Operational Monitoring of ATLAS Trigger and Automatic MC Tuning for Minimum Bias Events at LHC.

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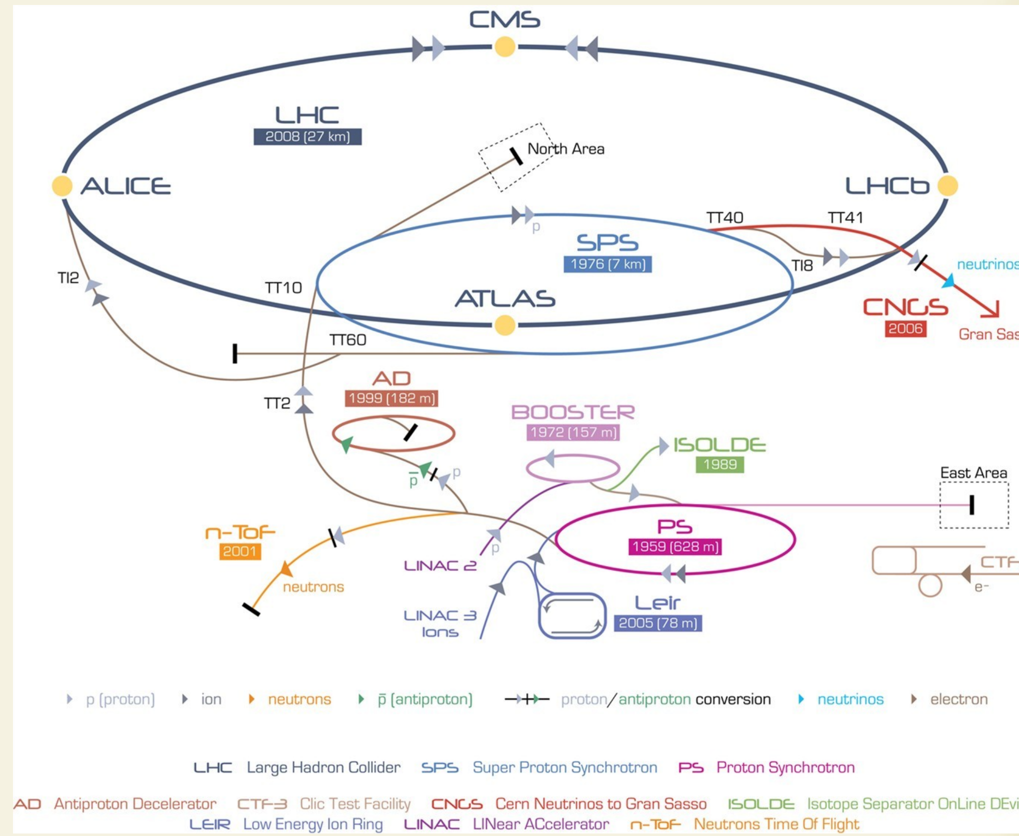
Outline

- Introduction to LHC, ATLAS and ATLAS Trigger
- Trigger Monitoring
    - Operational Monitoring Display
- Minimum Bias Events
- Monte-Carlo Tuning for Minimum Bias
    - Genetic Algorithms in MC Tuning
- Results
- LHC predictions
- Conclusions

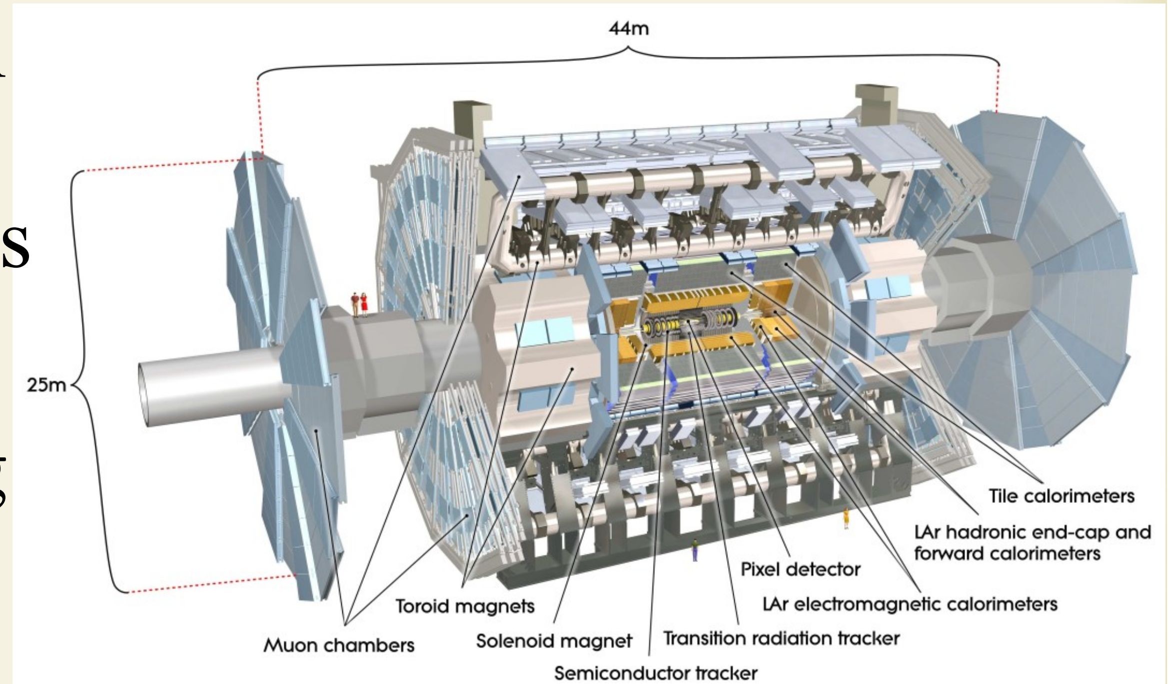
Large Hadron Collider

- LHC is the *pp* collider at CERN accelerator complex.
- It is designed to produce 14TeV center of mass collisions with a luminosity of $10^{34} cm^{-2} s^{-1}$.
- It contains 2 general purpose and 3 specialized detectors.



ATLAS Detector

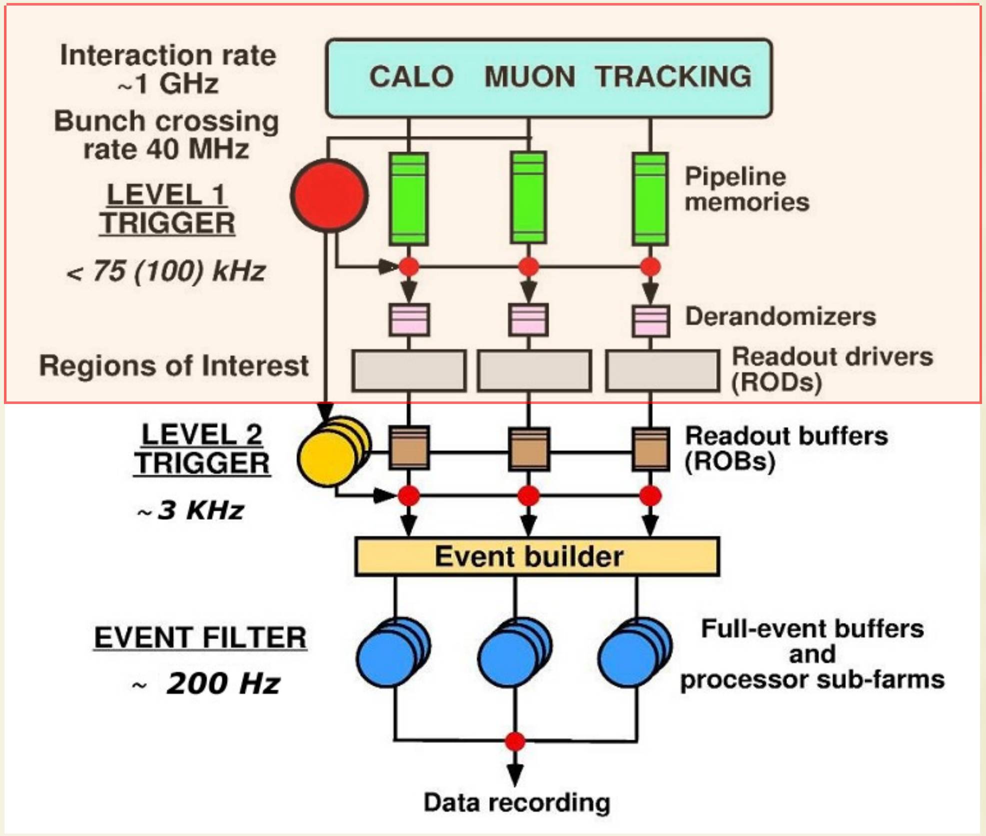
- ATLAS is a general purpose detector with a diverse physics program ranging from Standard model and Higgs physics to SUSY and BSM.
- It offers precise tracking and calorimetry information with fast triggering support.



- At 14 TeV and full luminosity LHC will provide pp bunch crossings at 40MHz.
- Only very few of these crossings will result in interesting events.
- At each bunch crossing about 18~20 soft interactions called minimum bias collisions are expected.
- These events must be filtered while interesting events are stored for studying.

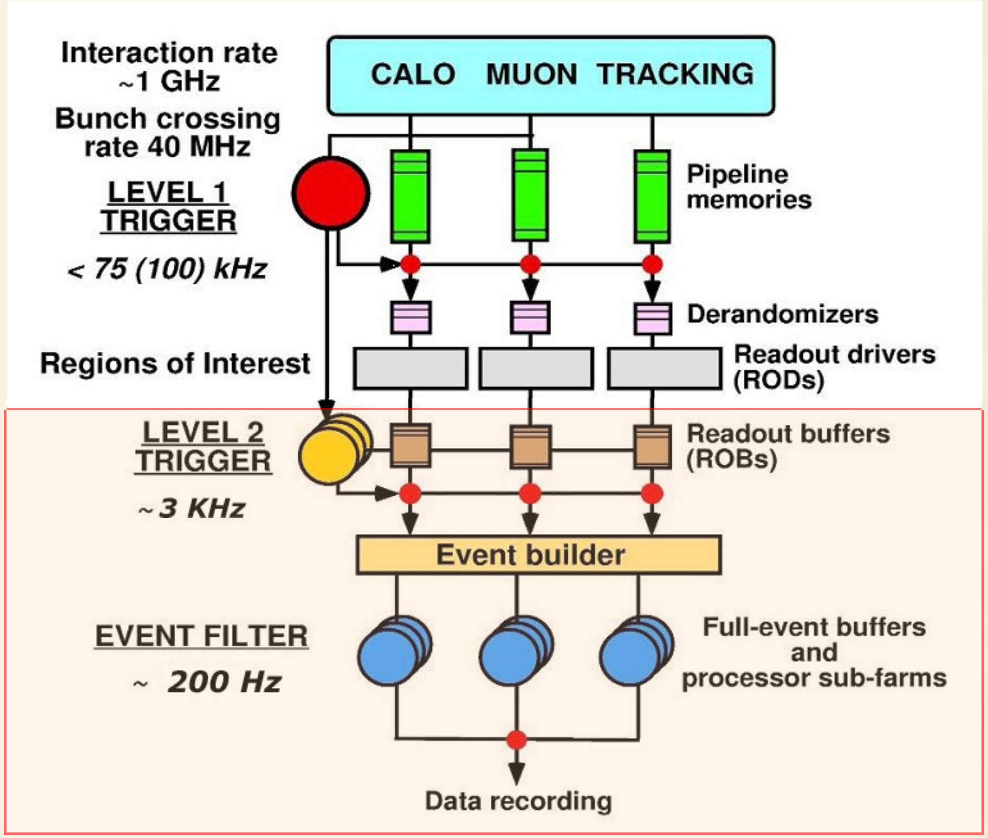
ATLAS Trigger

- Filtering and event selection is done at three levels
- Level 1 trigger is implemented in hardware.
- Reduces interaction rate to ~75kHz

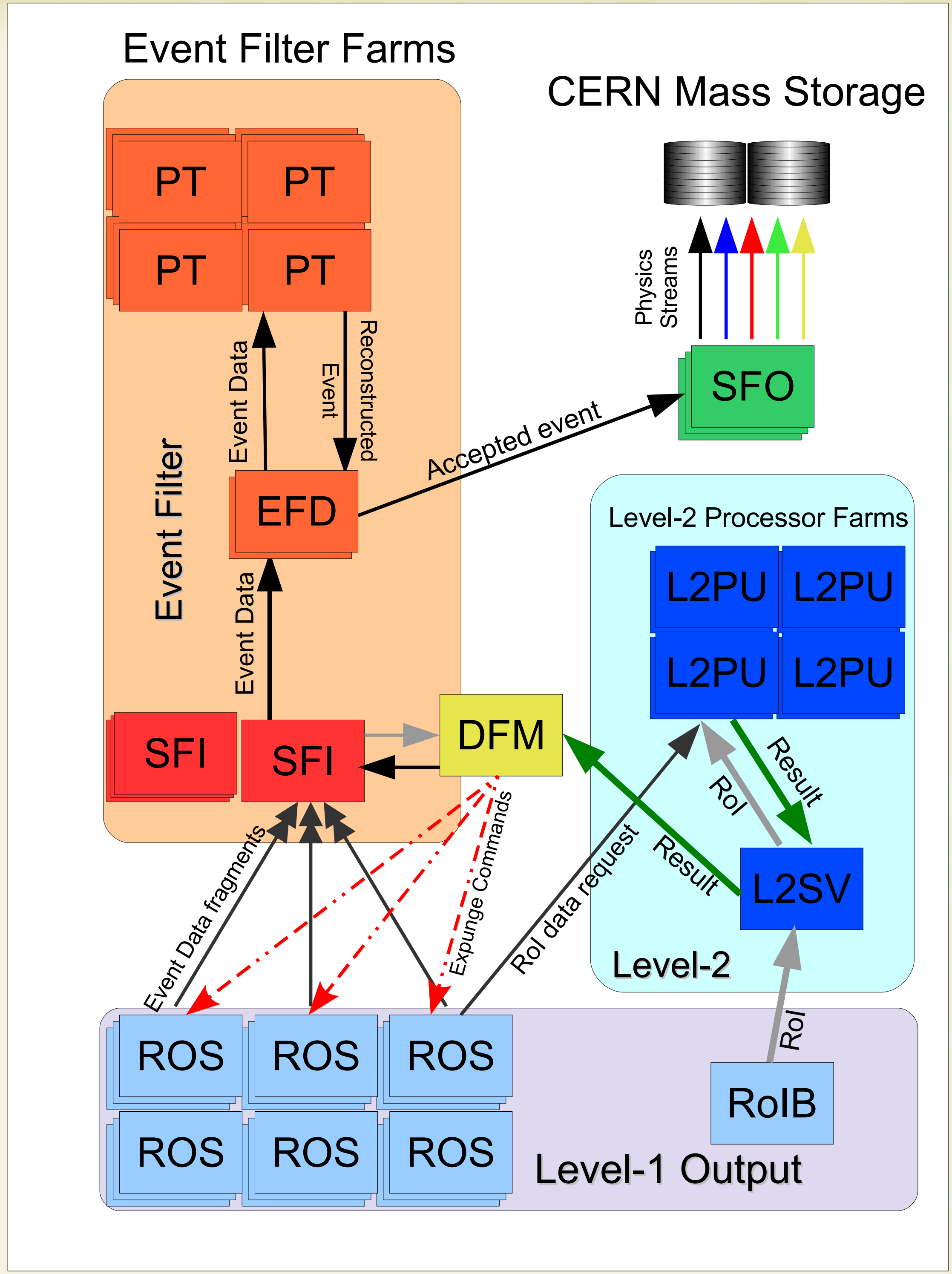


ATLAS Trigger

- Level 2 and Event Filter are implemented in software running on commodity PCs.
- Level 2 reduces event rate to ~3kHz, working on partial event information.
- Event Filter does final event selection, reducing event rate to ~200 Hz



