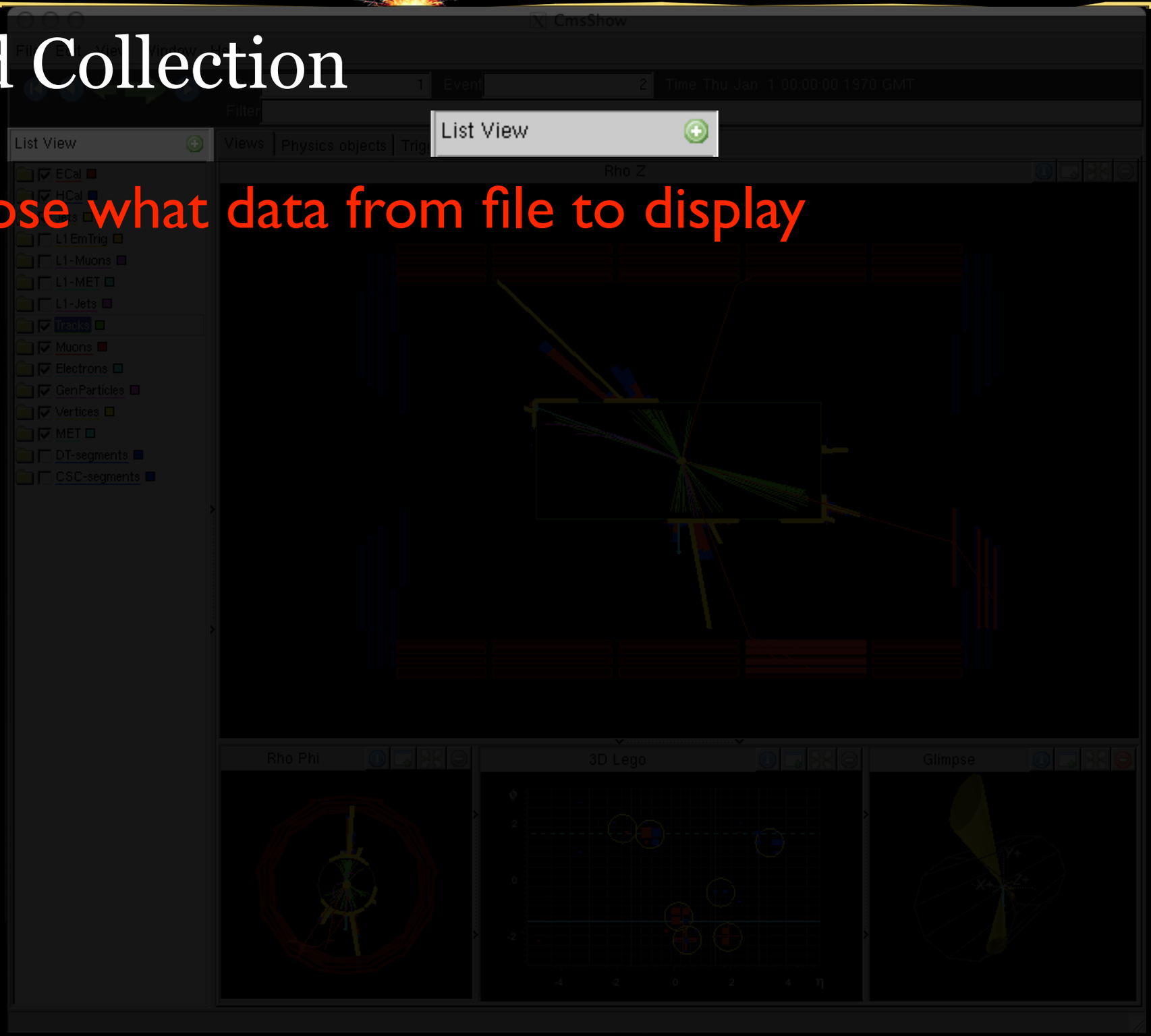
Interface


CmsShow
File Edit View Window Help
Run 1 Event 2 Time Thu Jan 1 00:00:00 1970 GMT
Filter
List View
Views Physics objects Triggers Tracking
ECal
HCal
Jets
L1EmTrig
L1-Muons
L1-MET
L1-Jets
Tracks
Muons
Electrons
GenParticles
Vertices
MET
DT-segments
CSC-segments
Rho Z
Rho Phi
3D Lego
Glimpse