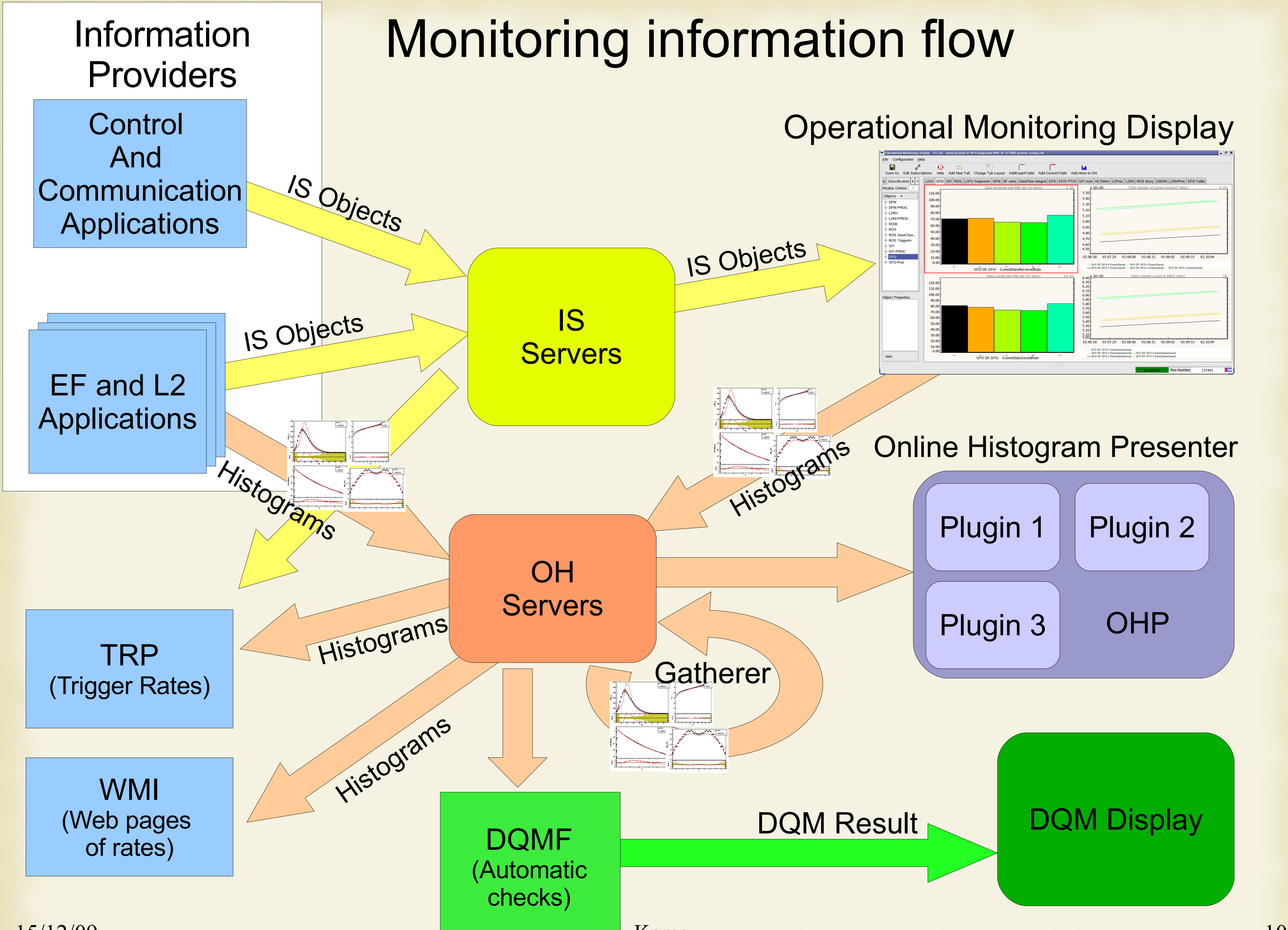
- Both levels contain many applications running in parallel.
- Events move through trigger PC farms at different detail levels.
- ~1500 multi-core PCs, running ~10000 applications.
- Final size ~3000 PCs running ~25000 applications.
- We need to make sure that every thing is working as expected



Trigger Monitoring

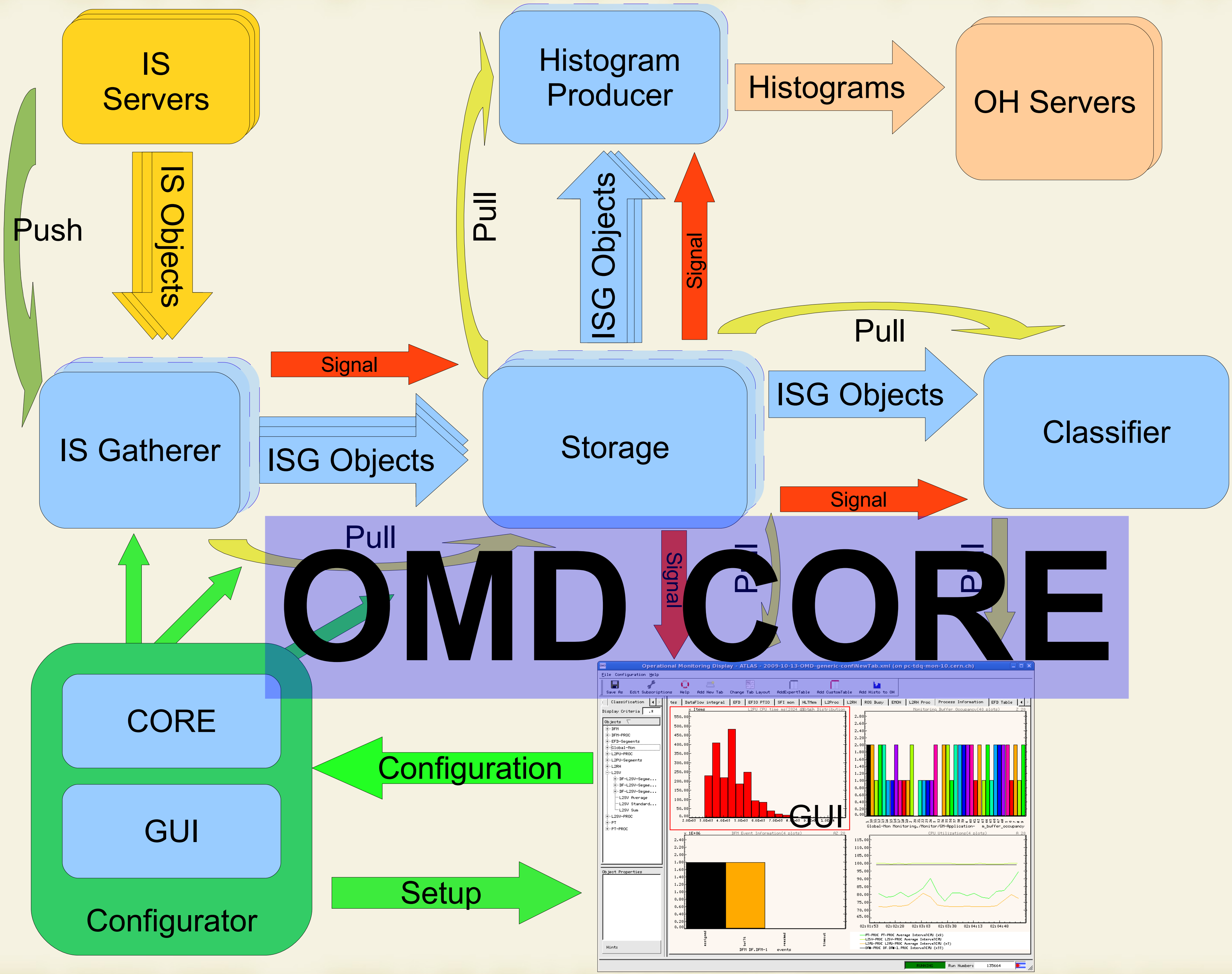
- Complicated structure requires constant monitoring in order to verify that trigger is filtering common events while keeping interesting ones
- Each application publishes information about its status to Information Service(IS) Servers either as data structures (IS Objects) or histograms containing trigger rates or physics distributions.
- Most of the applications publish several different information types processing them is a challenge itself.
- Several tools provide means for monitoring and presenting different aspects of the trigger systems in compact yet representative way.

Monitoring information flow



Operational Monitoring Display

- It is tool for displaying information on IS servers in (quasi)real-time in various detail levels.
- Its configuration is done in real-time through drag-and-drop approach.
- It is composed of two parts ***Core*** and ***GUI***.
- Core retrieves IS Objects, calculates statistics, classifies and converts them to histograms. It generate alerts when configured criteria are met.
- GUI displays the information in the form of time-series, bar charts, distributions or tables.


IS Servers
IS Objects
Push
Pull
Histogram Producer
Histograms
OH Servers
ISG Objects
Signal
Pull
Signal
IS Gatherer
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Classifier
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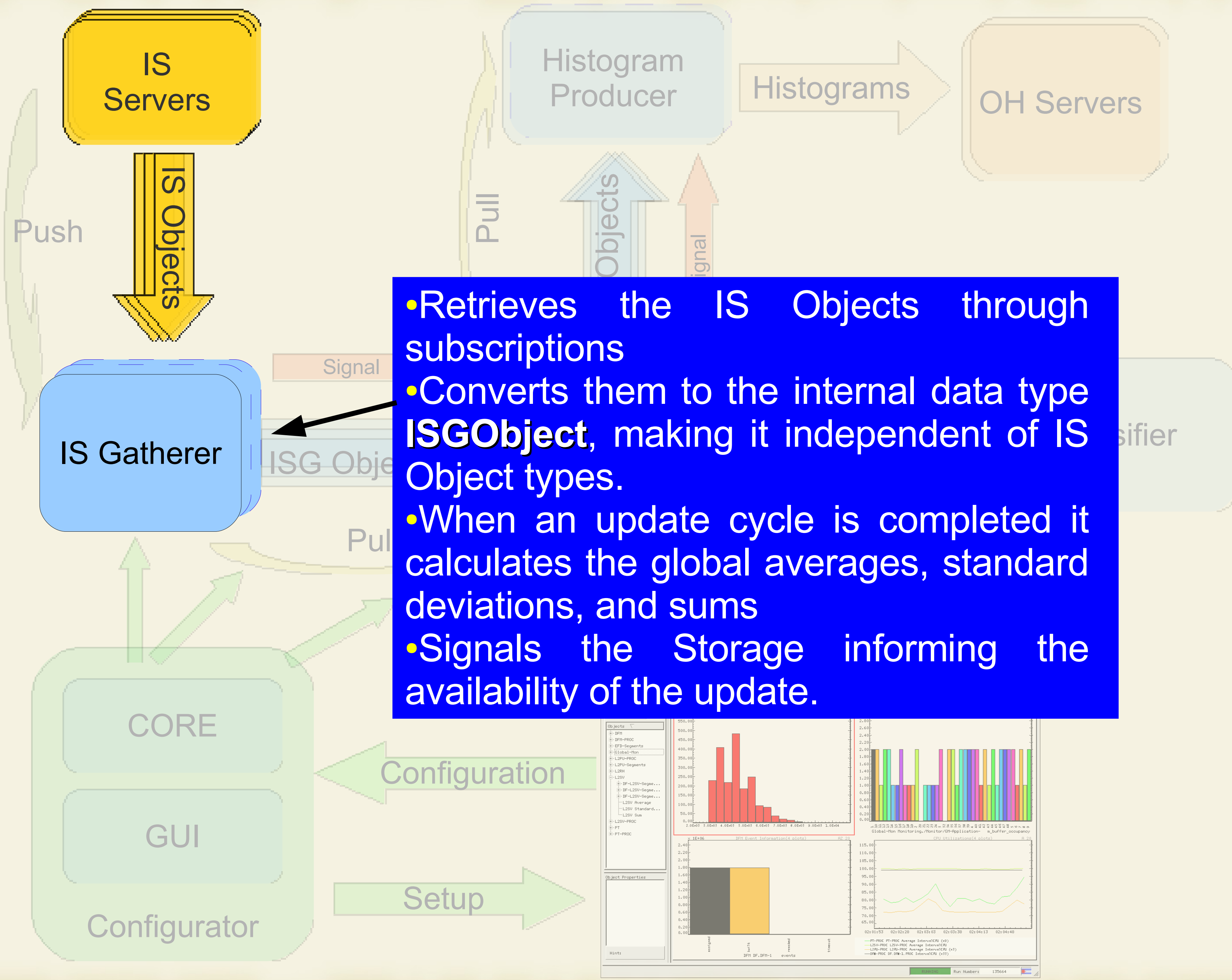
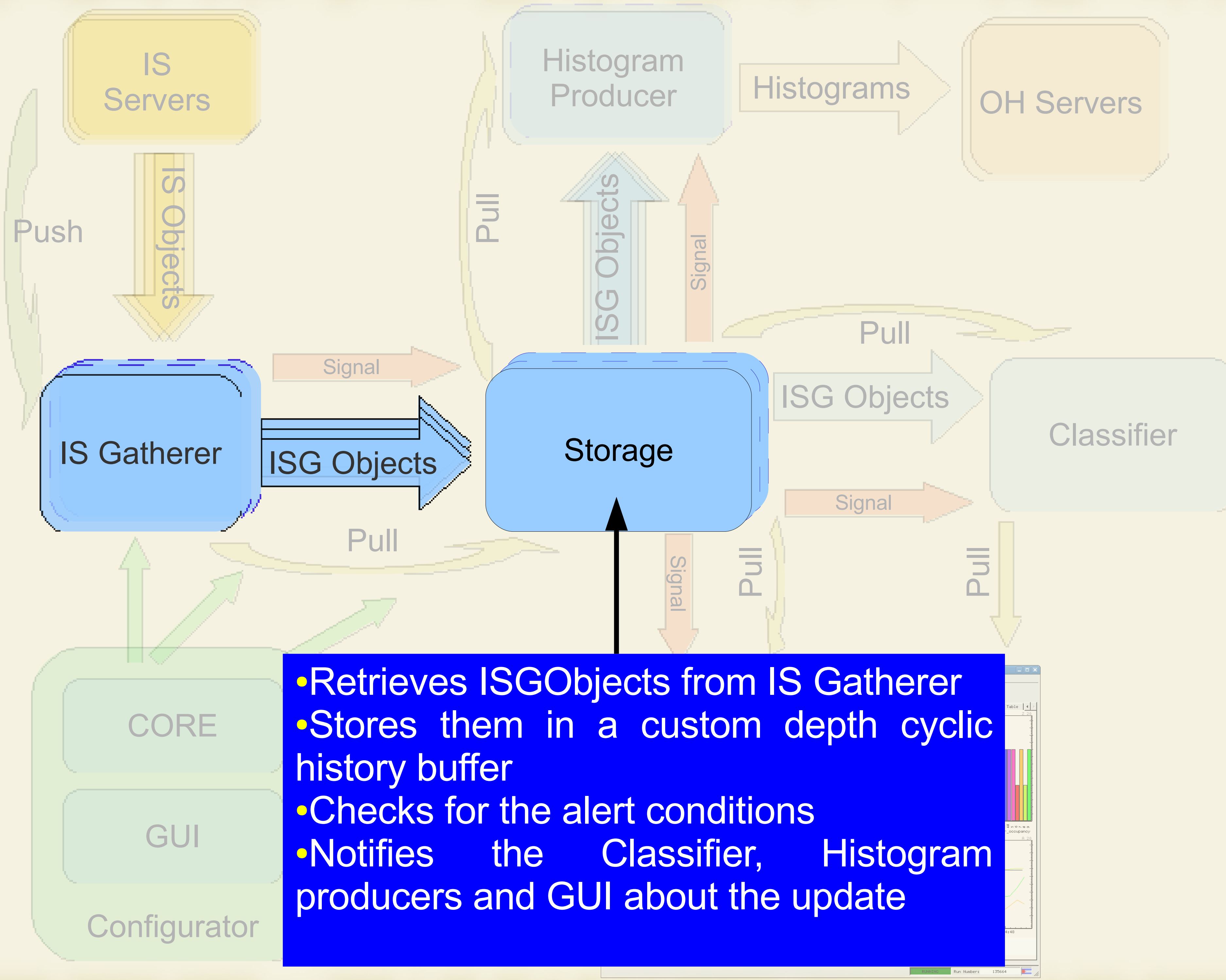
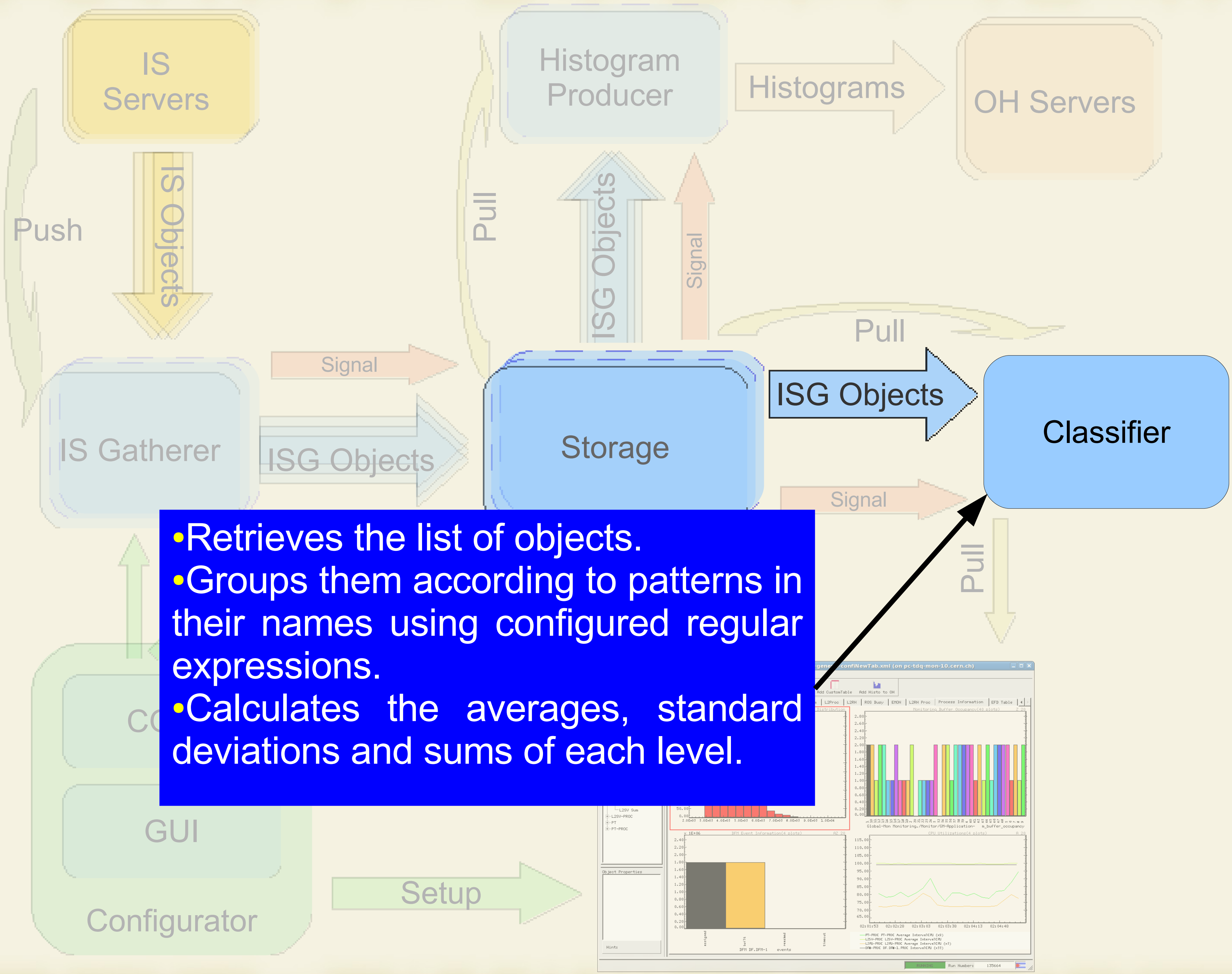
CORE
GUI
Configurator
Configuration
Setup
GUI



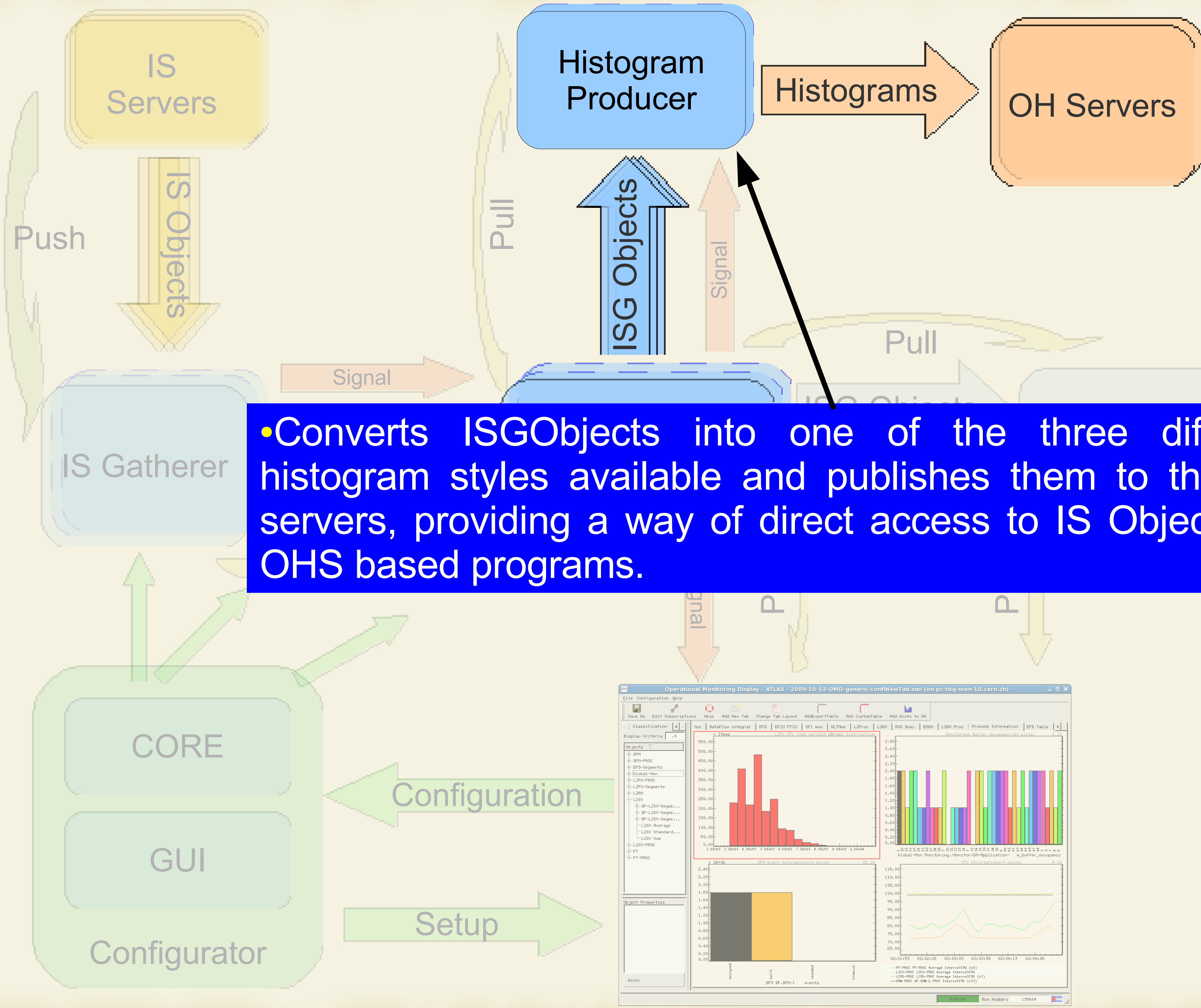
- Retrieves the IS Objects through subscriptions
- Converts them to the internal data type **ISGObject**, making it independent of IS Object types.
- When an update cycle is completed it calculates the global averages, standard deviations, and sums
- Signals the Storage informing the availability of the update.



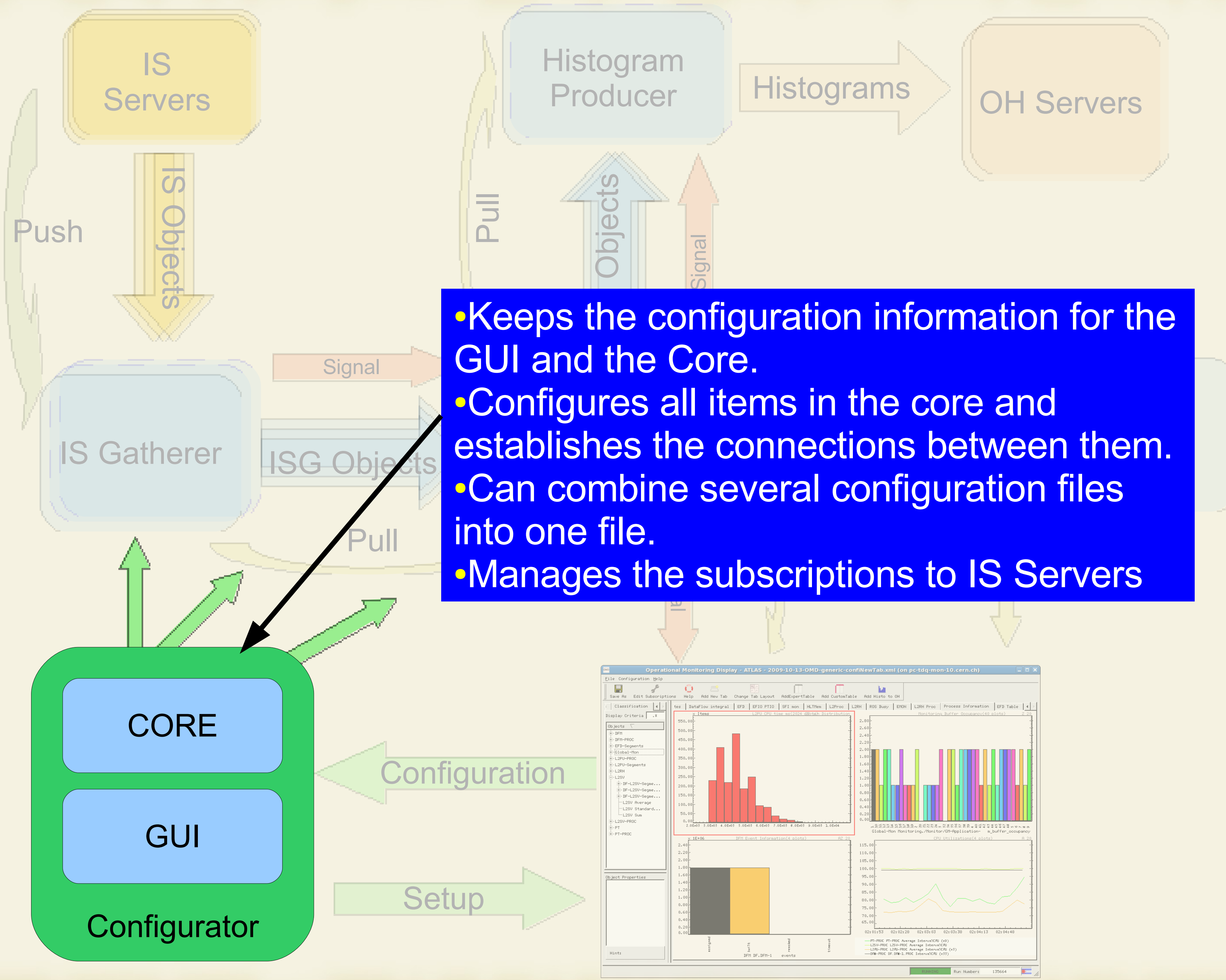
- Retrieves ISGObjects from IS Gatherer
- Stores them in a custom depth cyclic history buffer
- Checks for the alert conditions
- Notifies the Classifier, Histogram producers and GUI about the update



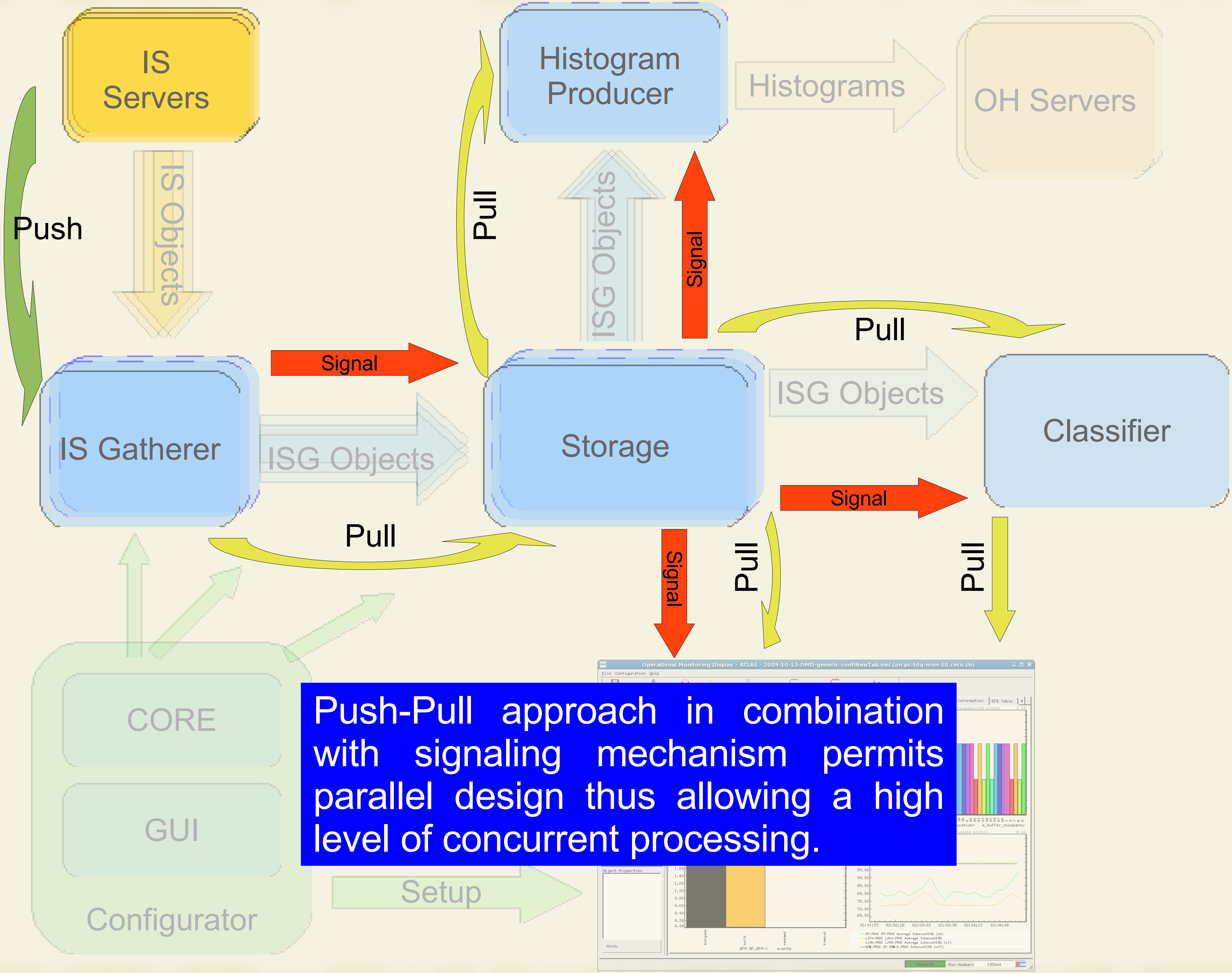
- Retrieves the list of objects.
- Groups them according to patterns in their names using configured regular expressions.
- Calculates the averages, standard deviations and sums of each level.



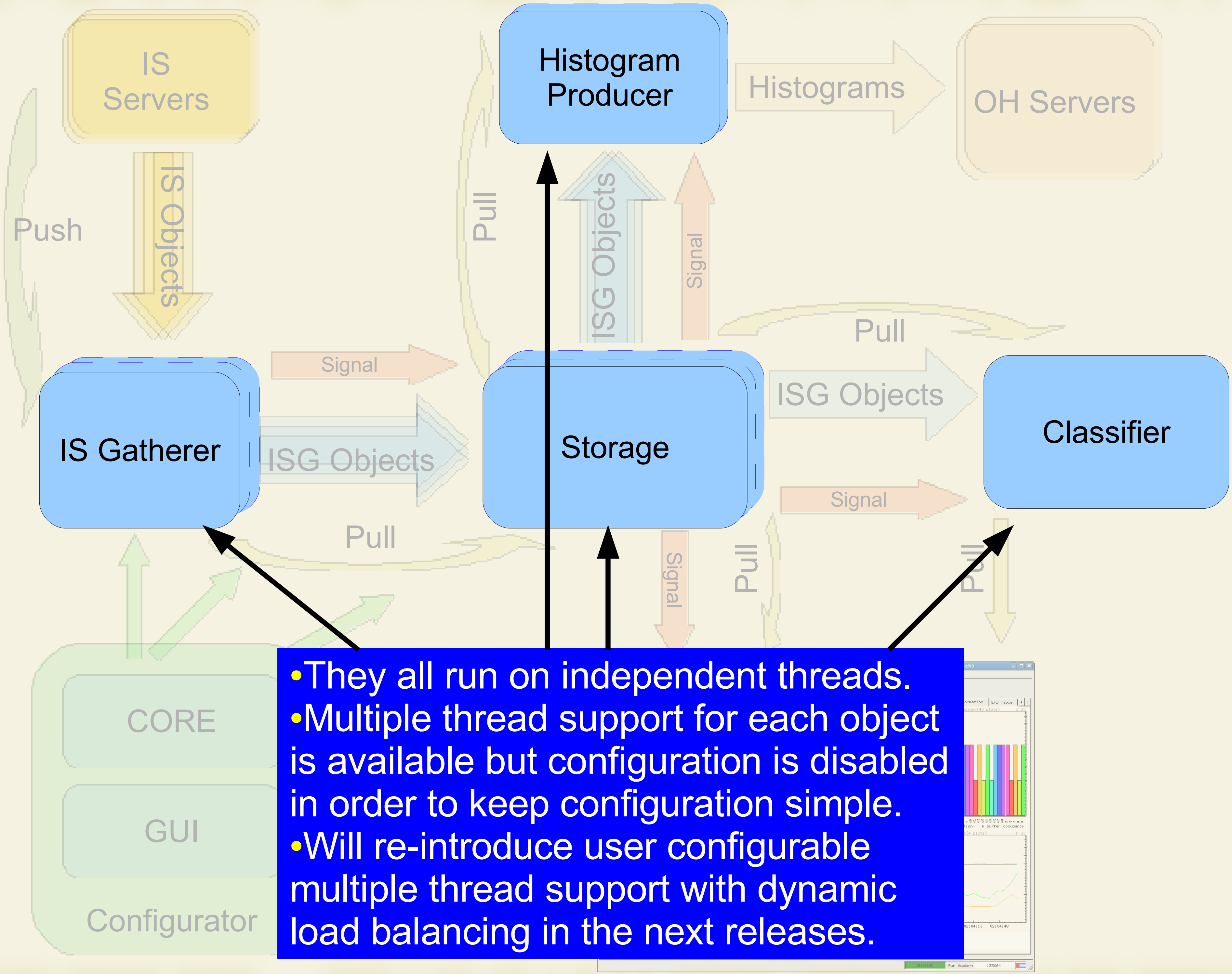
- Converts ISGObjects into one of the three different histogram styles available and publishes them to the OH servers, providing a way of direct access to IS Objects for OHS based programs.