Interface

Add Collection

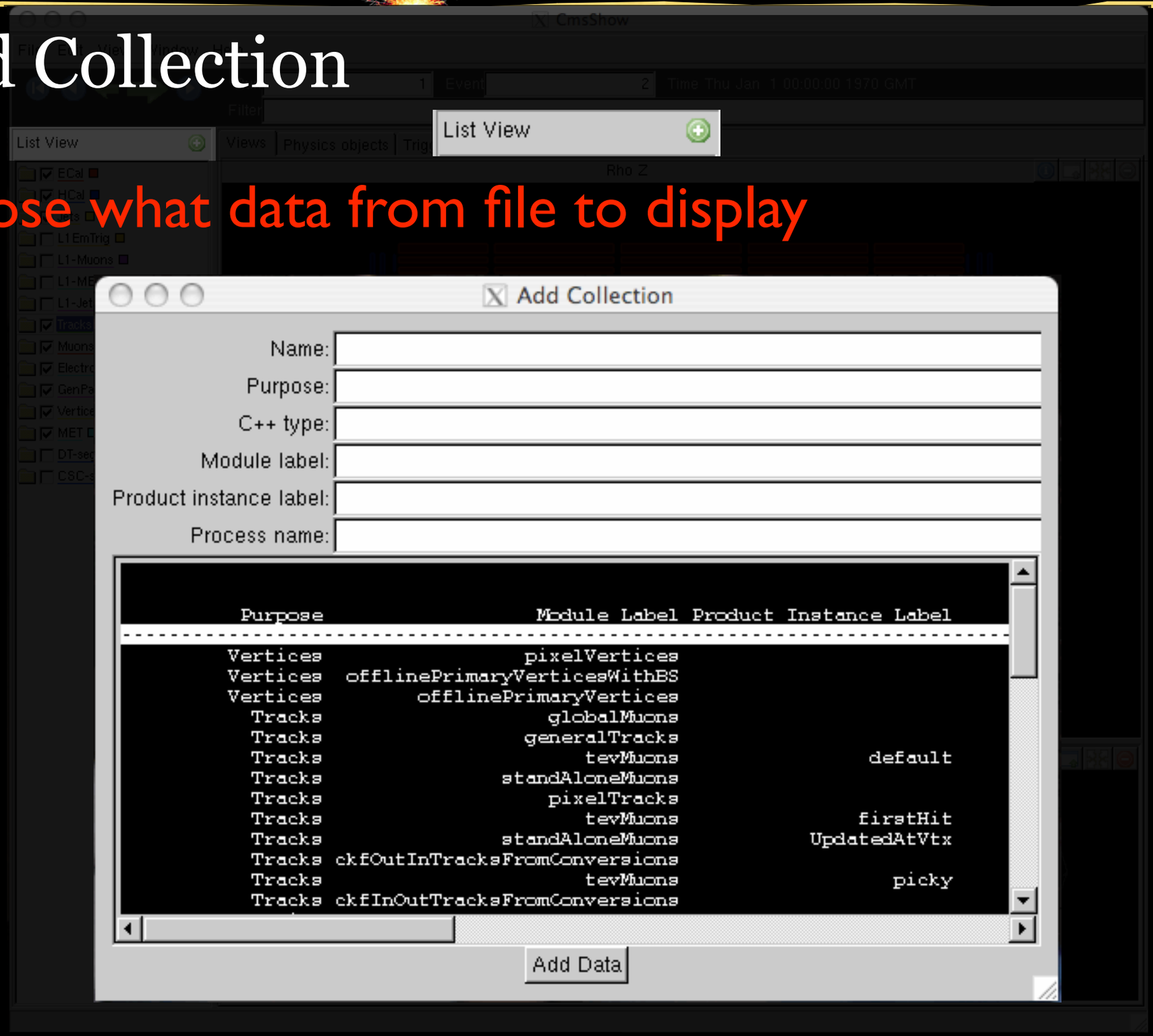
Choose what data from file to display



Interface

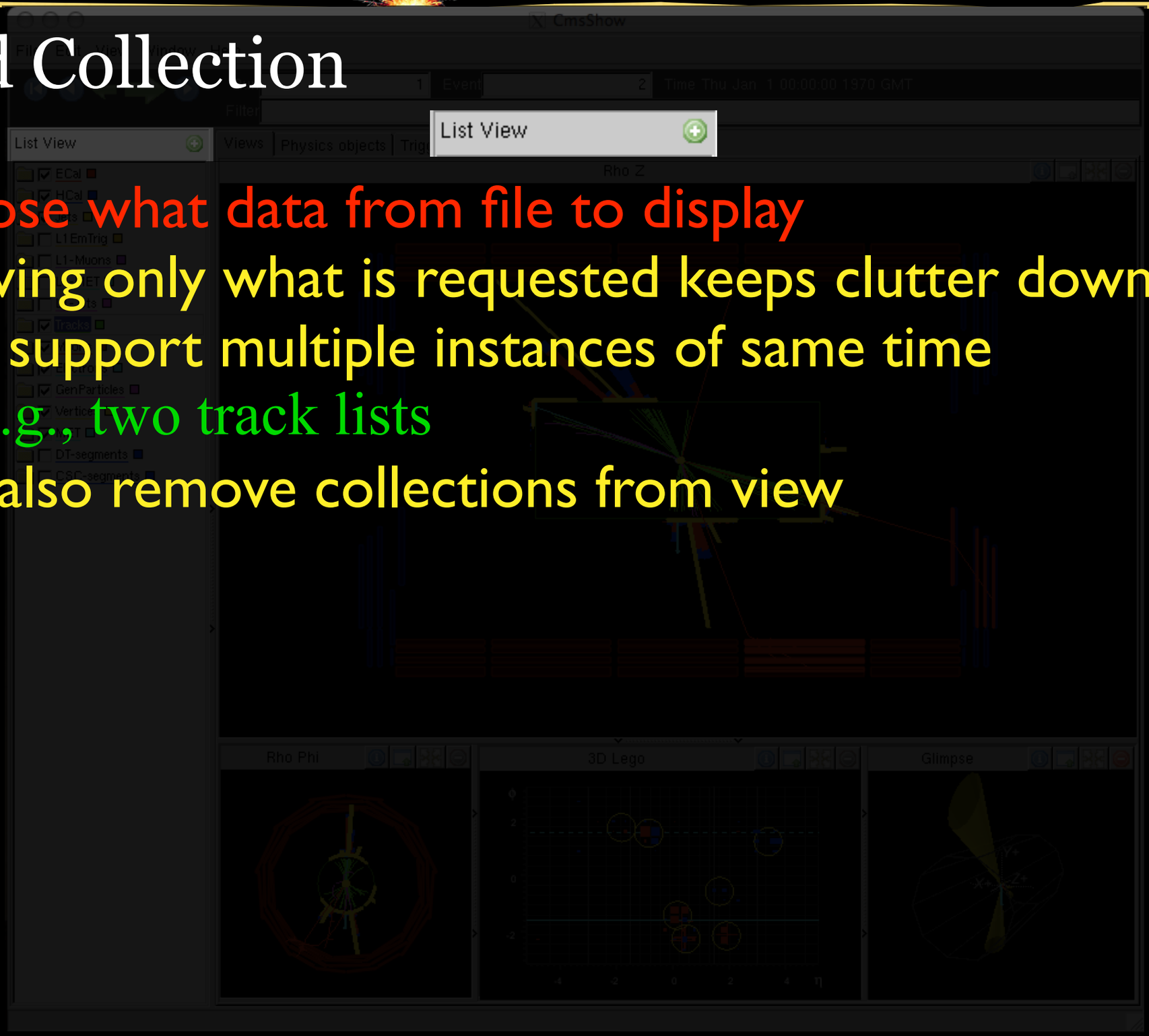
Add Collection

Choose what data from file to display



Interface

Add Collection



Choose what data from file to display

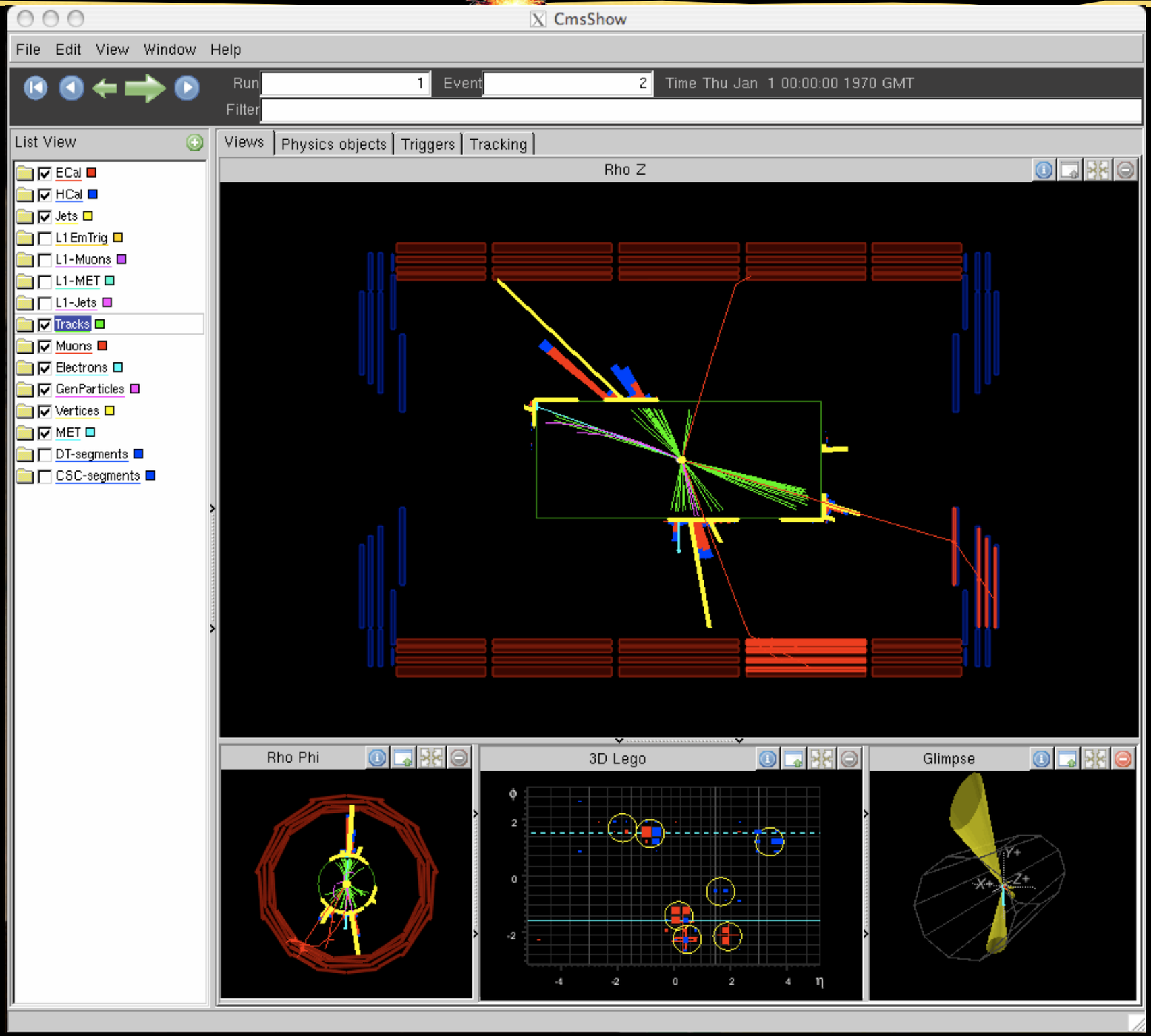
Showing only what is requested keeps clutter down

Also support multiple instances of same time