- Keeps the configuration information for the GUI and the Core.
- Configures all items in the core and establishes the connections between them.
- Can combine several configuration files into one file.
- Manages the subscriptions to IS Servers



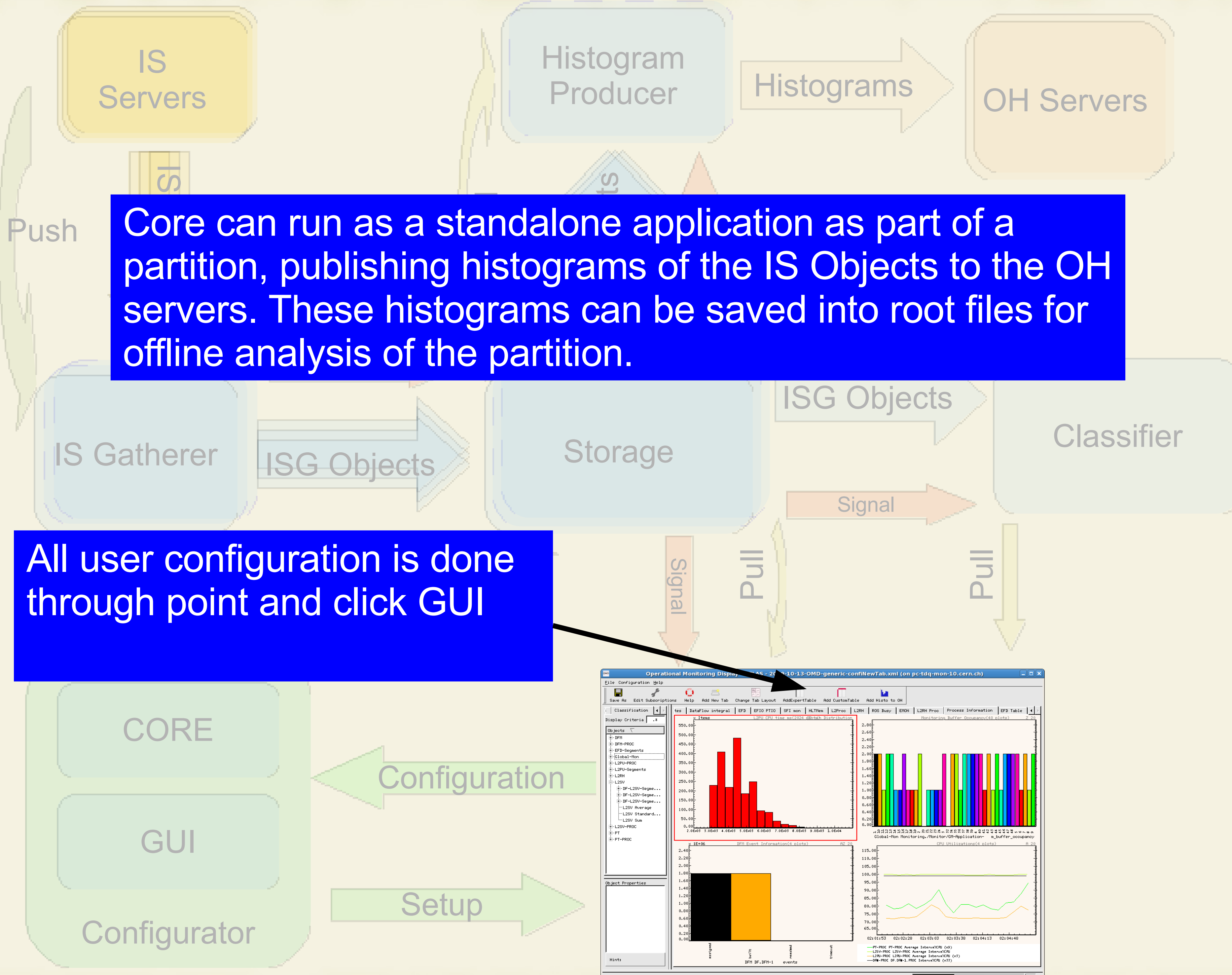
Push-Pull approach in combination with signaling mechanism permits parallel design thus allowing a high level of concurrent processing.



- They all run on independent threads.
- Multiple thread support for each object is available but configuration is disabled in order to keep configuration simple.
- Will re-introduce user configurable multiple thread support with dynamic load balancing in the next releases.

Core can run as a standalone application as part of a partition, publishing histograms of the IS Objects to the OH servers. These histograms can be saved into root files for offline analysis of the partition.

All user configuration is done through point and click GUI




Operational Monitoring Display - ATLAS - /atlas/moncfg/tdaq-02-00-03/daq/omd/OMD-generic-config-2009-12-07.xml
File
Configuration
Help
Save As
Edit Subscriptions
Help
Add New Tab
Change Tab Layout
AddExpertTable
Add CustomTable
Add Histo to OH
Statistics
Objects
Classification
Display Criteria
L2SV
SFO
SFI
ROS
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DataFlow integral
EFD
EFIO PTIO
SFI mon
HLT Mem cpu
L2RH
ROS Busy
EMON
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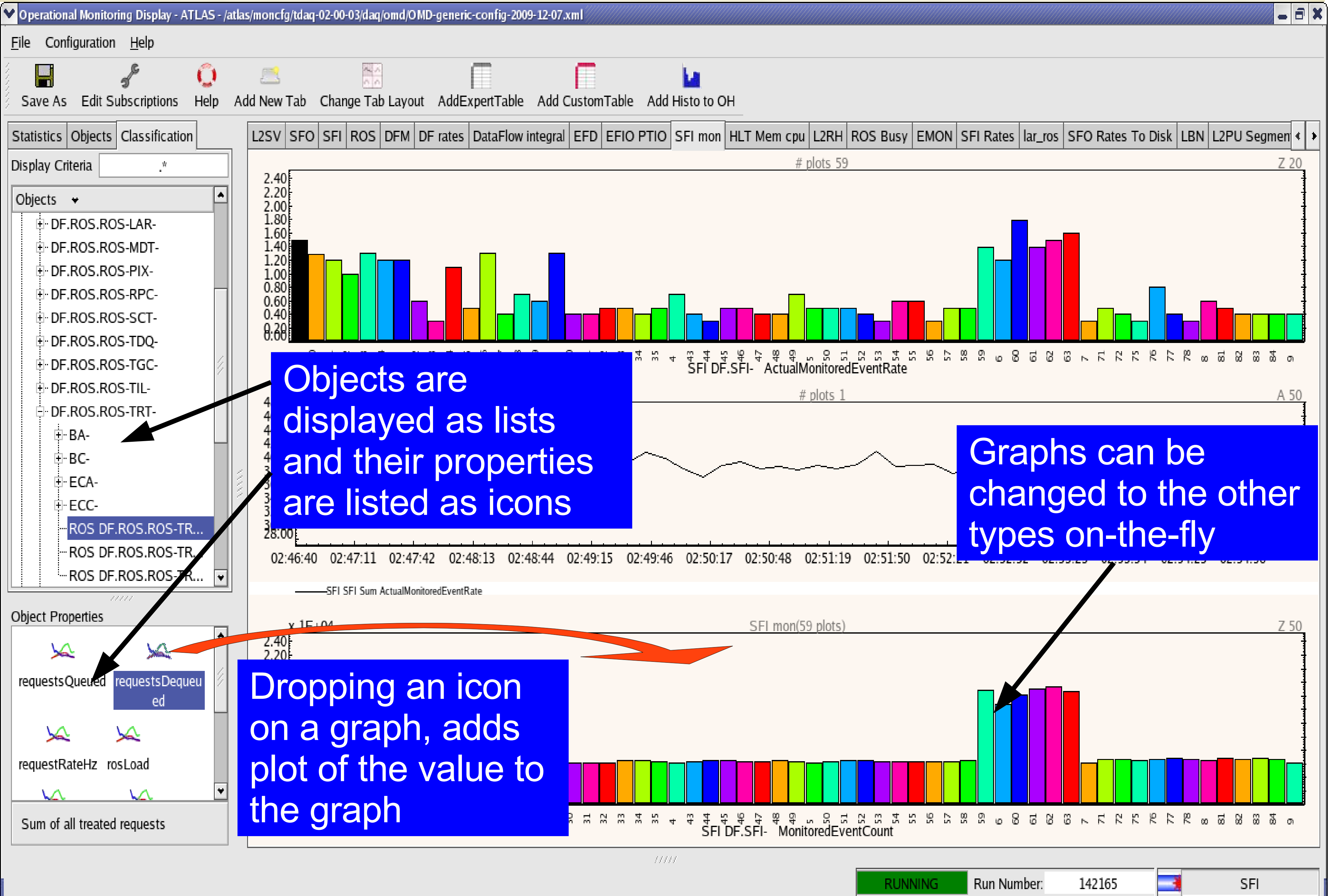
lar_ros
SFO Rates To Disk
LBN
L2PU Segment 1
Bar Charts plots
Time Series plots
Distribution plots
plots 59
SFI DF.SFI- ActualMonitoredEventRate
plots 1
SFI SFI Sum ActualMonitoredEventRate
SFI mon(59 plots)
50 bin Distribution
Object Properties
requestRateHz
rosLoad
Sum of all treated requests
RUNNING
Run Number:
142165
SFO



Operational Monitoring Display - ATLAS - /atlas/moncfg/tdaq-02-00-03/daq/omd/OMD-generic-config-2009-12-07.xml
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DF.ROS.ROS-TGC-
DF.ROS.ROS-TIL-
DF.ROS.ROS-TRT-
BA-
BC-
ECA-
ECC-
Object Properties
requestsQueued
requestsDequeued
requestRateHz
rosLoad
Sum of all treated requests
L2SV
SFO
SFI
ROS
DFM
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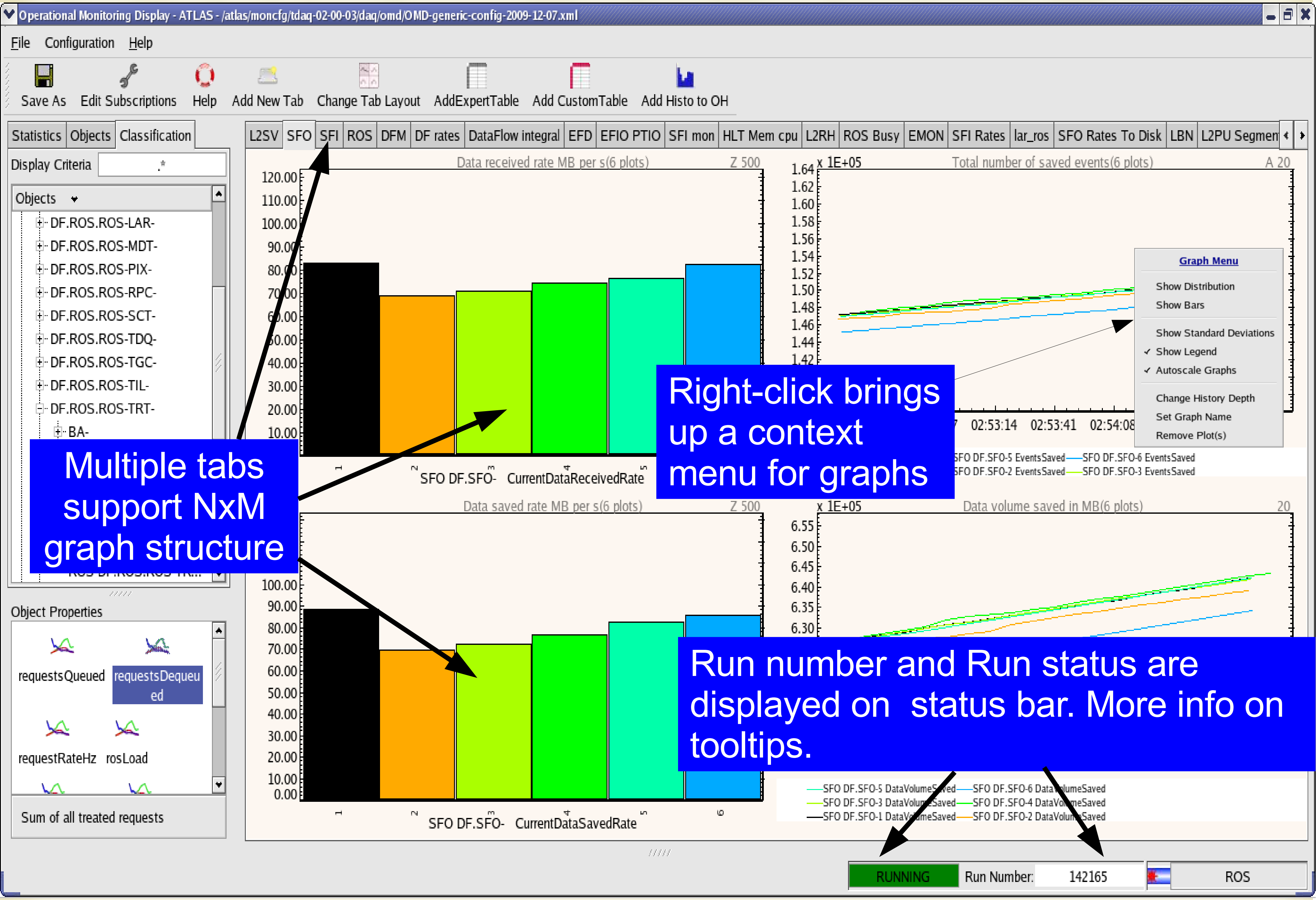
DataFlow integral
EFD
EFIO PTIO
SFI mon
HLT Mem cpu
L2RH
ROS Busy
EMON
SFI Rates
lar_ros
SFO Rates To Disk
LBN
plots 59
SFI DF.SFI- ActualMonitoredEventRate
plots 1
SFI SFI Sum ActualMonitoredEventRate
SFI mon(59 plots)
SFI DF.SFI- MonitoredEventCount
RUNNING
Run Number:
142165
SFI
Objects are displayed as lists and their properties are listed as icons
Graphs can be changed to the other types on-the-fly
Dropping an icon on a graph, adds plot of the value to the graph


Operational Monitoring Display - ATLAS - /atlas/moncfg/tdaq-02-00-03/daq/omd/OMD-generic-config-2009-12-07.xml
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DF.ROS.ROS-TIL-
DF.ROS.ROS-TRT-
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Object Properties
requestsQueued
requestsDequeued
requestRateHz
rosLoad
Sum of all treated requests
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SFI
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HLT Mem cpu
L2RH
ROS Busy
EMON
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lar_ros
SFO Rates To Disk
LBN
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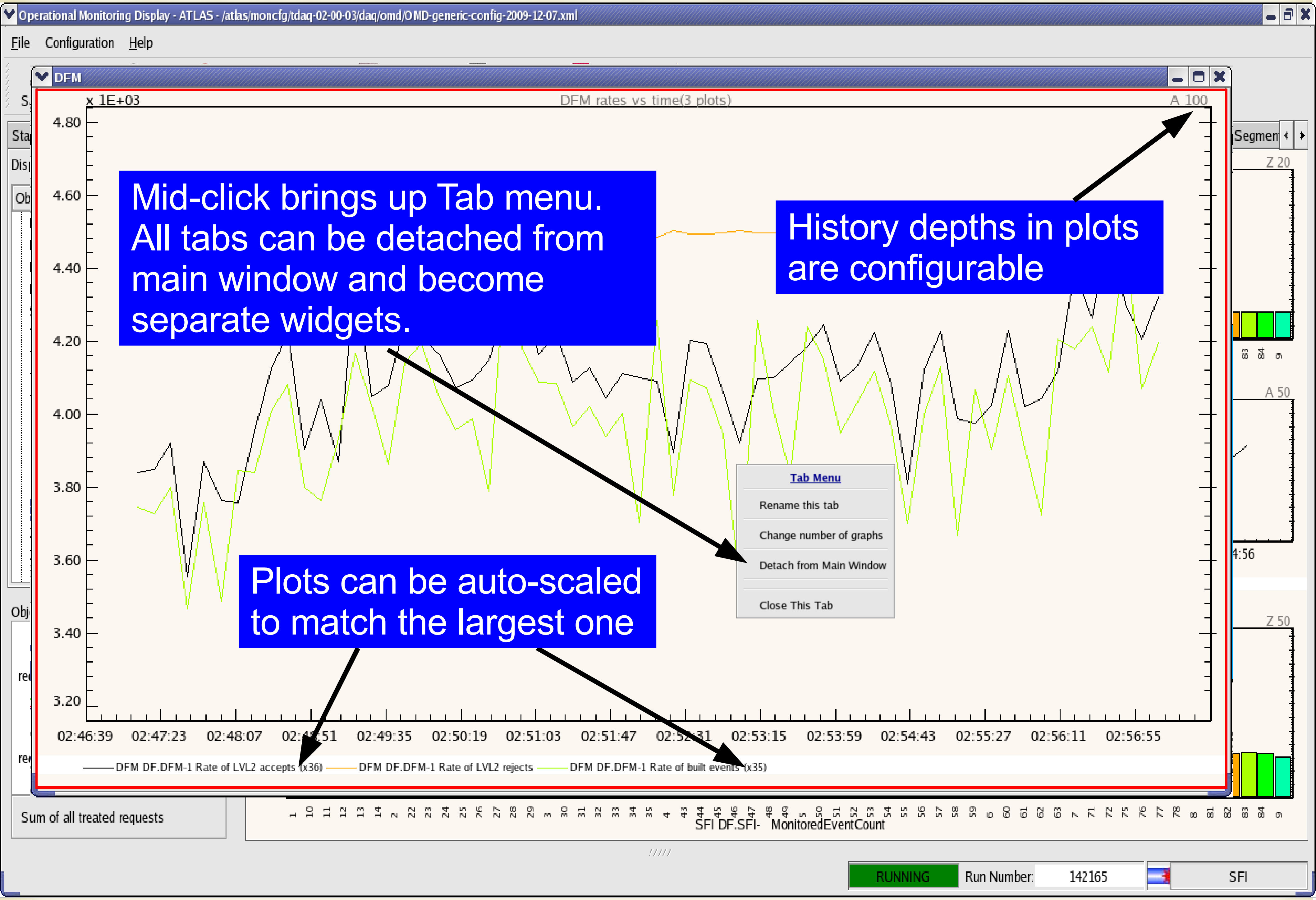
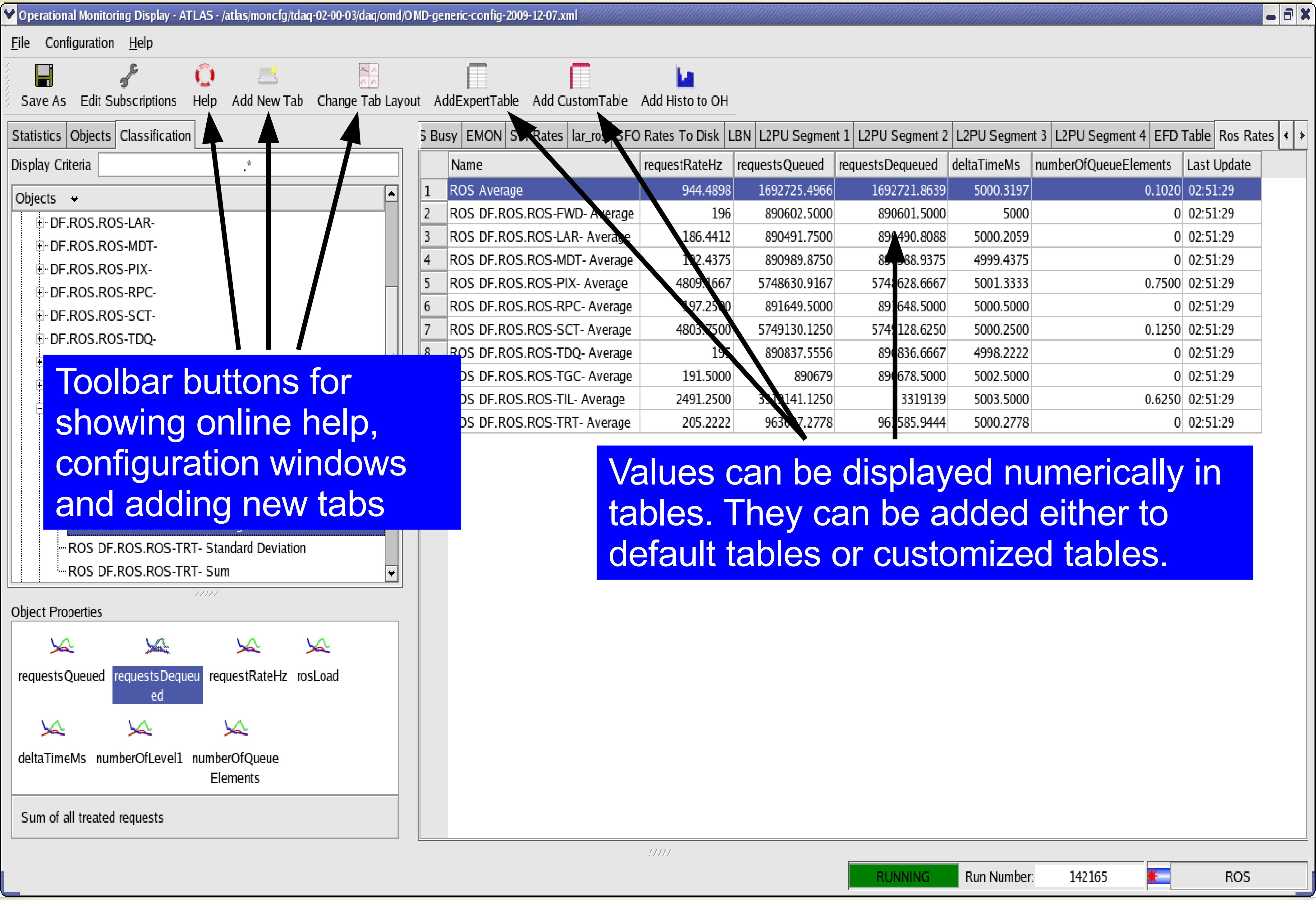
Data received rate MB per s(6 plots)
SFO DF.SFO- CurrentDataReceivedRate
Total number of saved events(6 plots)
Graph Menu
Show Distribution
Show Bars
Show Standard Deviations
Show Legend
Autoscale Graphs
Change History Depth
Set Graph Name
Remove Plot(s)
Data saved rate MB per s(6 plots)
SFO DF.SFO- CurrentDataSavedRate
Data volume saved in MB(6 plots)
RUNNING
Run Number:
142165
ROS
Multiple tabs support NxM graph structure
Right-click brings up a context menu for graphs
Run number and Run status are displayed on status bar. More info on tooltips.


Operational Monitoring Display - ATLAS - /atlas/moncfg/tdaq-02-00-03/daq/omd/OMD-generic-config-2009-12-07.xml
File Configuration Help
DFM
x 1E+03
DFM rates vs time(3 plots)
A 100
Mid-click brings up Tab menu. All tabs can be detached from main window and become separate widgets.
History depths in plots are configurable
Tab Menu
Rename this tab
Change number of graphs
Detach from Main Window
Close This Tab
Plots can be auto-scaled to match the largest one
DFM DF.DFM-1 Rate of LVL2 accepts (x36)
DFM DF.DFM-1 Rate of LVL2 rejects
DFM DF.DFM-1 Rate of built events (x35)
Sum of all treated requests
SFI DF.SFI- MonitoredEventCount
RUNNING
Run Number: 142165
SFI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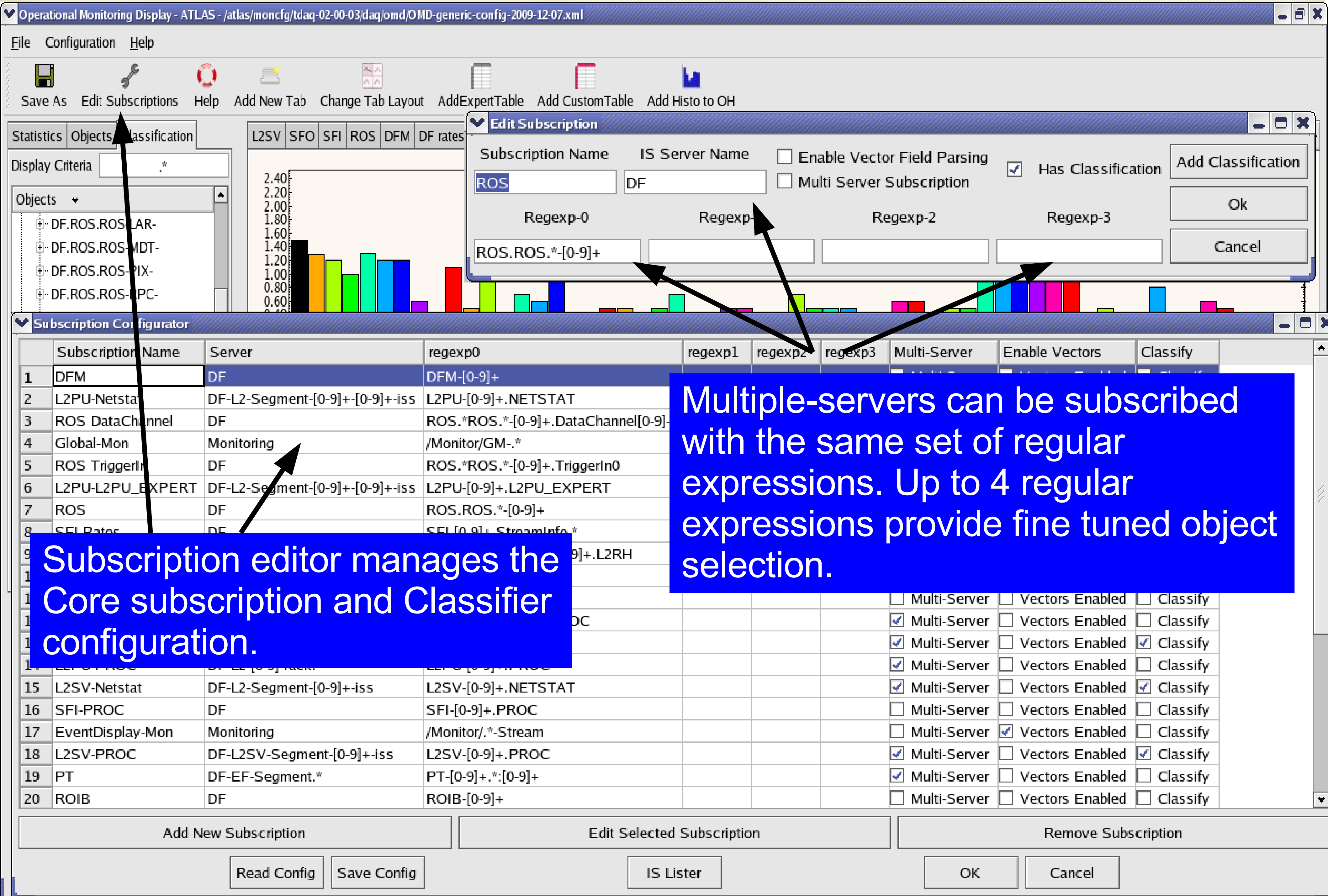
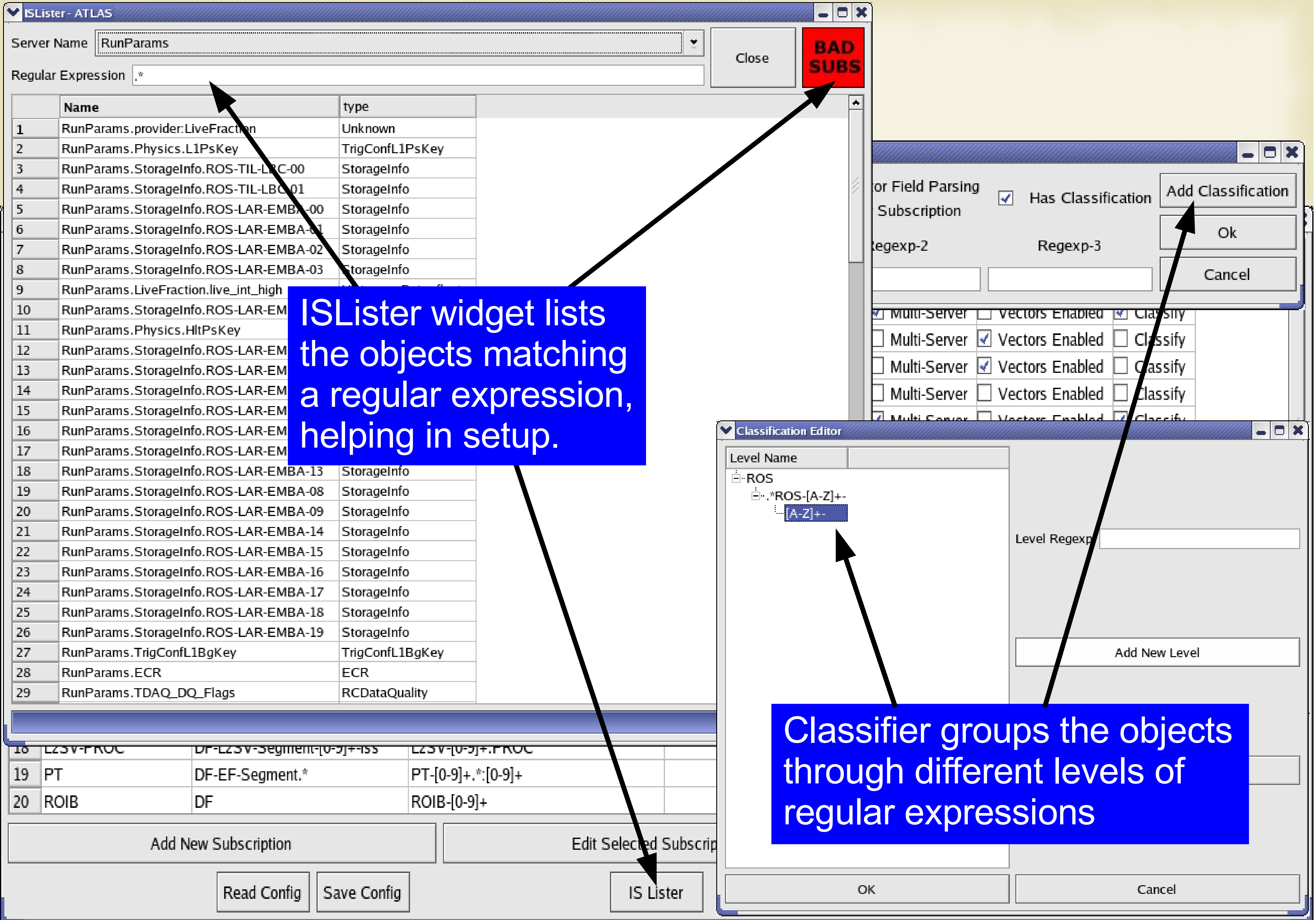
ROS DF.ROS.ROS-TRT- Sum
Object Properties
requestsQueued
requestsDequeued
requestRateHz
rosLoad
deltaTimeMs
numberOfLevel1
numberOfQueueElements
Sum of all treated requests
EMON
LBN
L2PU Segment 1
L2PU Segment 2
L2PU Segment 3
L2PU Segment 4
EFD Table
Ros Rates
Name
requestRateHz
requestsQueued
requestsDequeued
deltaTimeMs
numberOfQueueElements
Last Update
ROS Average
RUNNING
Run Number:
142165
ROS
Toolbar buttons for showing online help, configuration windows and adding new tabs
Values can be displayed numerically in tables. They can be added either to default tables or customized tables.



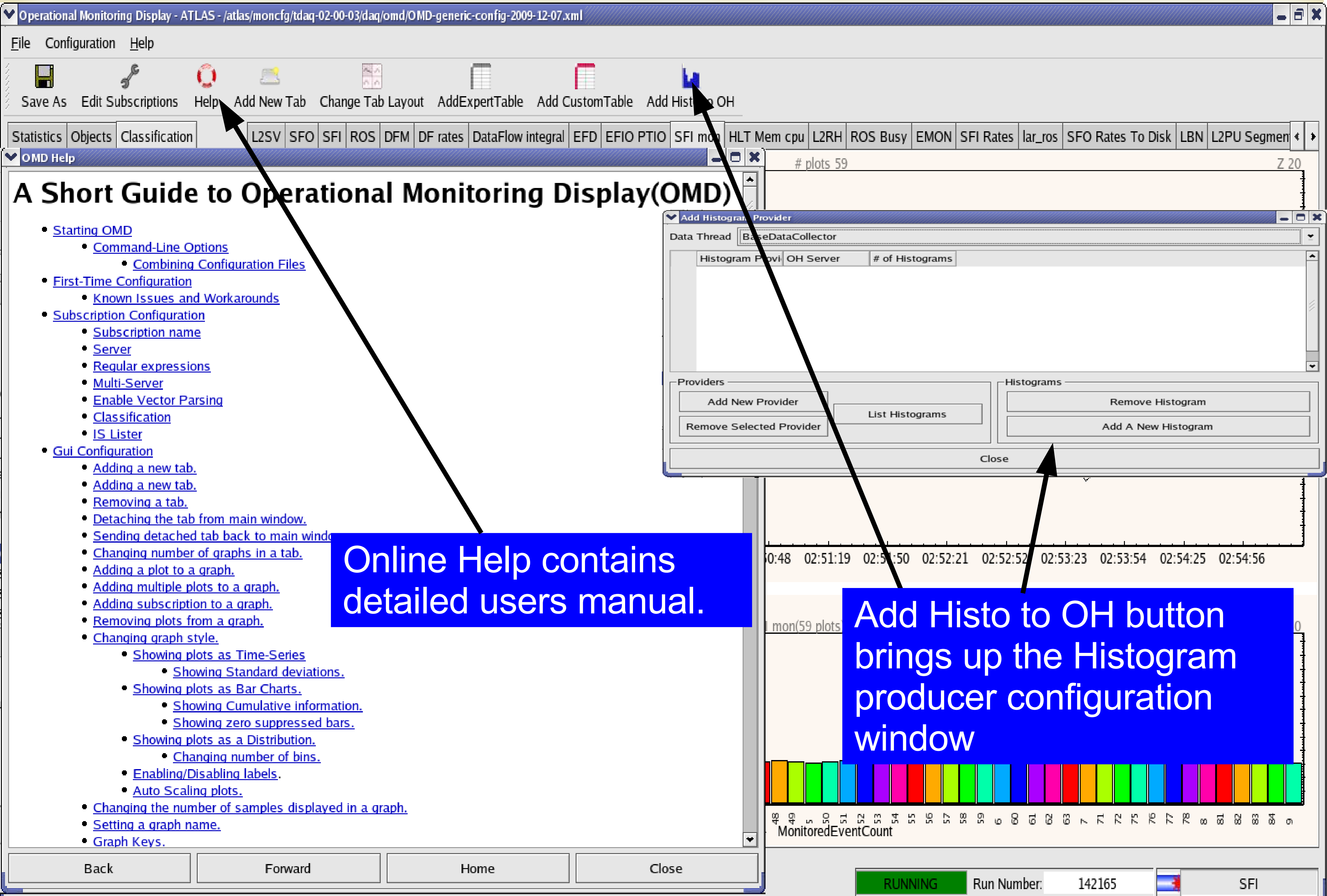
Subscription editor manages the Core subscription and Classifier configuration.

Multiple-servers can be subscribed with the same set of regular expressions. Up to 4 regular expressions provide fine tuned object selection.



ISLister widget lists the objects matching a regular expression, helping in setup.

Classifier groups the objects through different levels of regular expressions



Online Help contains detailed users manual.