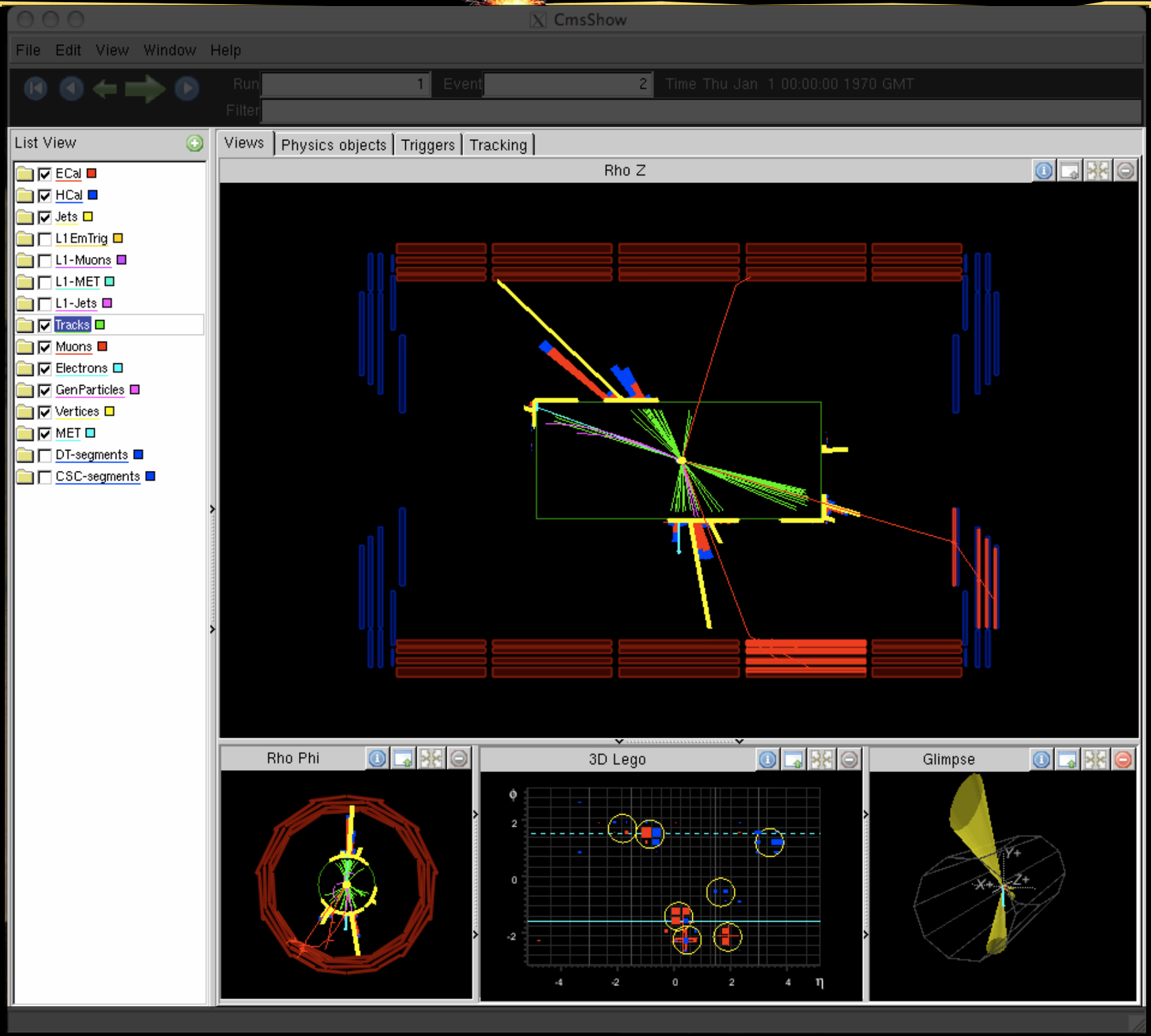
e.g., two track lists

Can also remove collections from view

Views

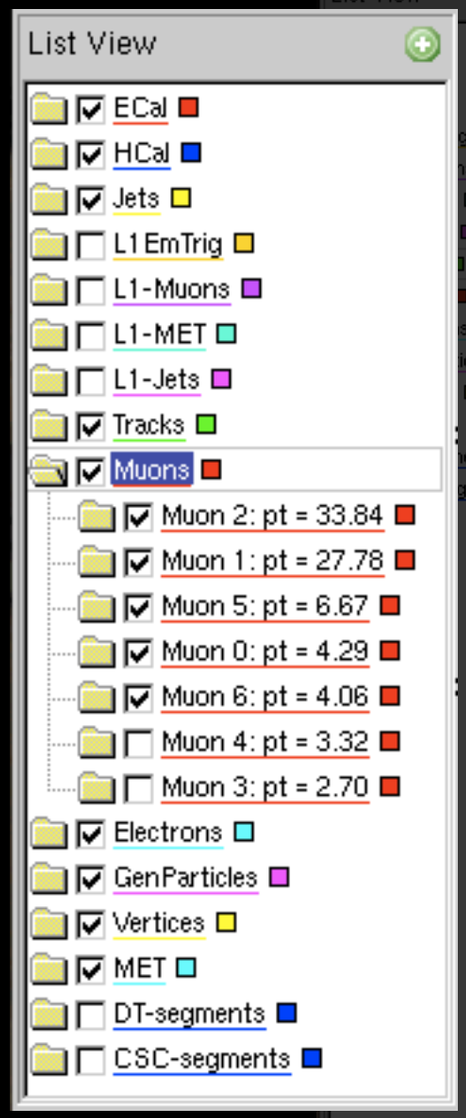

CmsShow
File Edit View Window Help
Run 1 Event 2 Time Thu Jan 1 00:00:00 1970 GMT
Filter
List View
ECal
HCal
Jets
L1EmTrig
L1-Muons
L1-MET
L1-Jets
Tracks
Muons
Electrons
GenParticles
Vertices
MET
DT-segments
CSC-segments
Views
Physics objects
Triggers
Tracking
Rho Z
Rho Phi
3D Lego
Glimpse