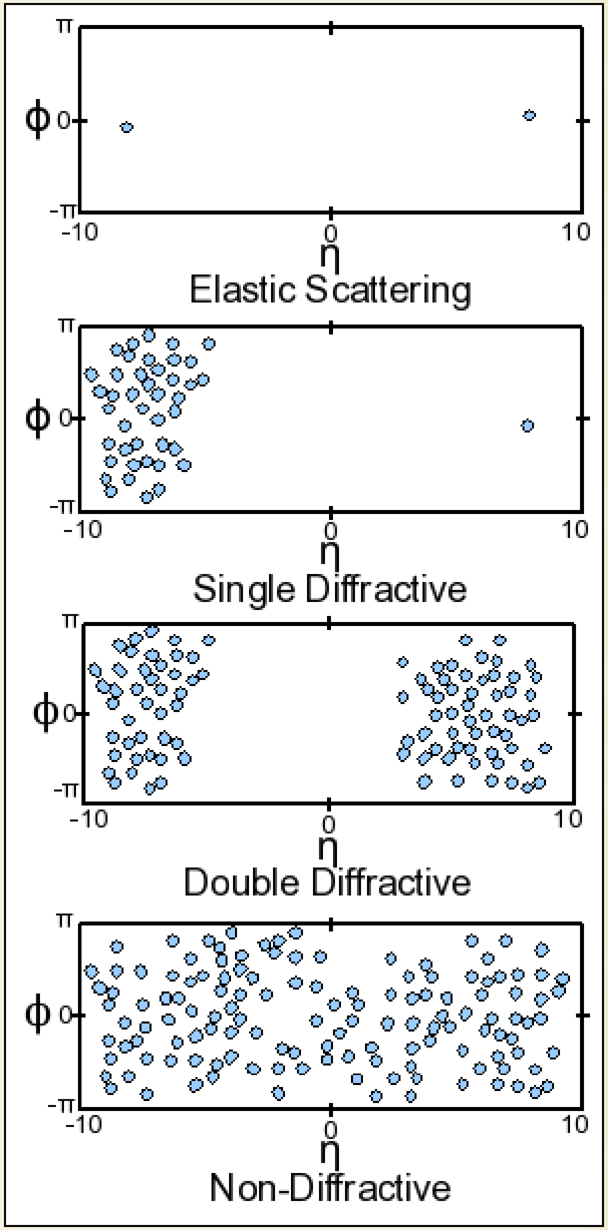
Add Histo to OH button brings up the Histogram producer configuration window

OMD Summary

- OMD provides an easy way of accessing the information available IS servers.
- It can display the information in various styles.
- Both experts and shifters can use it easily.
- It has great flexibility and real time response.

Event Topologies

- Events classified with respect to their topologies in η-ϕ plane
- Elastic scattering leaves both protons intact
- In single diffractive events only one of the protons is destroyed through a colorless particle exchange.
- In double diffractive interaction both protons are destroyed with a rapidity gap between.
- In non-diffractive events both protons break-up with a colored particle exchange creating activity in all of the plane



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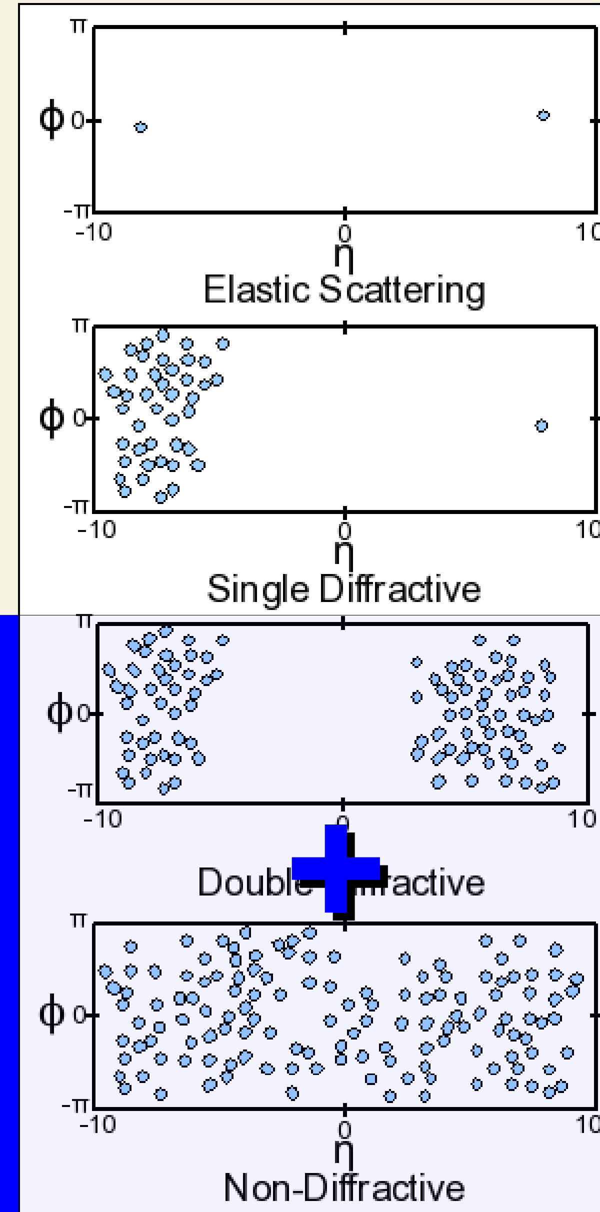
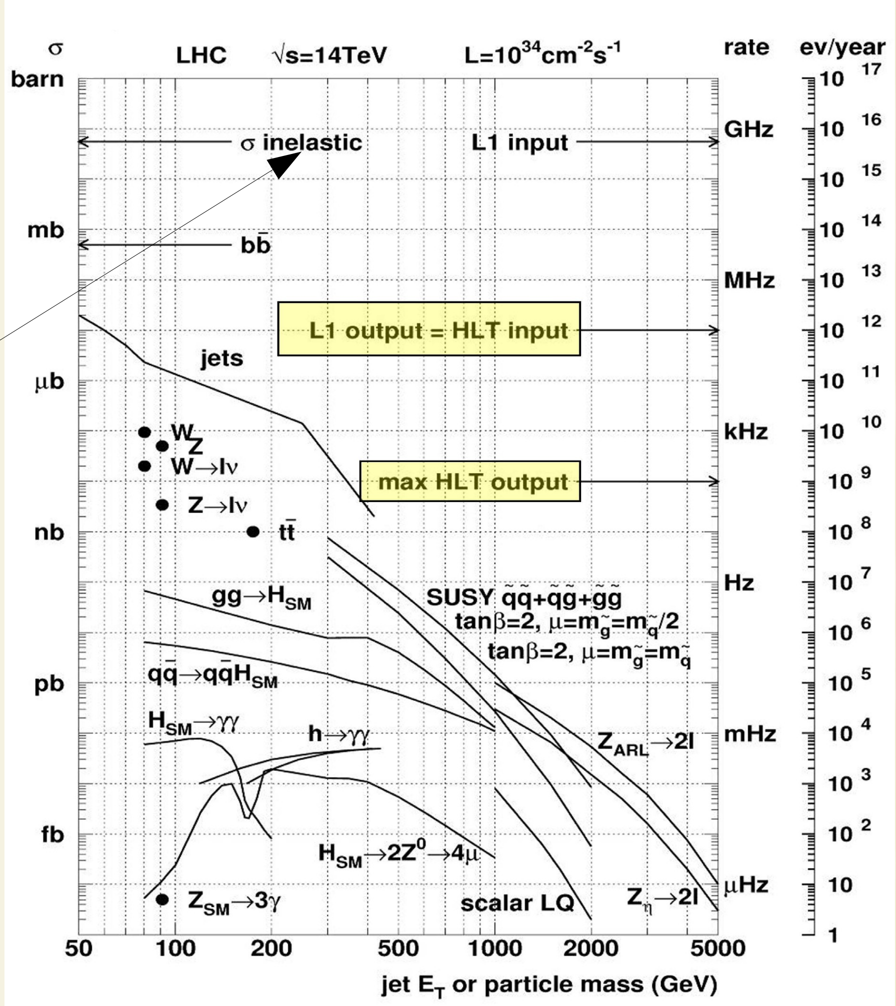
- In non-diffractive events both
up with a colored particle exc
activity in all of the plane

Common definition of minimum bias



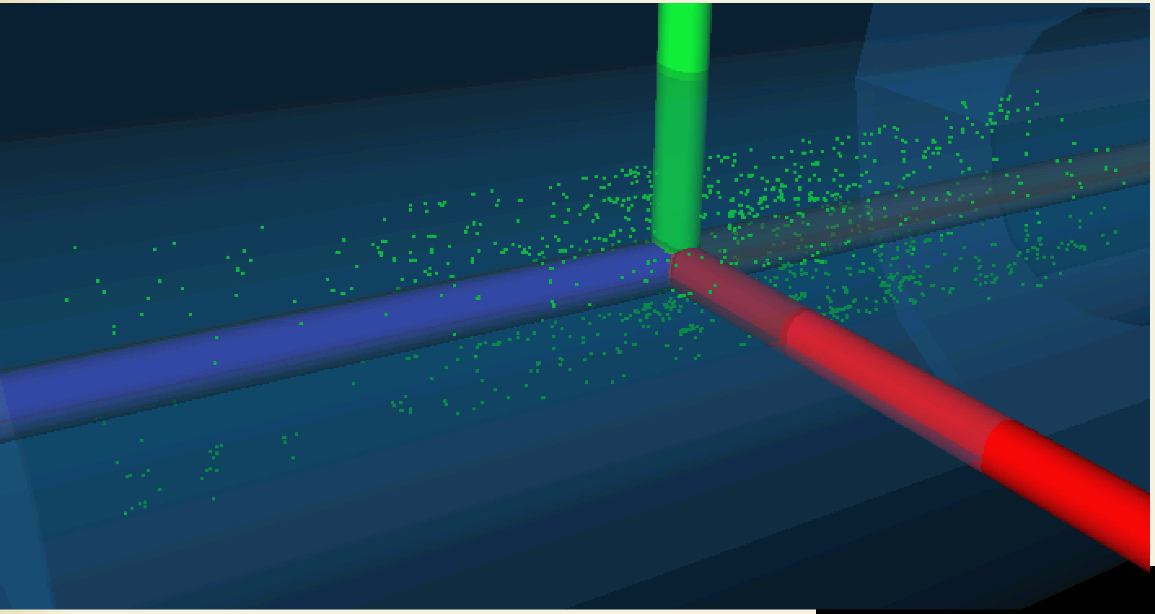
Minimum Bias Events

- Minimum bias (MB) events are the events collected with as little bias from the trigger as possible.
- They are mostly composed of soft interactions and majority of the collisions at the LHC will be MB events.
- We need to understand MB events since they will be a background for interesting physics events.



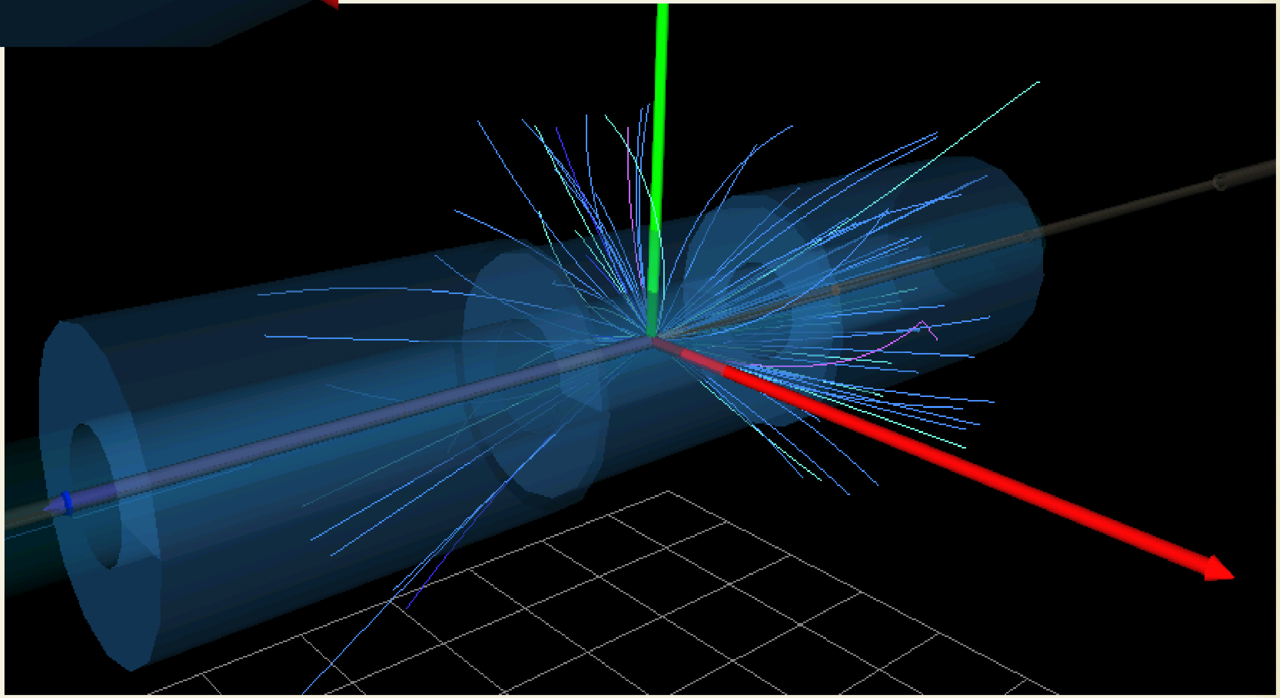
from Exp. Perf. of the ATLAS Det. Det. Trig, and Phys.

$Z \rightarrow jj$ event



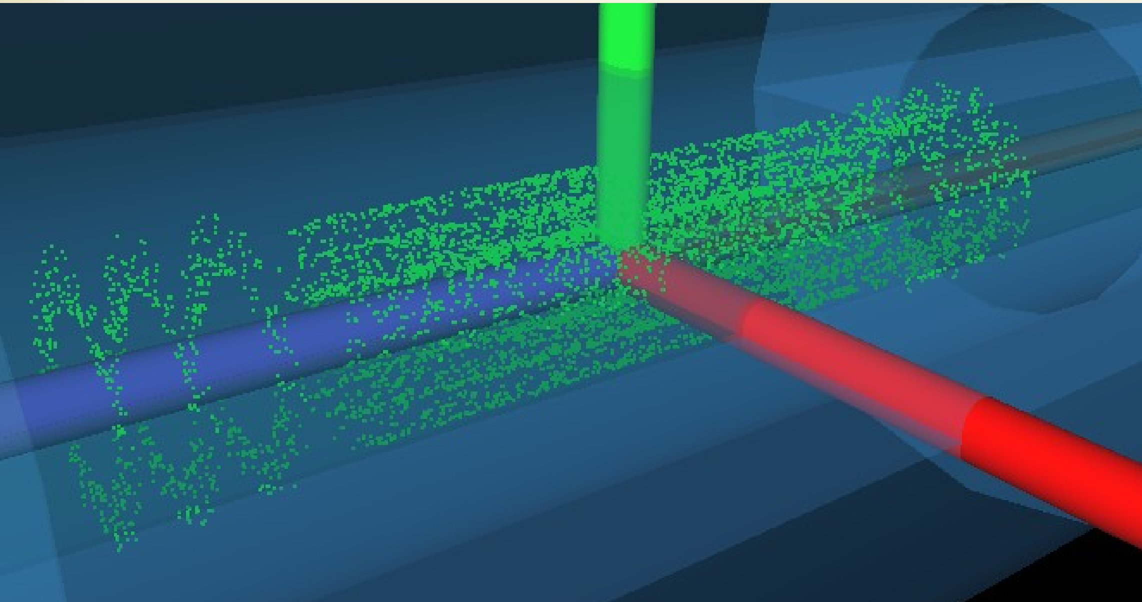
A $Z \rightarrow jj$ event simulated with Pythia

Occupancy in the pixel detector.



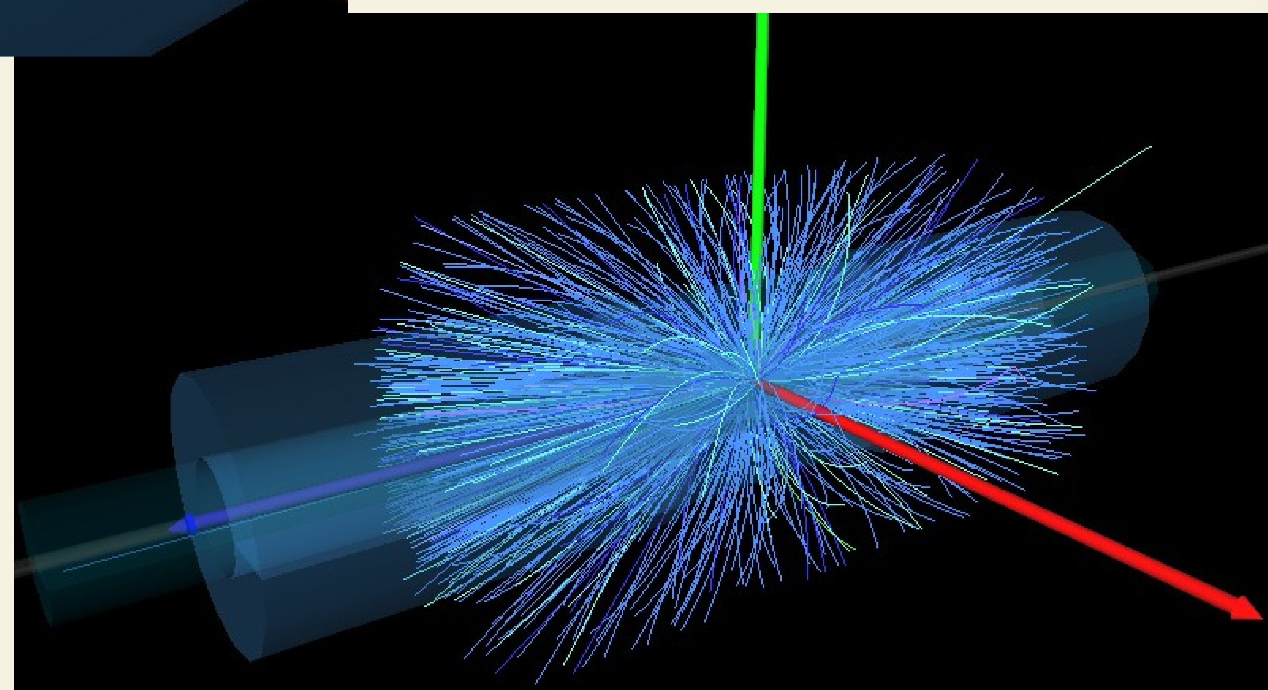
Tracks in the inner detector

Z→jj + 23 Minimum Bias pile-up



Without understanding MB any study would be significantly harder.