Views


CmsShow
File Edit View Window Help
Run 1 Event 2 Time Thu Jan 1 00:00:00 1970 GMT
Filter
List View
ECal
HCal
Jets
L1EmTrig
L1-Muons
L1-MET
L1-Jets
Tracks
Muons
Electrons
GenParticles
Vertices
MET
DT-segments
CSC-segments
Views
Physics objects
Triggers
Tracking
Rho Z
Rho Phi
3D Lego
Glimpse

Views

List View

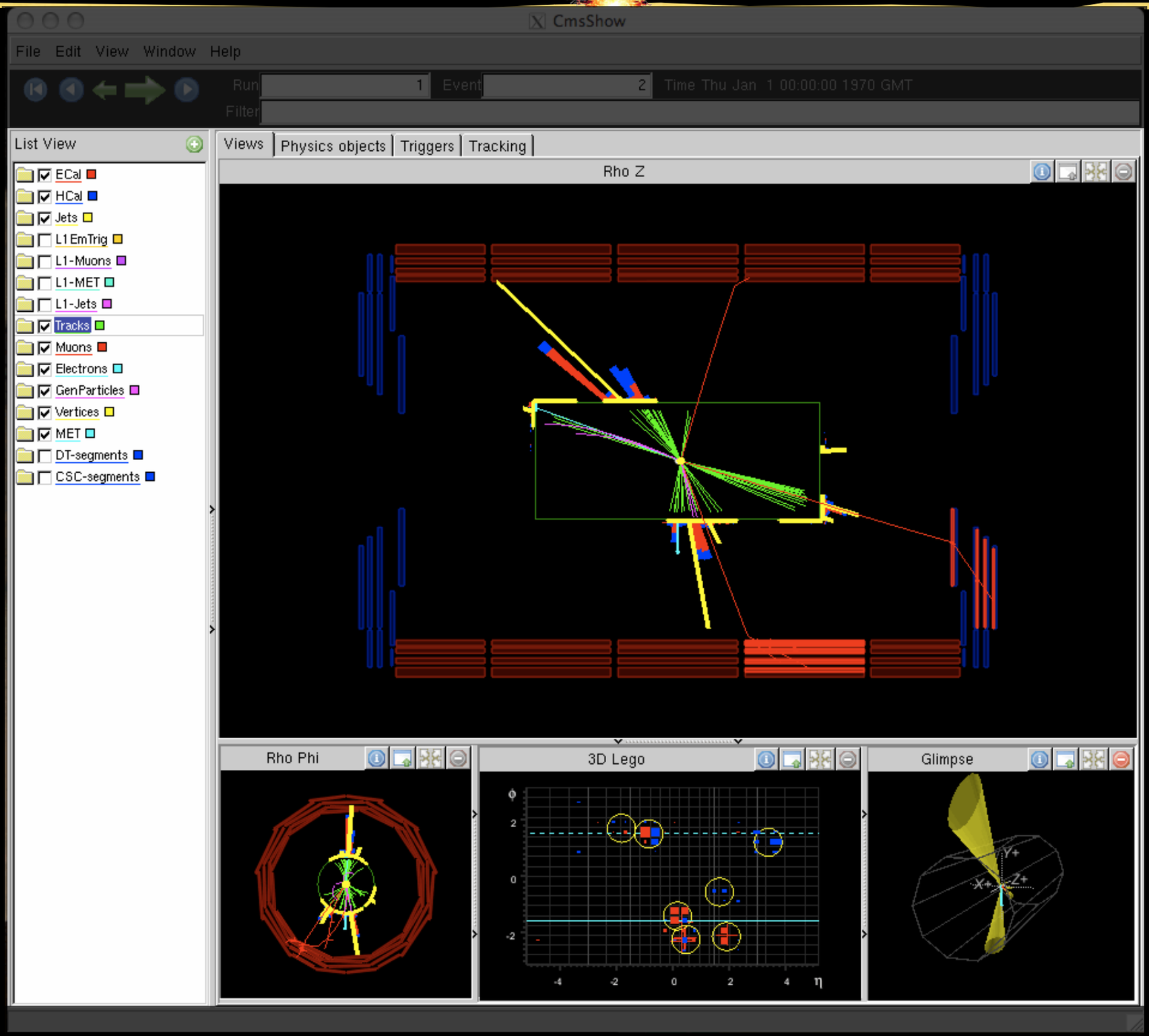


Shows all chosen collections and individual items

Works as a color key for all other views

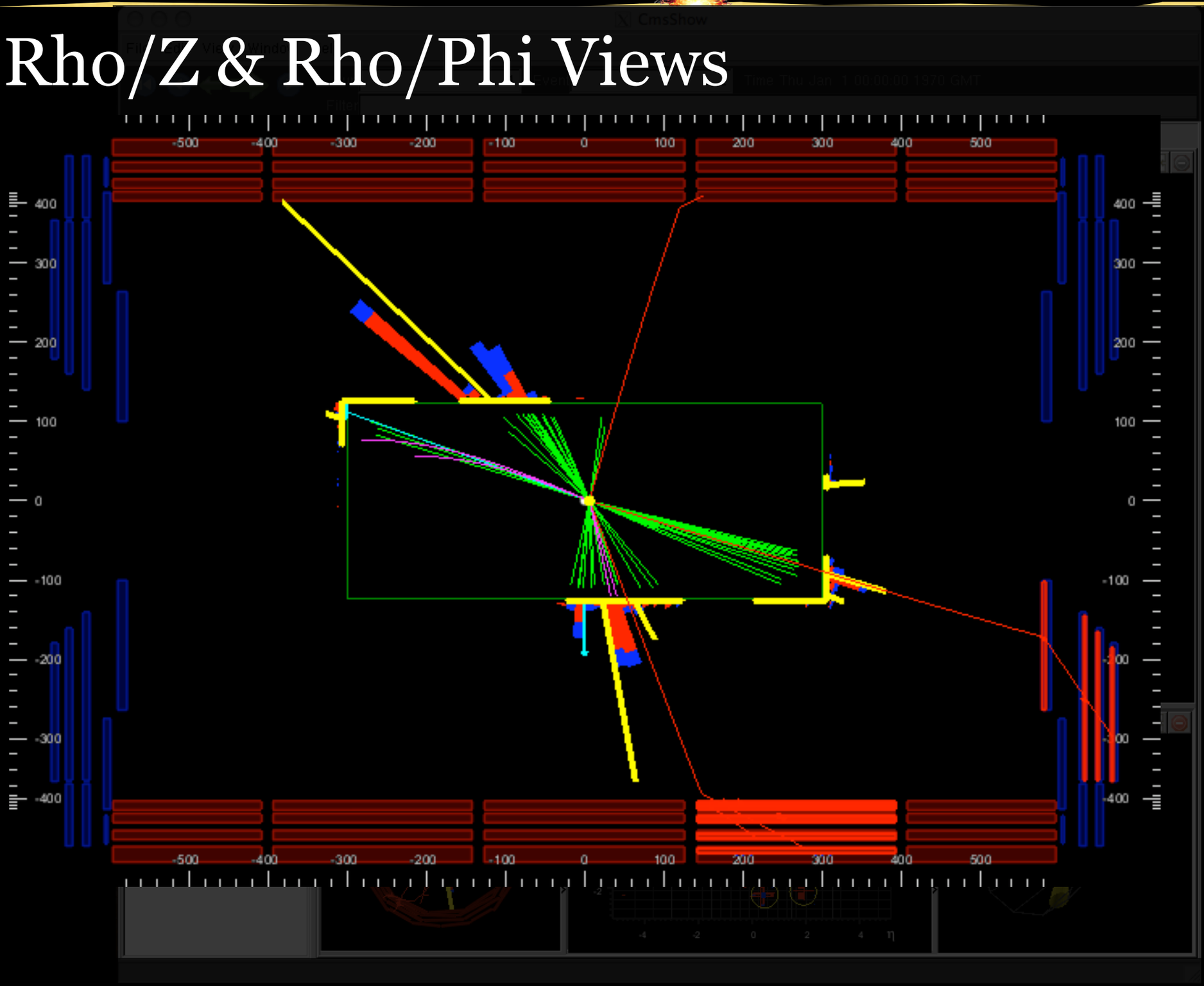
Provides easy way to temporarily hide collections

Views


CmsShow
File Edit View Window Help
Run 1 Event 2 Time Thu Jan 1 00:00:00 1970 GMT
Filter
List View
ECal
HCal
Jets
L1EmTrig
L1-Muons
L1-MET
L1-Jets
Tracks
Muons
Electrons
GenParticles
Vertices
MET
DT-segments
CSC-segments
Views
Physics objects
Triggers
Tracking
Rho Z
Rho Phi
3D Lego
Glimpse

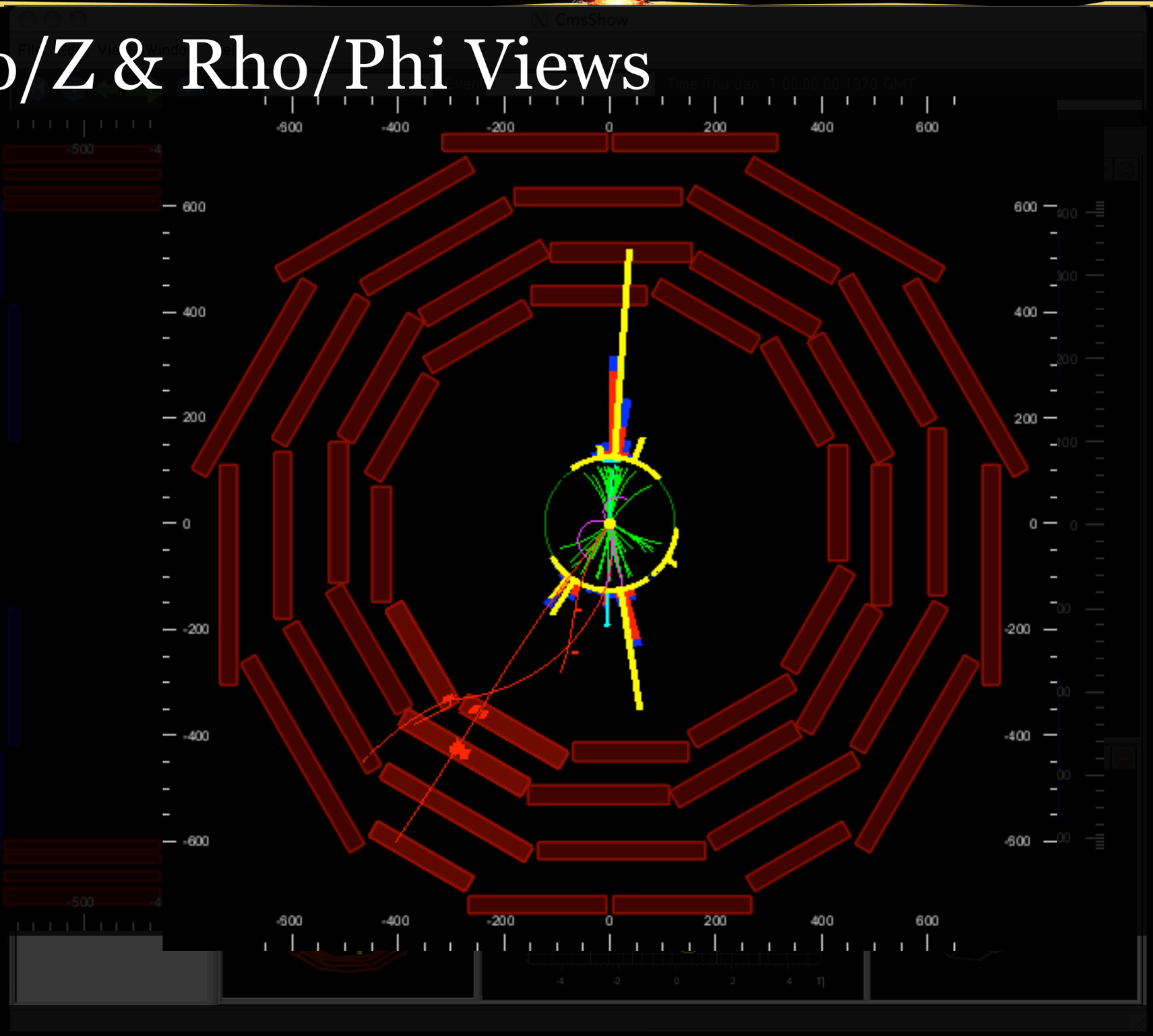
Views

Rho/Z & Rho/Phi Views



Views

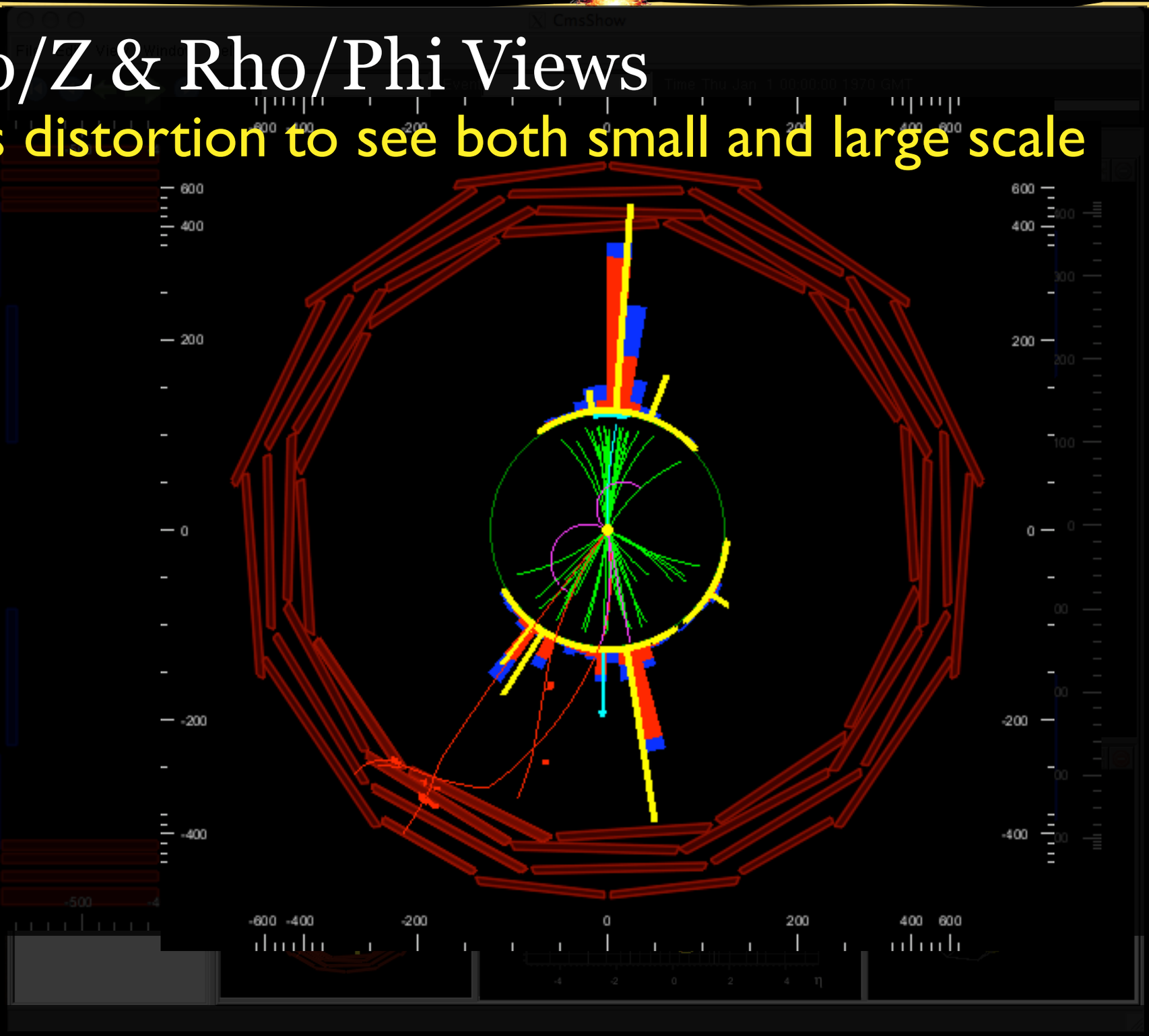
Rho/Z & Rho/Phi Views



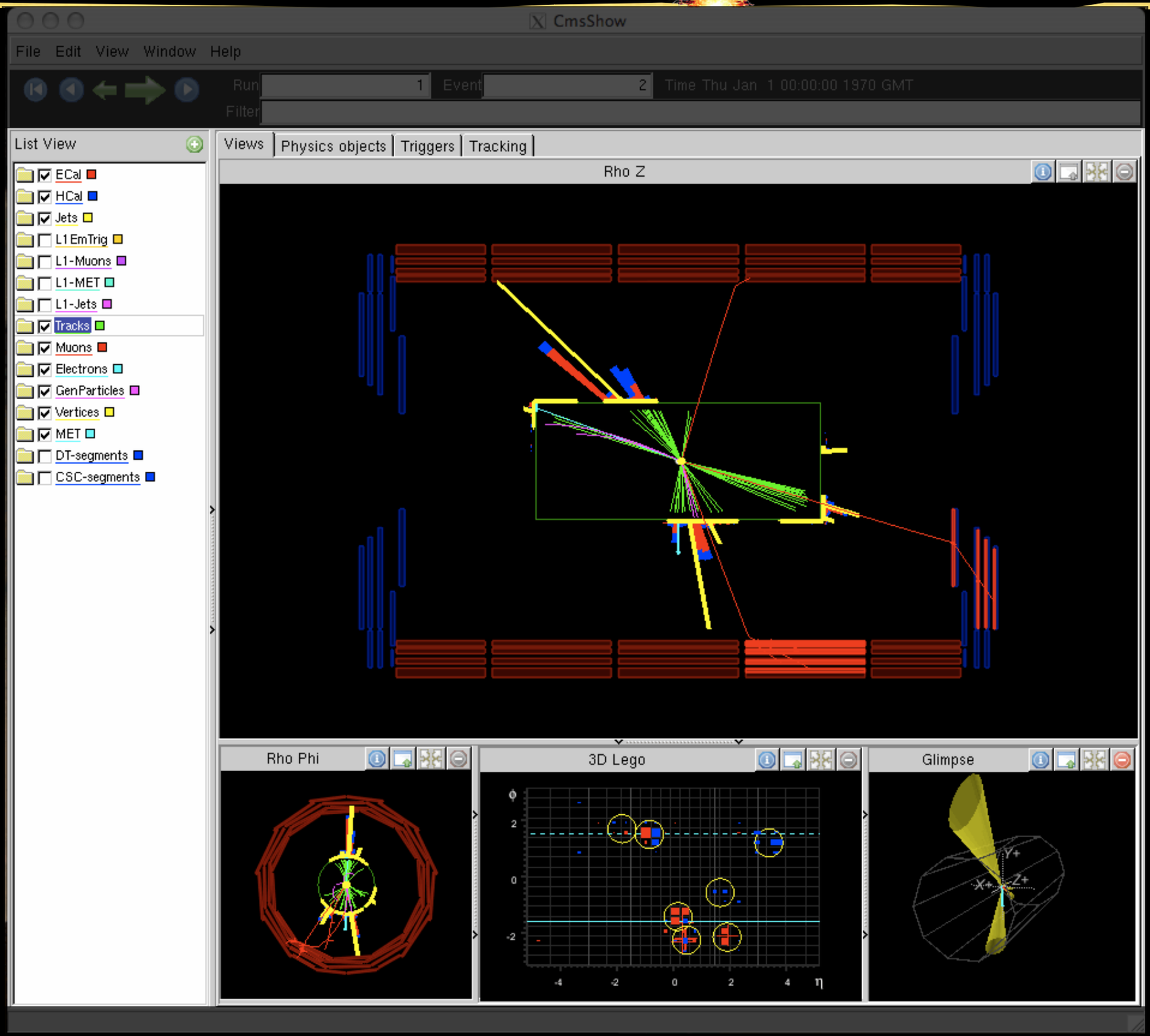
Views

Rho/Z & Rho/Phi Views

Uses distortion to see both small and large scale



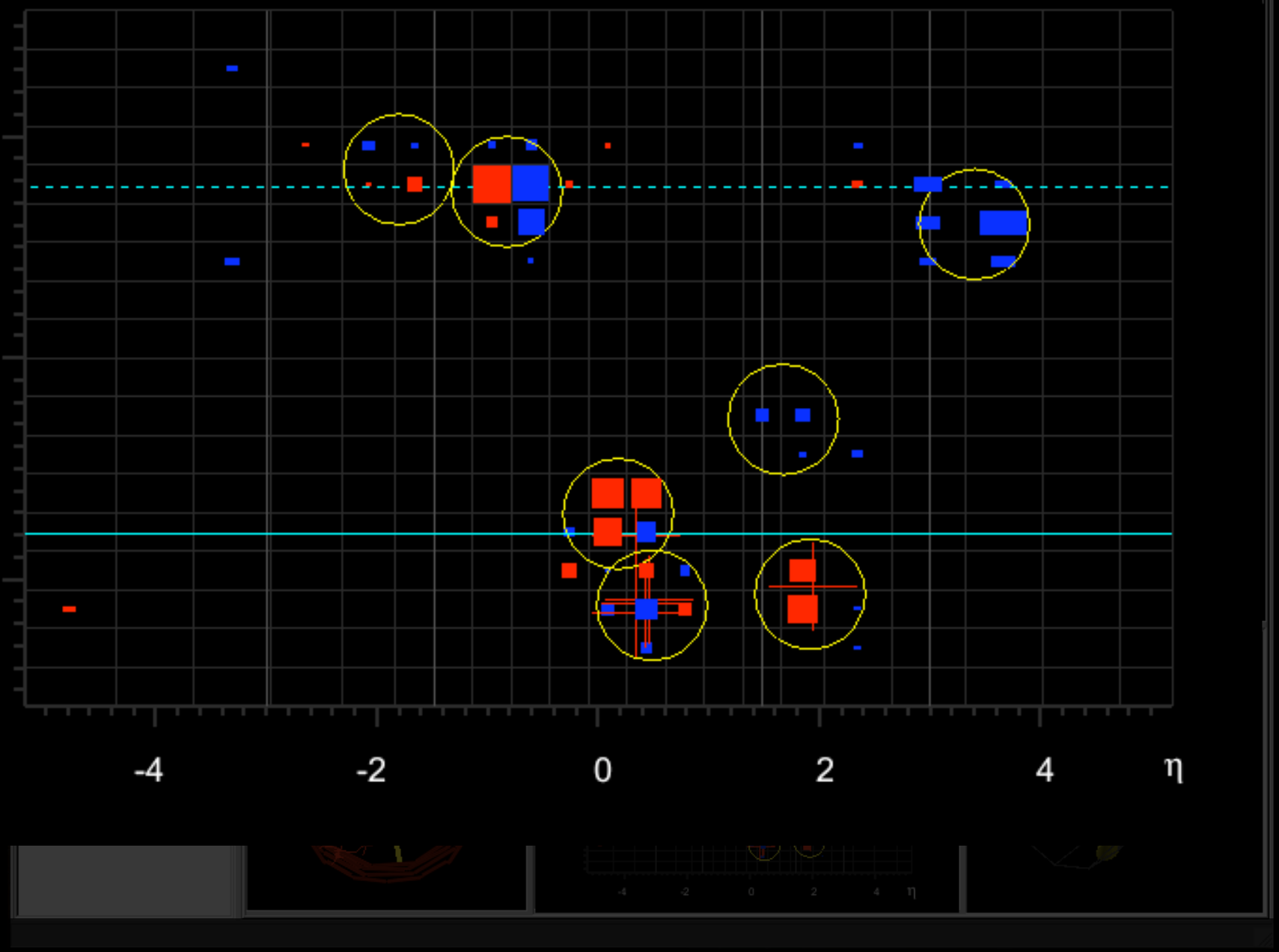
Views


CmsShow
File Edit View Window Help
Run 1 Event 2 Time Thu Jan 1 00:00:00 1970 GMT
Filter
List View
ECal
HCal
Jets
L1EmTrig
L1-Muons
L1-MET
L1-Jets
Tracks
Muons
Electrons
GenParticles
Vertices
MET
DT-segments
CSC-segments
Views
Physics objects
Triggers
Tracking
Rho Z
Rho Phi
3D Lego
Glimpse