Occupancy in the pixel detector.



Tracks in the inner detector

Minimum Bias Monte-Carlos

- Unfortunately perturbative QCD can not describe MB events.
- There aren't any theories for soft interactions.
- Several models explain soft interactions with varying accuracy, quite a few predating QCD.
- Some of them are implemented in Monte-Carlo programs such as Phojet, EPOS and Pythia. They all somewhat agree at low energies however extrapolations to LHC are different
- Sometimes these MC programs have user tunable parameters.
- Fine-tuning these parameters can improve agreement with data.

Minimum Bias Monte-Carlos

- Phojet uses Dual Parton Model where soft interactions are modeled by the exchange of colorless particles called *Pomerons*. Free parameters of the model are found by the fits to the data.
- EPOS is a new hadronic interaction model with multiple scattering approach based on partons and pomerons. It is used for heavy ion collision and cosmic-ray interactions. It doesn't have any user tunable parameters.
- Pythia is probably the most widely used MC generator in high energy physics. It uses an approach combining Regge theory and “Eikonalized” QCD models for soft interactions. It has many tunable parameters.

Tuning Problem

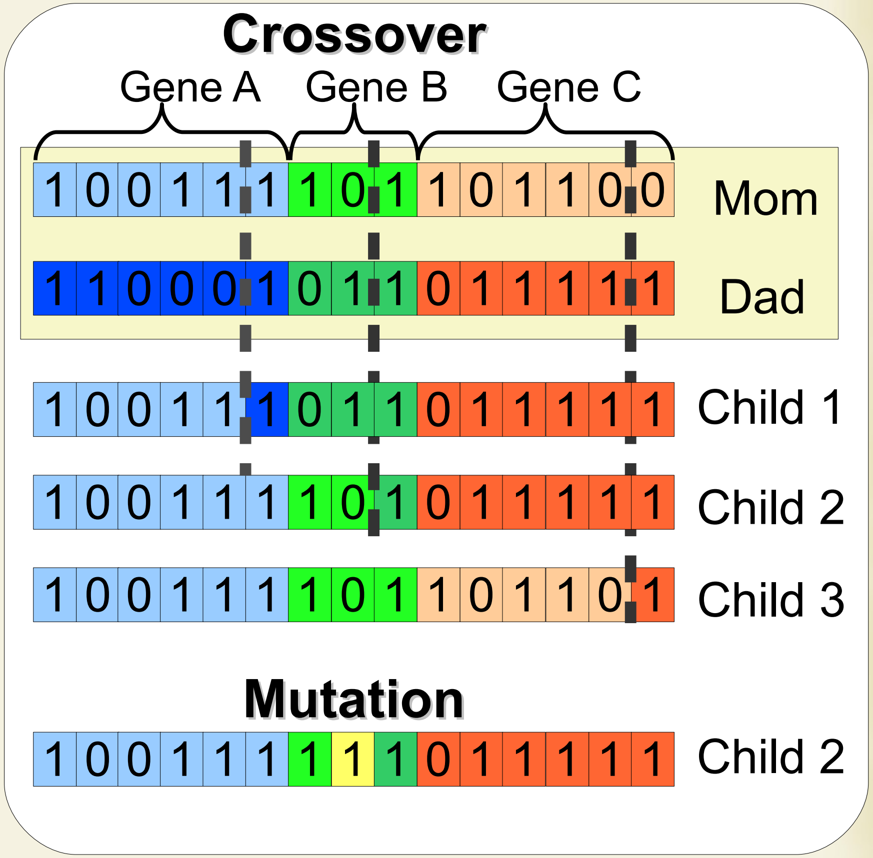
- Relationship between the parameters and the observables are extremely complex and usually there are several tuning parameters and many data sets to check for.
- Comparing distributions by eye is subjective and inefficient, i.e. for 5 parameters, 3 different values for each parameter and 10 data sets, 1250 comparisons.
- Brute force random sampling is very inefficient ~3-6 hours of event generation for each parameter value set. Parameter space grows exponentially.
- Parameterization is a good approach but it is based on the approximation of the generator response.
- A good search and optimization method could be useful.

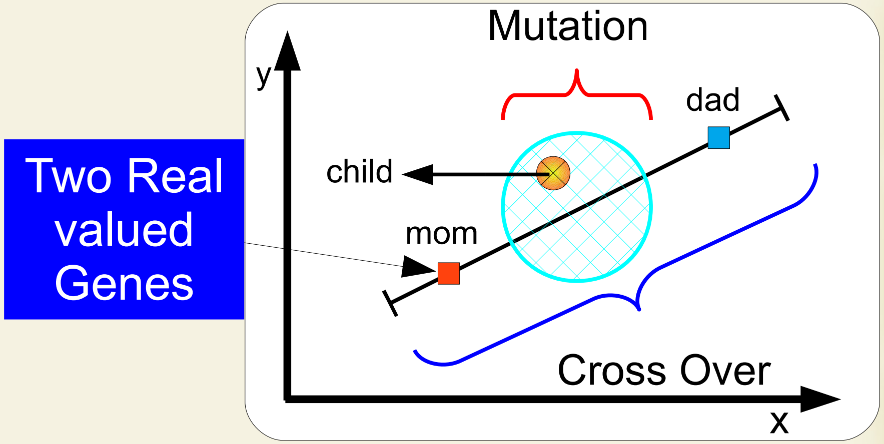
Genetic Algorithms

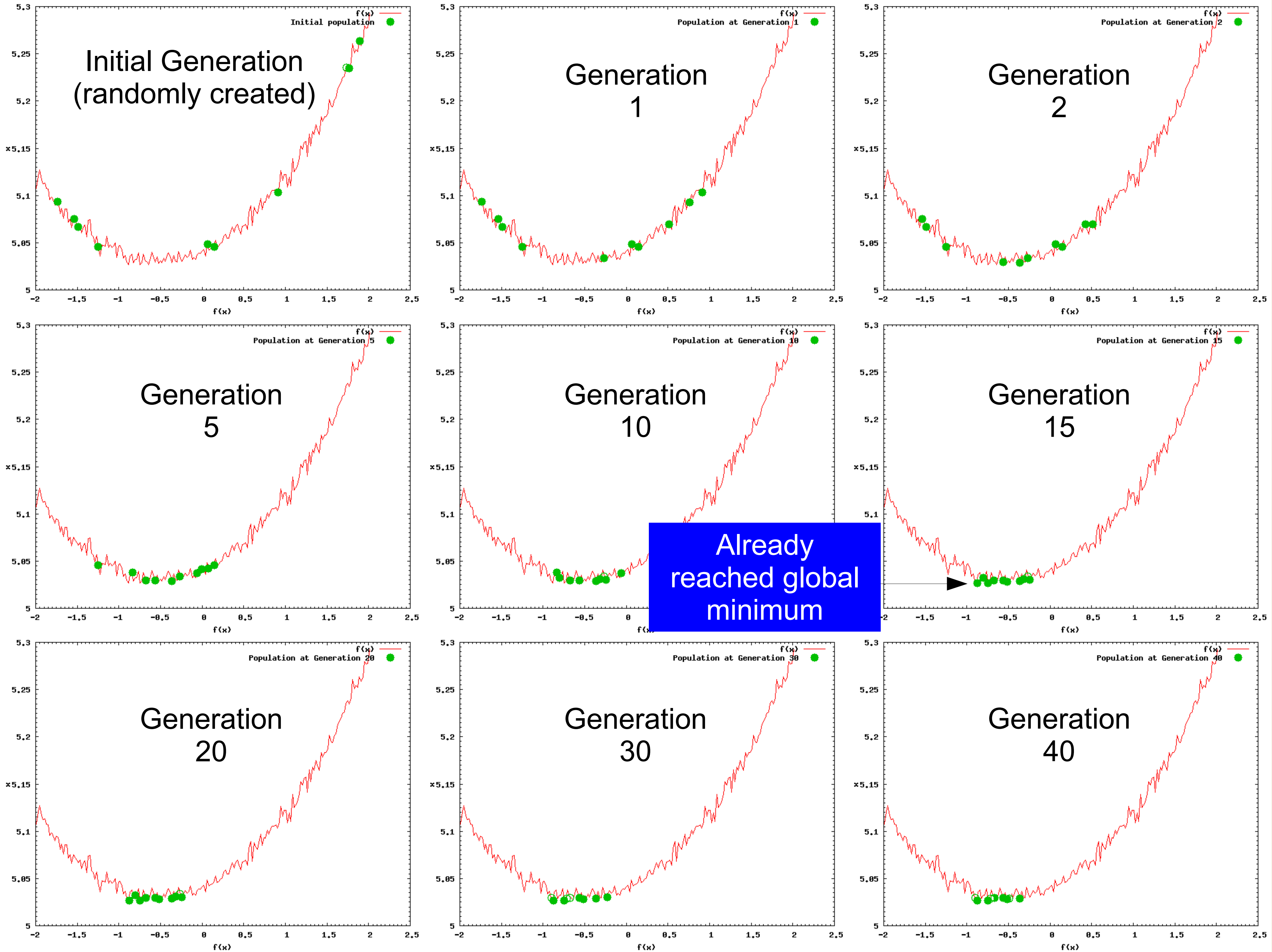
- Genetic algorithms (GA) are based on the evolutionary principles observed in the nature.
- They are a compromise between random and systematic search and very good at problems where solution is unknown or too hard to calculate.
- GA's are composed of “individuals” which are a potential solution to the problem.
- Collection of individuals are called “population”
- Each individual is tested for their goodness as a solution through a fitness function and assigned a “fitness score”.
- Solution is achieved as the population evolves through genetic operations.

Genetic Operations

- Individuals are given a chance to procreate proportional to their fitness. Higher score means higher chance of mating.
- Parents create a child through crossover operation. The child posses genes coming from both parents with random portions.
- Mutation alters a randomly selected gene with a given chance.
- Through cross-over and mutation, fitness of the population increase.







Initial Generation (randomly created)
f(x)
Initial population
Generation 1
Population at Generation 1
Generation 2
Population at Generation 2
Generation 5
Population at Generation 5
Generation 10
Population at Generation 10
Generation 15
Population at Generation 15
Already reached global minimum
Generation 20
Population at Generation 20
Generation 30
Population at Generation 30
Generation 40
Population at Generation 40

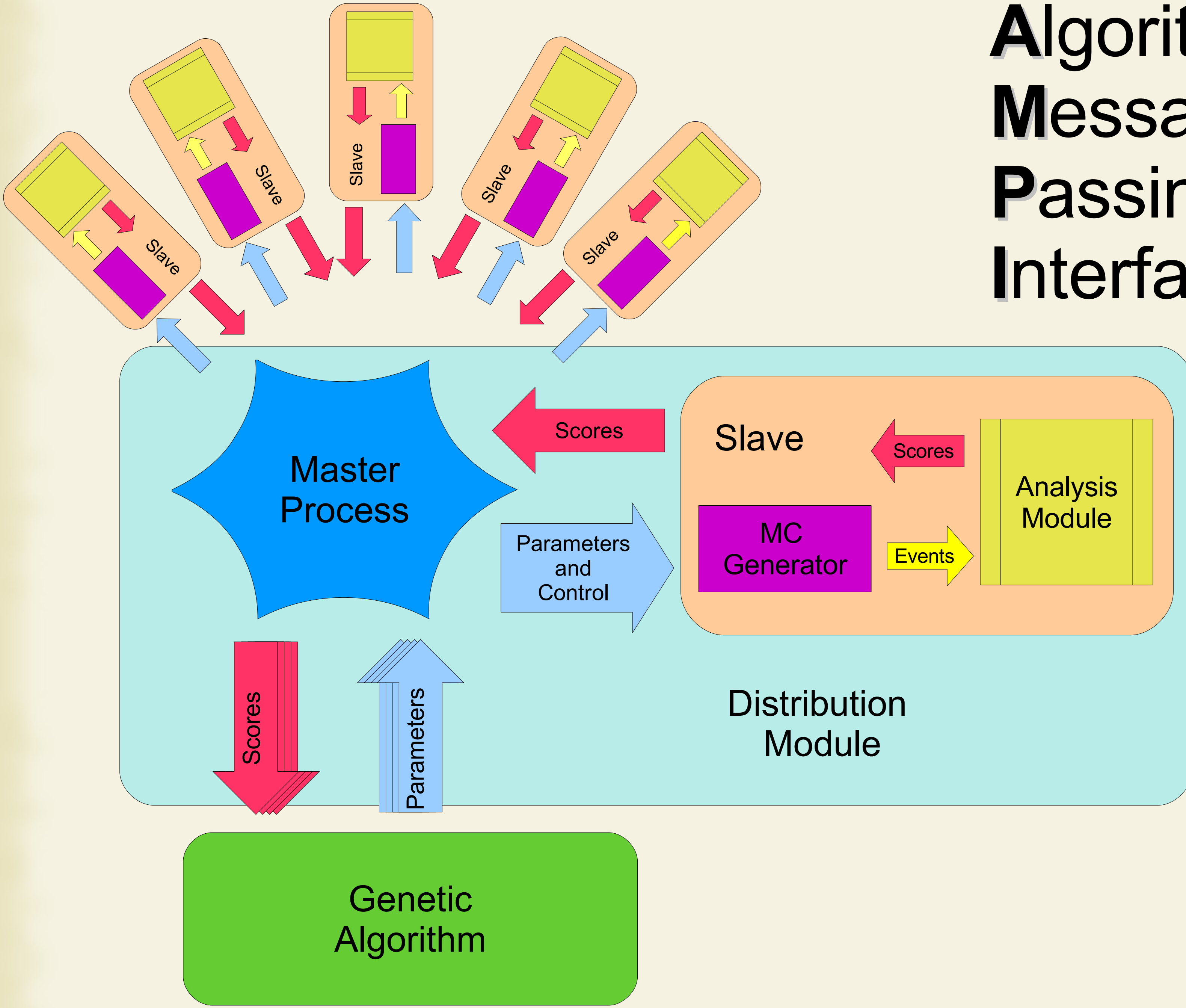
Applying GA's to MC tuning

- GA's has a good application in MC tuning problem (i.e. solution is unknown, perfect description does not exist, a multi-dimensional optimization and search problem).
- Parameters can be assigned to the genes of individuals.
- The similarity between data and MC distributions can be used as a fitness function.
- But evaluation requires generation of MC samples for all individuals. It takes too long to generate samples for all data sets of all individuals in the population.
- However MC event generation is an embarrassingly parallel problem. Thus sample generation can be distributed.

Distributing the sample generation

- Message Passing Interface (MPI) provides a way to inter-process communication over a network.
- However passing all events over the network is inefficient.
- Generating events and evaluating the distributions remotely then sending only the results is much more efficient.
- This approach requires a binary wrapping the MC generator, an analysis library for generating the distributions from the events, data sets and communicating through MPI.
- All these features can be connected with a modular approach.

Genetic **A**lgorithms and **M**essage **P**assing **I**nterface



Tuning Pythia

- Pythia uses parton shower approach to simulate $2 \rightarrow n$ processes which occur in ISR and FSR.
- It uses string model for fragmentation and hadronization.
- Fragmentation, flavor and hadronization parameters are tuned by LEP data.
- Divergence of hard cross-section is regulated by the factor

$$\frac{d\sigma}{dp_T^2} \propto \frac{\alpha_s^2(p_T^2)}{p_T^4} \rightarrow \frac{\alpha_s^2(p_{T_0}^2 + p_T^2)}{(p_{T_0}^2 + p_T^2)^2}$$

where p_{T_0} is an energy dependent parameter and α_s is the strong coupling constant.