Views

Lego View

From top shows 2D

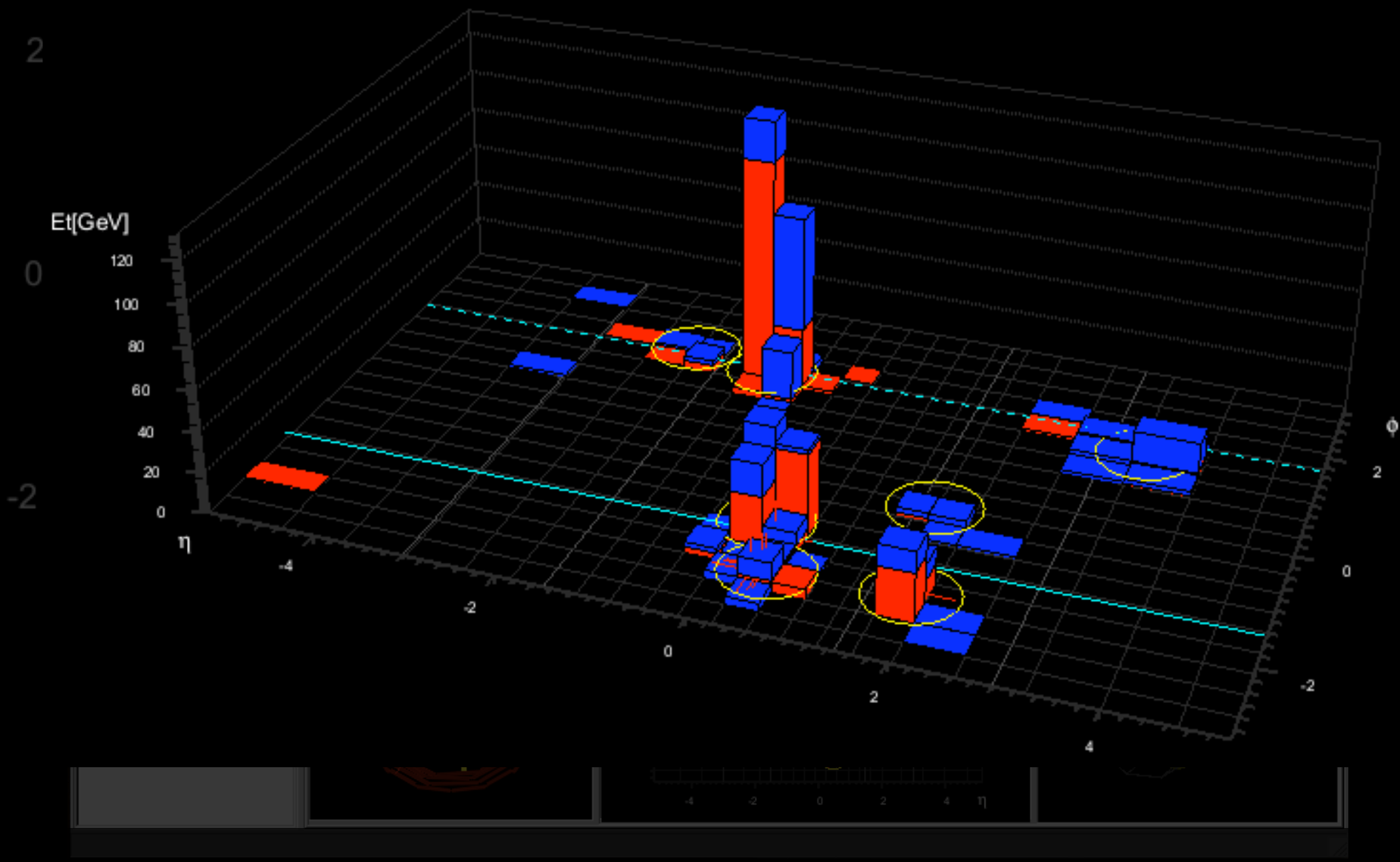


Views

Lego View

From top shows 2D

Rotation will show 3D



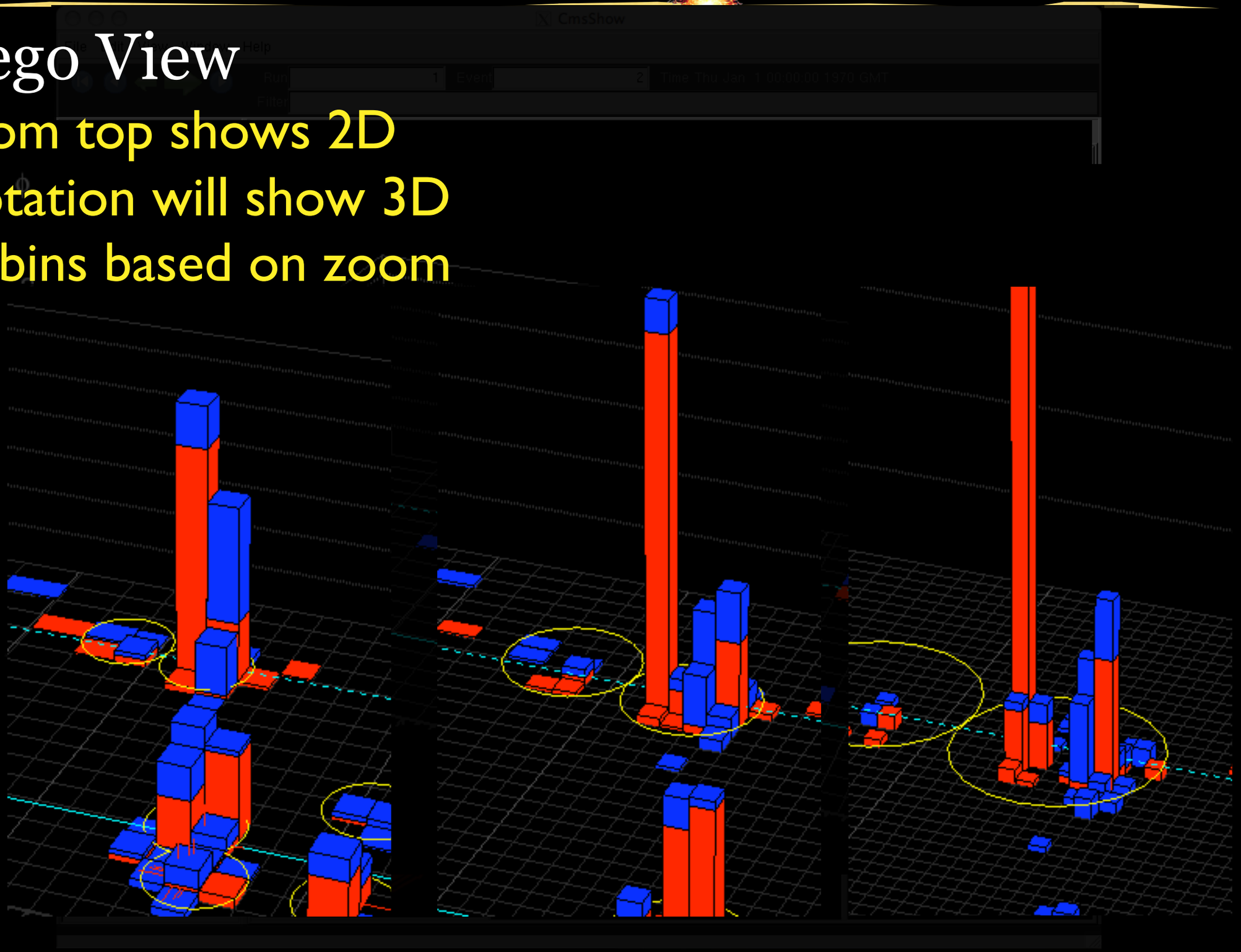
Views

Lego View

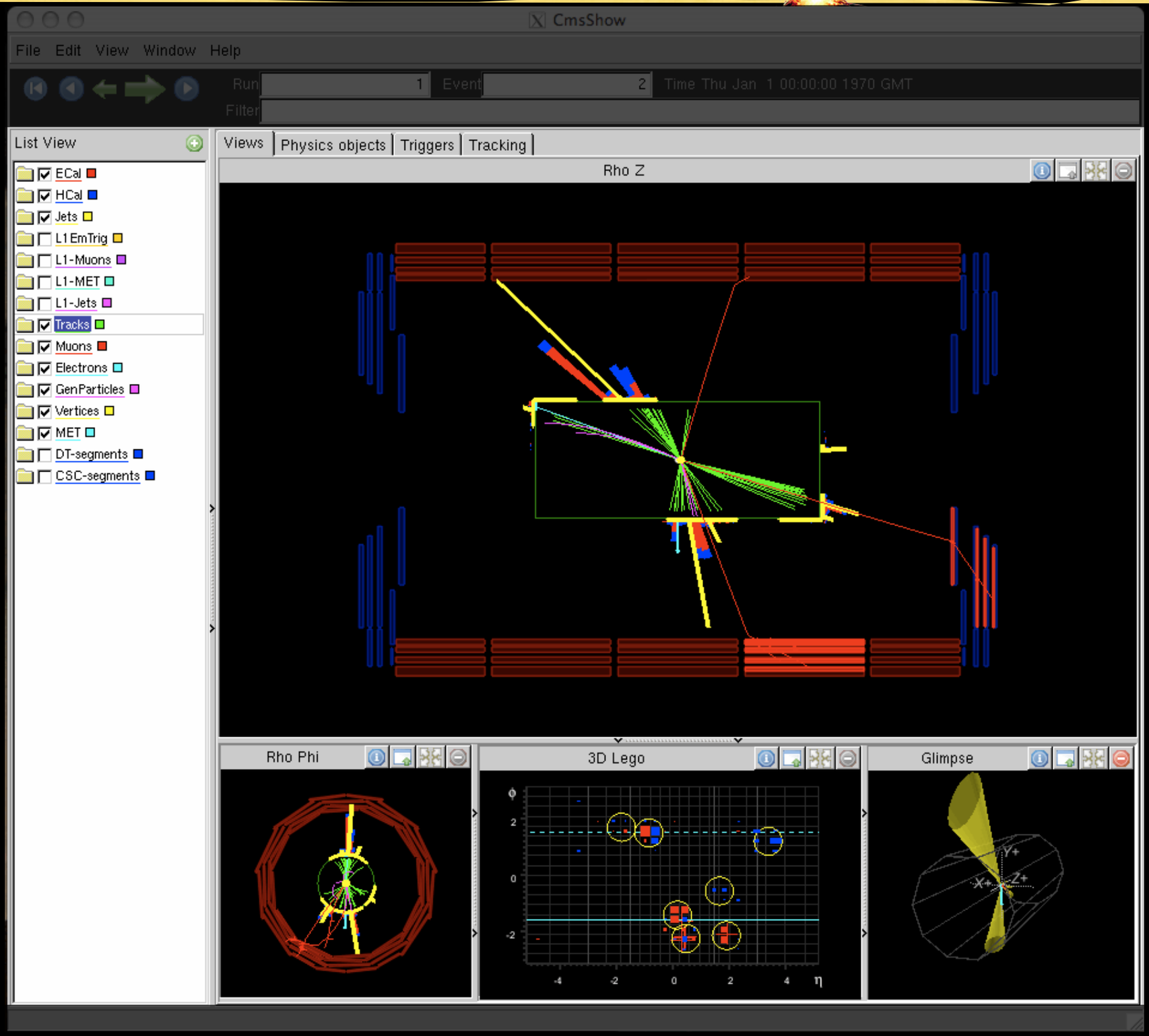
From top shows 2D

Rotation will show 3D

Rebins based on zoom



Views

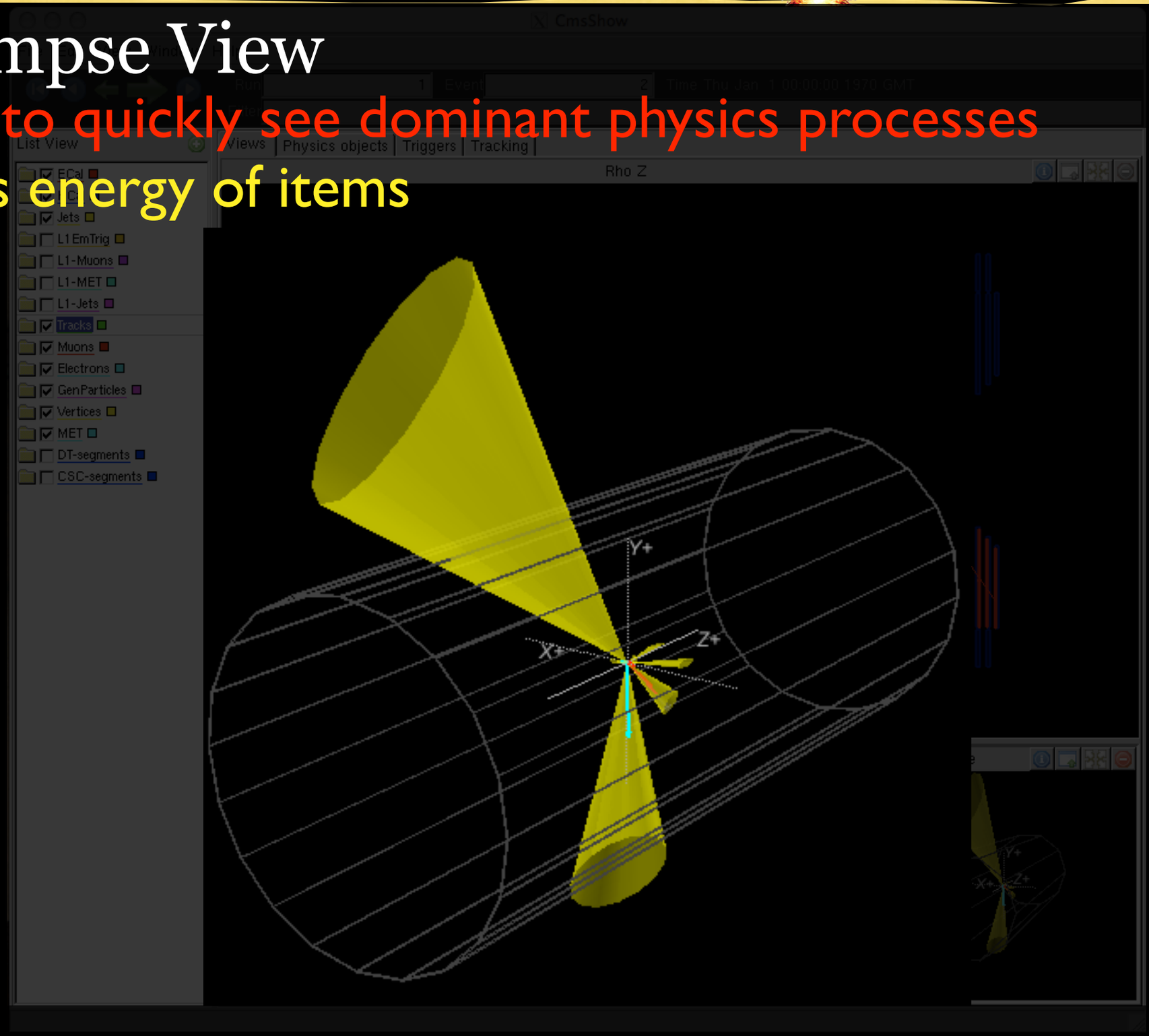

CmsShow
File Edit View Window Help
Run 1 Event 2 Time Thu Jan 1 00:00:00 1970 GMT
Filter
List View
ECal
HCal
Jets
L1EmTrig
L1-Muons
L1-MET
L1-Jets
Tracks
Muons
Electrons
GenParticles
Vertices
MET
DT-segments
CSC-segments
Views
Physics objects
Triggers
Tracking
Rho Z
Rho Phi
3D Lego
Glimpse

Views

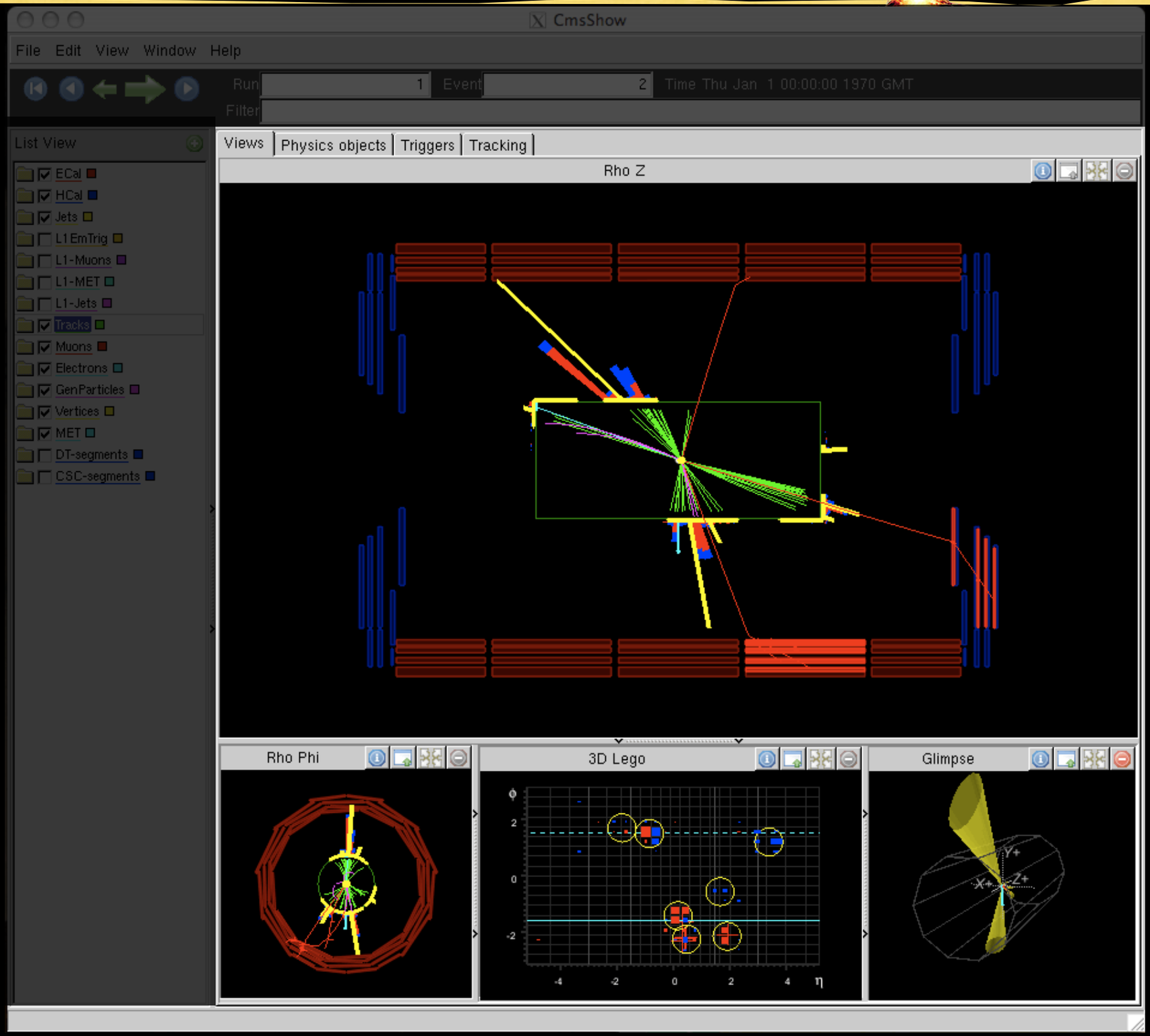
Glimpse View

Use to quickly see dominant physics processes

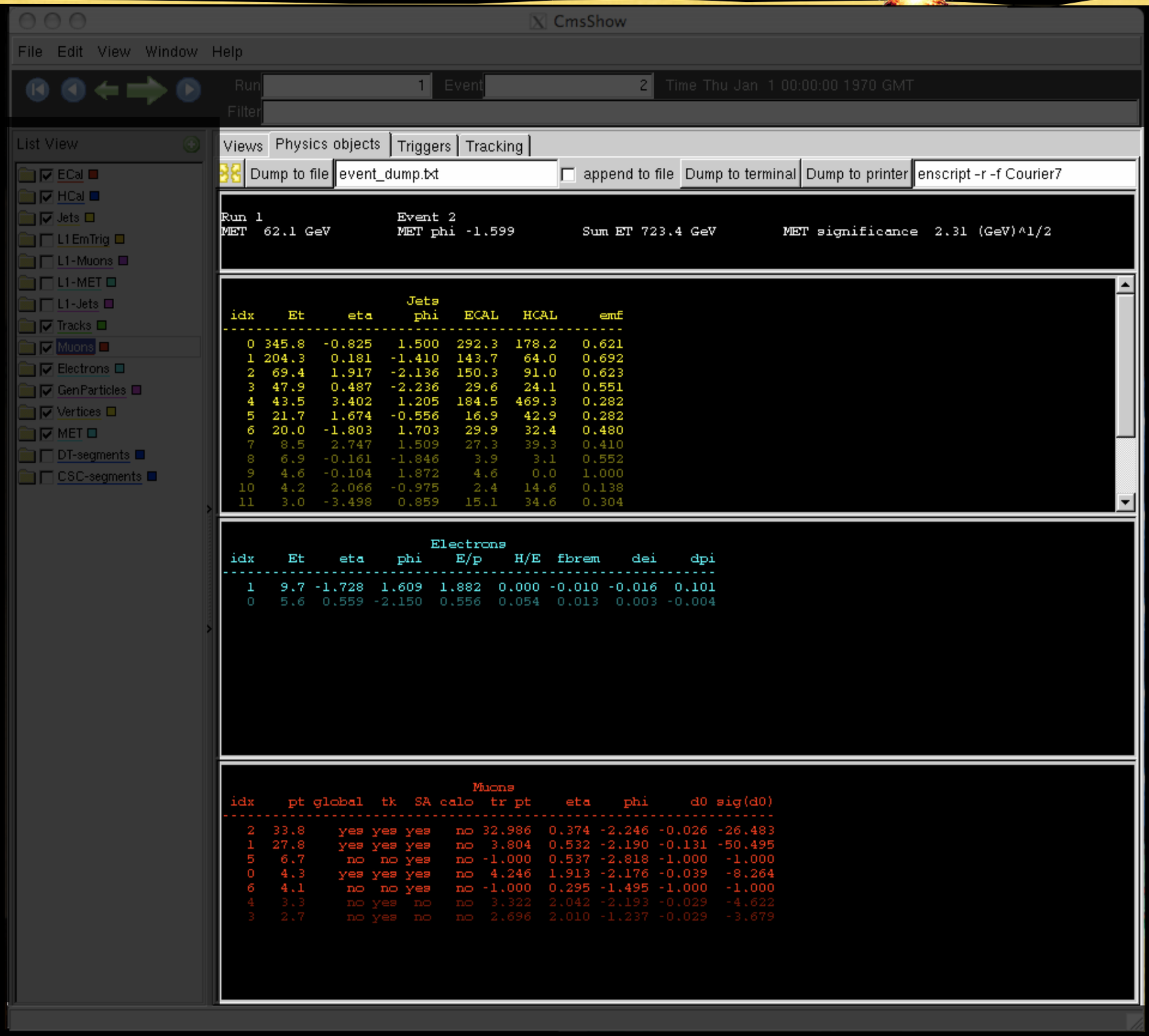
Plots energy of items



Views


CmsShow
File Edit View Window Help
Run 1 Event 2 Time Thu Jan 1 00:00:00 1970 GMT
Filter
List View
ECal
HCal
Jets
L1EmTrig
L1-Muons
L1-MET
L1-Jets
Tracks
Muons
Electrons
GenParticles
Vertices
MET
DT-segments
CSC-segments
Views
Physics objects
Triggers
Tracking
Rho Z
Rho Phi
3D Lego
Glimpse

Views

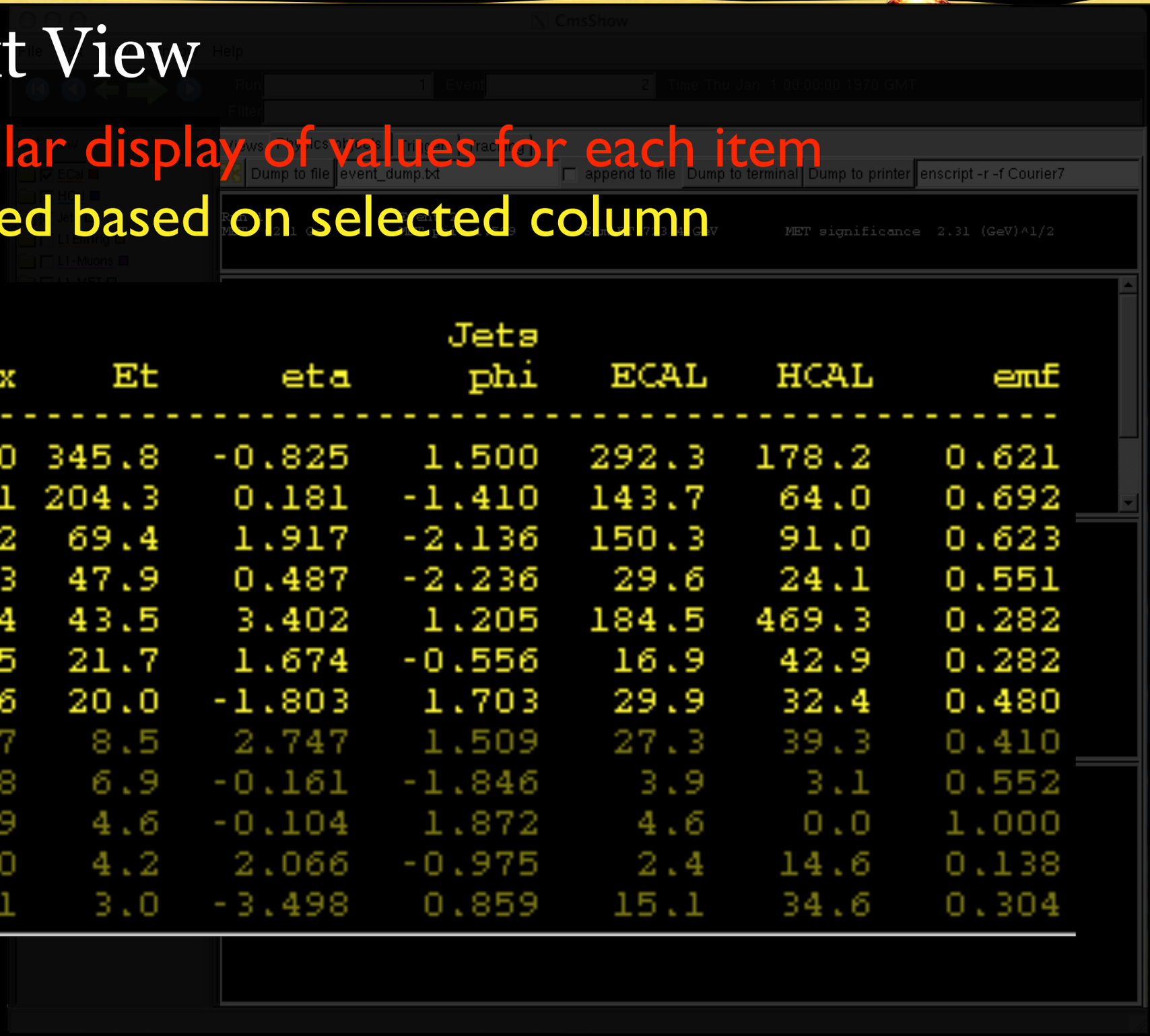

CmsShow
File Edit View Window Help
Run 1 Event 2 Time Thu Jan 1 00:00:00 1970 GMT
Filter
List View
ECal
HCal
Jets
L1 EmTrig
L1-Muons
L1-MET
L1-Jets
Tracks
Muons
Electrons
GenParticles
Vertices
MET
DT-segments
CSC-segments
Views
Physics objects
Triggers
Tracking
Dump to file
event_dump.txt
append to file
Dump to terminal
Dump to printer
enscript -r -f Courier7
Run 1 Event 2
MET 62.1 GeV MET phi -1.599 Sum ET 723.4 GeV MET significance 2.31 (GeV)^1/2
Jets
idx Et eta phi ECAL HCAL emf
0 345.8 -0.825 1.500 292.3 178.2 0.621
1 204.3 0.181 -1.410 143.7 64.0 0.692
2 69.4 1.917 -2.136 150.3 91.0 0.623
3 47.9 0.487 -2.236 29.6 24.1 0.551
4 43.5 3.402 1.205 184.5 469.3 0.282
5 21.7 1.674 -0.556 16.9 42.9 0.282
6 20.0 -1.803 1.703 29.9 32.4 0.480
7 8.5 2.747 1.509 27.3 39.3 0.410
8 6.9 -0.161 -1.846 3.9 3.1 0.552
9 4.6 -0.104 1.872 4.6 0.0 1.000
10 4.2 2.066 -0.975 2.4 14.6 0.138
11 3.0 -3.498 0.859 15.1 34.6 0.304
Electrons
idx Et eta phi E/p H/E fbrem dei dpi
1 9.7 -1.728 1.609 1.882 0.000 -0.010 -0.016 0.101
0 5.6 0.559 -2.150 0.556 0.054 0.013 0.003 -0.004
Muons
idx pt global tk SA calo tr pt eta phi d0 sig(d0)
2 33.8 yes yes yes no 32.986 0.374 -2.246 -0.026 -26.483
1 27.8 yes yes yes no 3.804 0.532 -2.190 -0.131 -50.495
5 6.7 no no yes no -1.000 0.537 -2.818 -1.000 -1.000
0 4.3 yes yes yes no 4.246 1.913 -2.176 -0.039 -8.264
6 4.1 no no yes no -1.000 0.295 -1.495 -1.000 -1.000
4 3.3 no yes no no 3.322 2.042 -2.193 -0.029 -4.622
3 2.7 no yes no no 2.696 2.010 -1.237 -0.029 -3.679

Views

Text View

Tabular display of values for each item

Sorted based on selected column



idx	Et	Jeta eta	phi	ECAL	HCAL	emf
0	345.8	-0.825	1.500	292.3	178.2	0.621
1	204.3	0.181	-1.410	143.7	64.0	0.692
2	69.4	1.917	-2.136	150.3	91.0	0.623
3	47.9	0.487	-2.236	29.6	24.1	0.551
4	43.5	3.402	1.205	184.5	469.3	0.282
5	21.7	1.674	-0.556	16.9	42.9	0.282
6	20.0	-1.803	1.703	29.9	32.4	0.480
7	8.5	2.747	1.509	27.3	39.3	0.410
8	6.9	-0.161	-1.846	3.9	3.1	0.552
9	4.6	-0.104	1.872	4.6	0.0	1.000
10	4.2	2.066	-0.975	2.4	14.6	0.138
11	3.0	-3.498	0.859	15.1	34.6	0.304

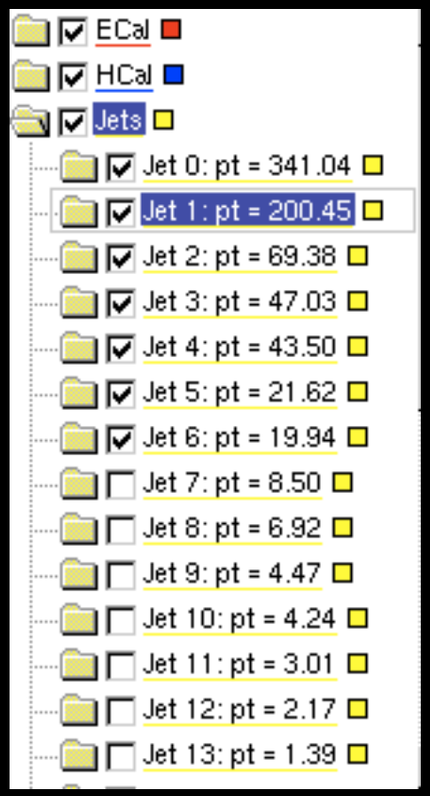
View Integration

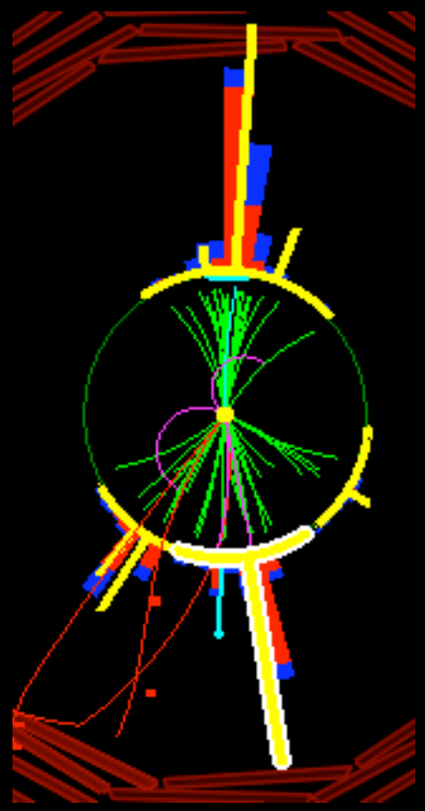
All Views

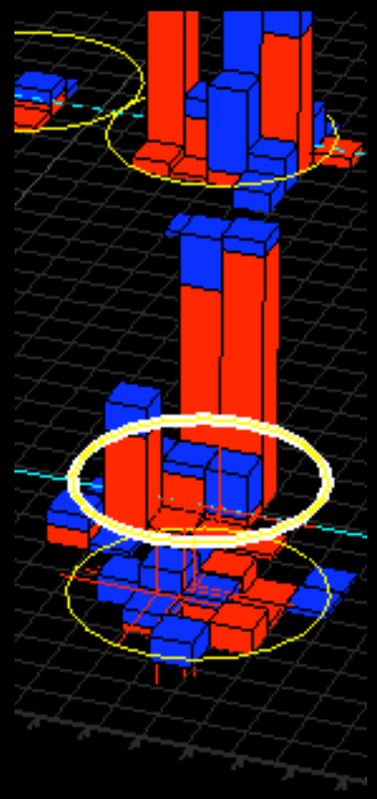
Use same object colors

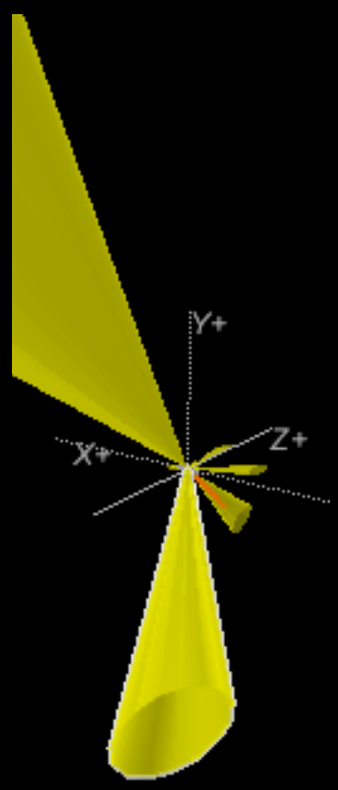
Allow individual object selections

Highlight selected objects









Jets

idx	Et	eta	phi	ECAL
0	345.8	-0.825	1.500	292.3
1	204.3	0.181	-1.410	143.7
2	69.4	1.917	-2.136	150.3
3	47.9	0.487	-2.236	29.6
4	43.5	3.402	1.205	184.5
5	21.7	1.674	-0.556	16.9
6	20.0	-1.803	1.703	29.9
7	8.5	2.747	1.509	27.3
8	6.9	-0.161	-1.846	3.9
9	4.6	-0.104	1.872	4.6
10	4.2	2.066	-0.975	2.4
11	3.0	-3.498	0.859	15.1
12	2.2	-4.379	-2.261	86.6
13	1.4	-2.934	2.007	11.3
14	1.3	-0.652	0.829	0.0
15	1.1	2.416	2.007	0.0

Filtering

Event Filtering

Uses ROOT's TEventList

E.g., Show events with at least one 10 GeV muon

```
$Muons.pt() > 10
```

Item Filtering

Uses custom parser

Uses ROOT Reflex dictionaries

More than 50 times faster than CINT

Provide tab completion of member functions

Filtering

Event Filtering

Uses ROOT's TEventList

E.g., Show events with at least one 10 GeV muon

```
$Muons.pt() > 10
```

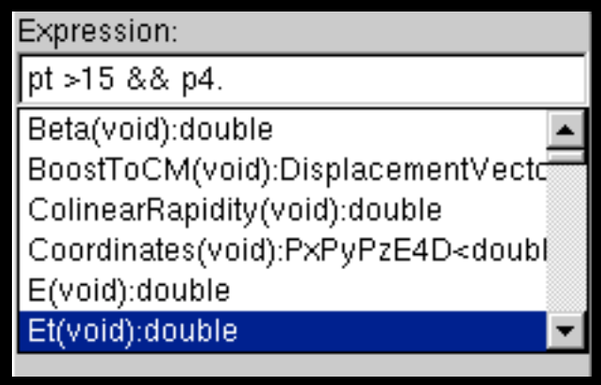
Item Filtering

Uses custom parser

Uses ROOT Reflex dictionaries

More than 50 times faster than CINT

Provide tab completion of member functions



Conclusion

User Response

Very positive

Like being able to install on laptops using tar

- Presently support Linux and Mac OS X

Steady request for new objects to display

Future Plans

Simplify how data are converted to graphics objects

Pick graphics object based on data object base classes

Improvements to user interface

Complete Windows port