- Energy dependency of p_{T_0} is given as

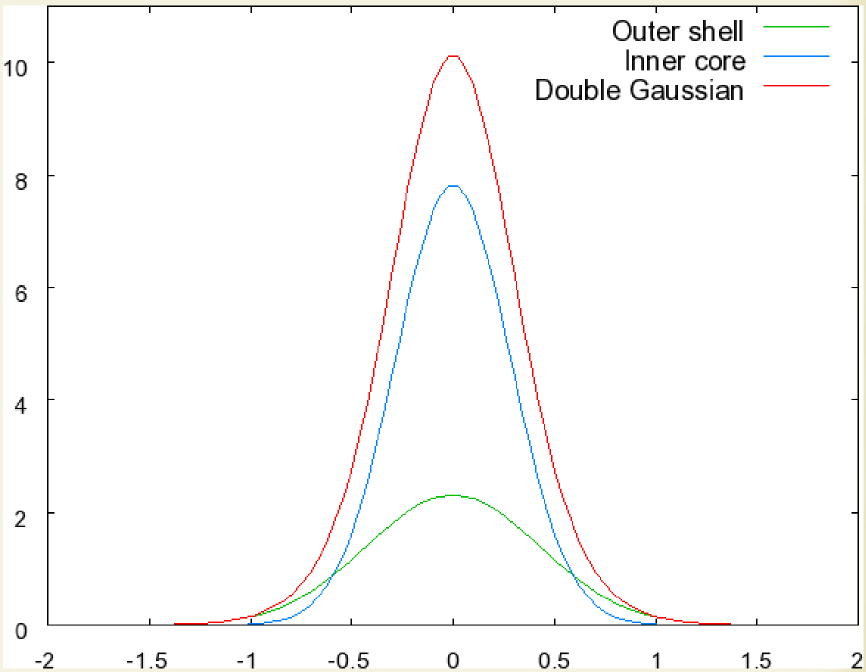
$$p_{T_0}(E_{cm}) = p_{T_0}^{ref}\left(\frac{E_{cm}}{E_0^{ref}}\right)^{E_{pow}}$$

where $p_{T_0}^{\ ref}$ is the value of p_{T_0} at the reference energy scale $E_0^{\ ref}$ and E_{pow} is the slope of evolution.

- Even though the divergence at low momentum transfer are regulated, at high energies hard cross-section can become larger than total cross-section. This effect is explained by multiple parton interactions where several interactions taking place between the partons of the incoming protons in the same collision.

- In multiple parton interactions matter distribution in the proton becomes significant.
- Multiple Parton Interactions are modeled with an impact parameter dependence. An example is double Gaussian matter distribution.

$$\rho(r) \propto \frac{1-\beta}{a_1^3} \exp\left(\frac{-r^2}{a_1^2}\right) + \frac{\beta}{a_2^3} \exp\left(\frac{-r^2}{a_2^2}\right)$$



- Shower evolution stops at 1 GeV. Primordial k_T is used to compensate the softer activity. In Pythia 8 it has a normal distribution with a width given by

$$\sigma = \frac{(\sigma_{soft} Q_{half} + \sigma_{hard} Q)}{Q_{half} + Q} \frac{m}{m_{half}}$$

where Q is the scale of the hardest process, m is the mass of the system, σ_{soft}, Q_{half}, σ_{hard} and m_{half} are the parameters of the model

- Beam remnants are also taken into account respecting to flavor, color and momentum correlations.

Pythia 8 Parameter set

Parameter	Explanation
MultipleInteractions:pT0Ref	Parameter controlling the energy dependence of the hard scattering cross-section regulation factor p_{T_0} .
MultipleInteractions:ecmPow	Slope of the energy dependence of the p_{T_0}
MultipleInteractions:coreRadius	Radius of the inner core in double Gaussian matter distribution
MultipleInteractions:coreFraction	Fraction of mass in the inner core
BeamRemnants:primordialKThard	σ_{hard} factor in the primordial k_T width
BeamRemnants:reconnectRange	Parameter controlling the probability of merging the gluons in a sub-processes in the multiple interactions.
MultipleInteractions:alphaSvalue	Value of the strong coupling constant at Z^0 *mass*

Data Sets

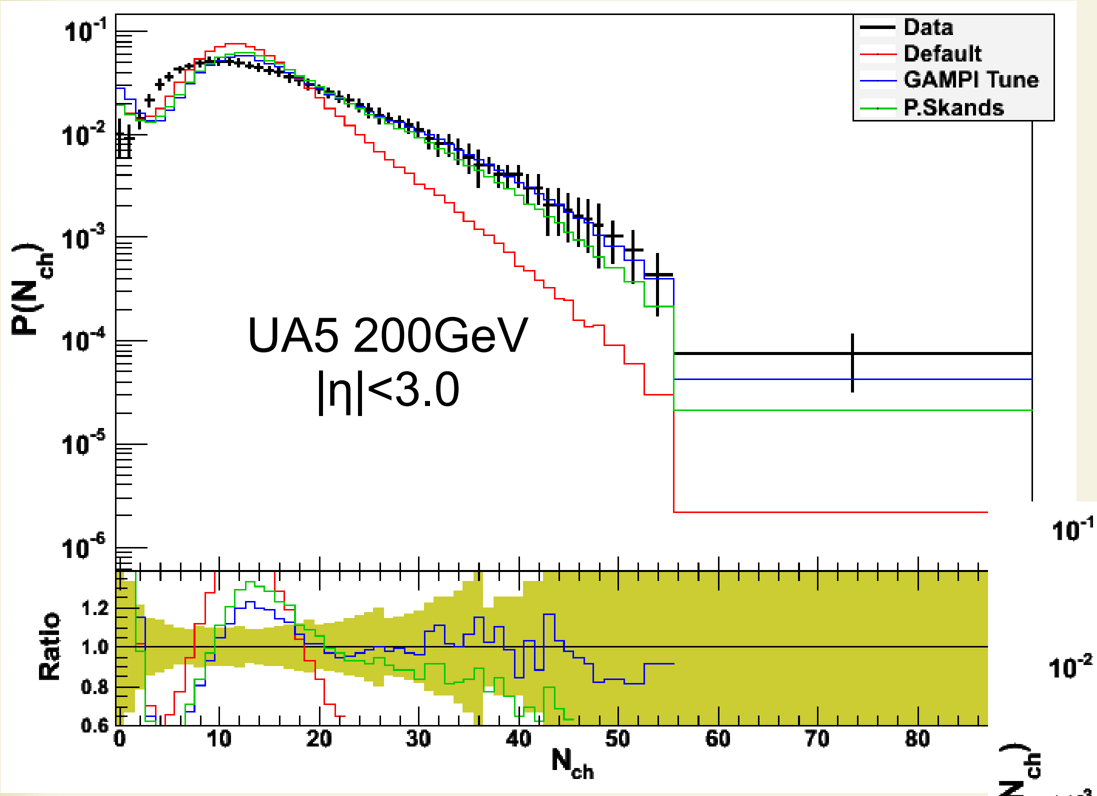
- Several measurements from CDF, D0 and UA5 are used in tuning.
- Analyses use trigger selection simulation whenever available. For example UA5 analyses require at least one charged particle in both sides of the detector in range 2.0<|η|<5.0
- It is not possible to directly relate the parameters to distributions.

Coll.	$\sqrt{s}$	**Data Set**
CDF	1960 GeV	$< p_T >$
		dN_{ch}/dp_T
		UE Trans-Min $\Sigma\, p_T$ density in Drell-Yan
		UE Trans-Max $\Sigma\, p_T$ density in Drell-Yan
		UE Trans-Min $\Sigma\, N_{ch}$ density in Drell-Yan
		UE Trans-Max $\Sigma\, N_{ch}$ density in Drell-Yan
	1800 GeV	dN_{ch}/dp_T $1/\sigma d\sigma/dp_T$ (Drell-Yan)
	630 GeV	dN_{ch}/dp_T
D0	1960 GeV	$d\sigma/dp_T$ Drell Yan
		$d\sigma/dp_T$, $y > 2$ $p_T < 30$ GeV
UA5	900 GeV	$dN_{ch}/d\eta$
		N_{ch}
		N_{ch}, $\lvert\eta\rvert < 0.5$
		N_{ch}, $\lvert\eta\rvert < 1.5$
		N_{ch}, $\lvert\eta\rvert < 3.0$
		N_{ch}, $\lvert\eta\rvert < 5.0$
	546 GeV	N_{ch}
	200 GeV	$dN_{ch}/d\eta$
		N_{ch}
		N_{ch}, $\lvert\eta\rvert < 0.5$
		N_{ch}, $\lvert\eta\rvert < 1.5$
		N_{ch}, $\lvert\eta\rvert < 3.0$

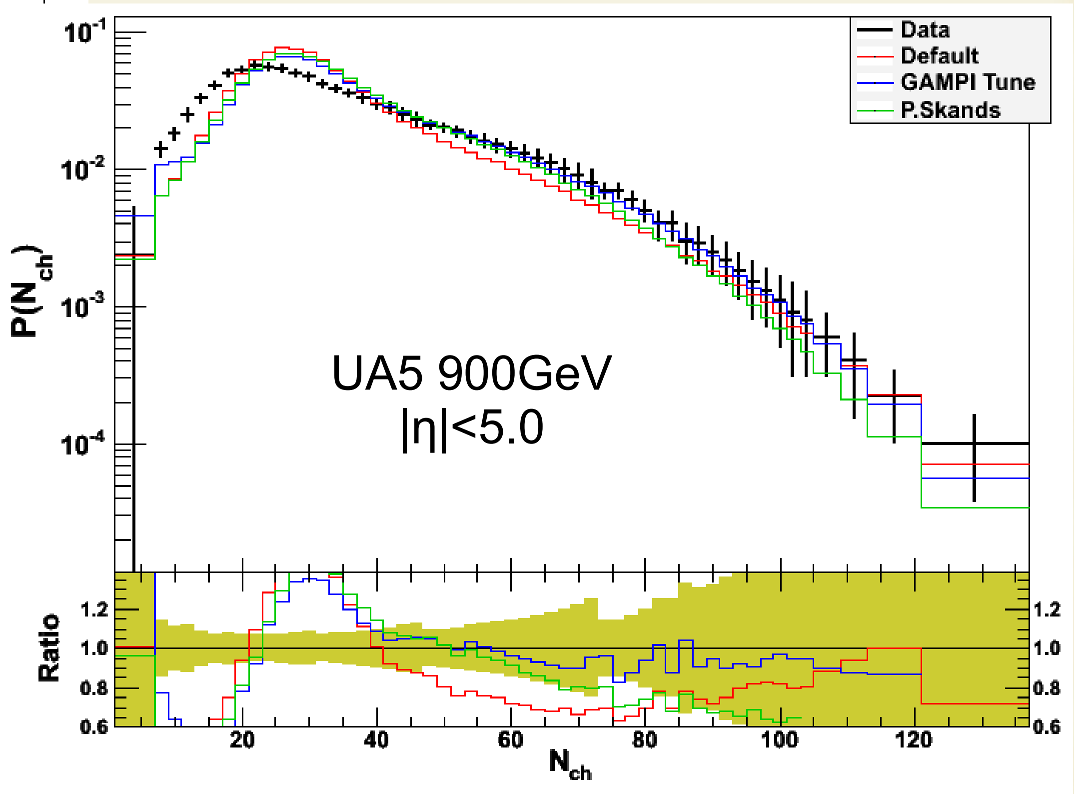
- $<p_T>$, $p_{T,}$ N_{ch} and $dN_{ch}/d\eta$ distributions are typical quantities in MB measurements.
- However they are not enough to constrain the parameters.
- The UE and Drell-Yan data sets help constraining the parameters.

Coll.	$\sqrt{s}$	Data Set
CDF	1960 GeV	$< p_T >$
		dN_{ch}/dp_T
		UE Trans-Min $\Sigma\, p_T$ density in Drell-Yan
		UE Trans-Max $\Sigma\, p_T$ density in Drell-Yan
		UE Trans-Min $\Sigma\, N_{ch}$ density in Drell-Yan
		UE Trans-Max $\Sigma\, N_{ch}$ density in Drell-Yan
	1800 GeV	dN_{ch}/dp_T $1/\sigma d\sigma/dp_T$ (Drell-Yan)
	630 GeV	dN_{ch}/dp_T
D0	1960 GeV	$d\sigma/dp_T$ Drell Yan
		$d\sigma/dp_T$, $y > 2$ $p_T < 30$ GeV
UA5	900 GeV	$dN_{ch}/d\eta$
		N_{ch}
		N_{ch}, $\lvert\eta\rvert < 0.5$
		N_{ch}, $\lvert\eta\rvert < 1.5$
		N_{ch}, $\lvert\eta\rvert < 3.0$
		N_{ch}, $\lvert\eta\rvert < 5.0$
	546 GeV	N_{ch}
	200 GeV	$dN_{ch}/d\eta$
		N_{ch}
		N_{ch}, $\lvert\eta\rvert < 0.5$
		N_{ch}, $\lvert\eta\rvert < 1.5$
		N_{ch}, $\lvert\eta\rvert < 3.0$

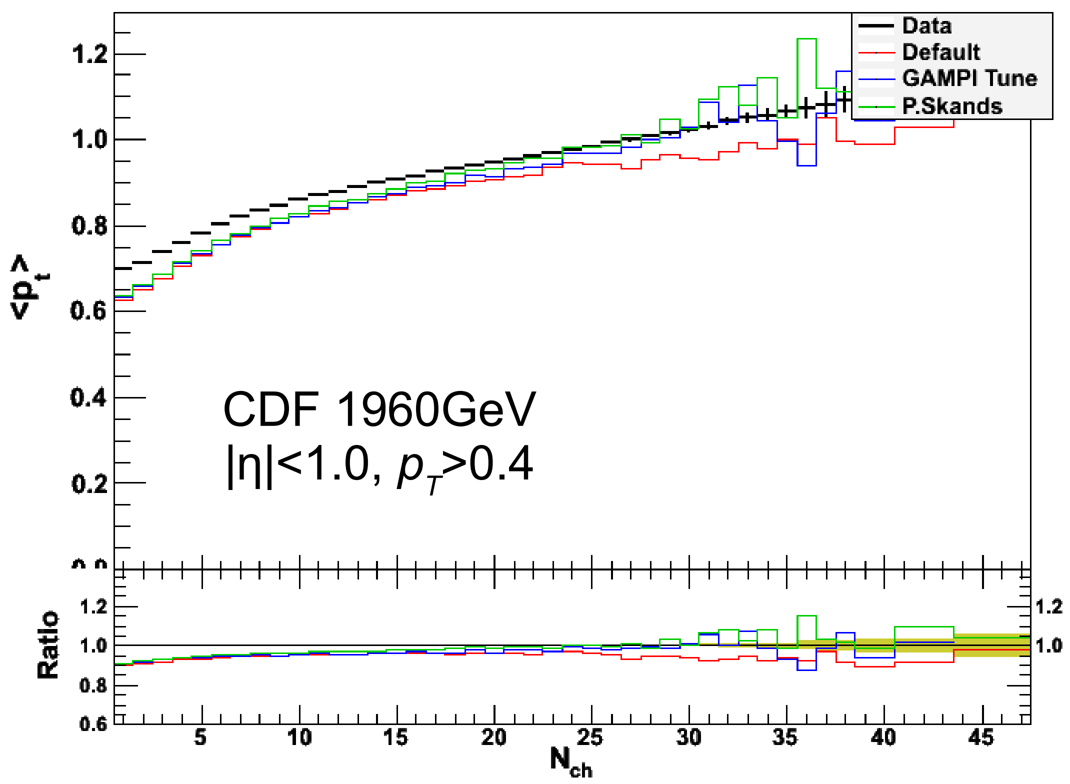
Results



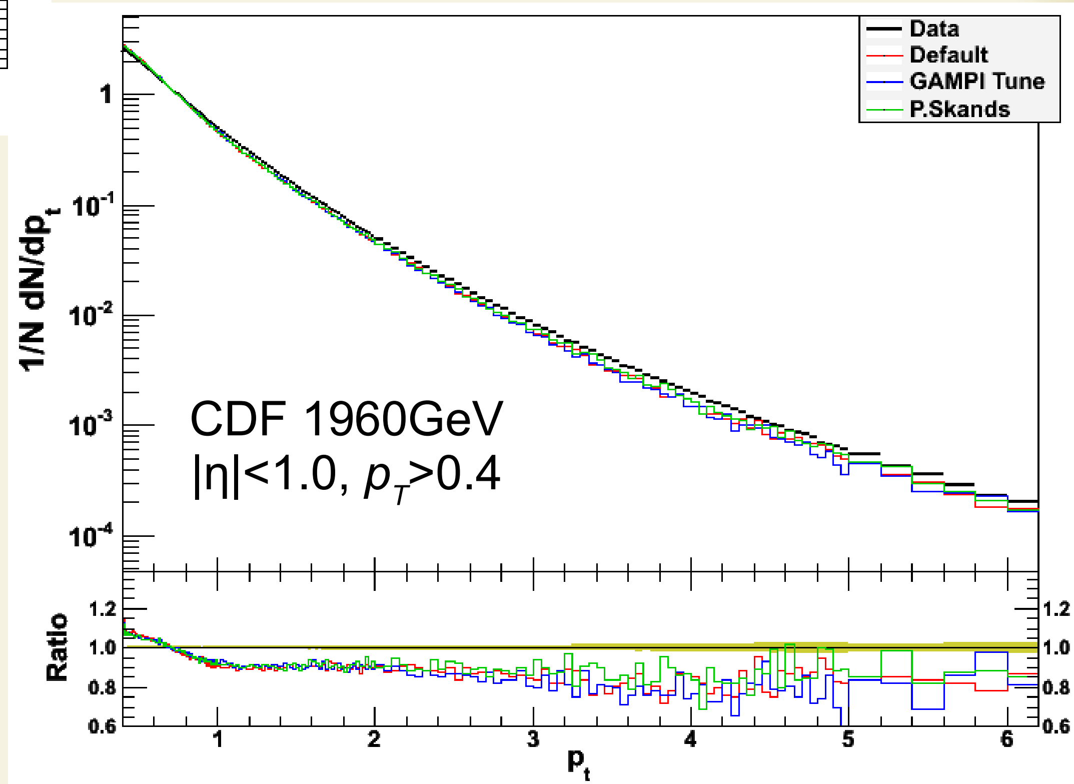
Charged Particle Multiplicity distribution is significantly improved. Low multiplicity region is not well described by the model.



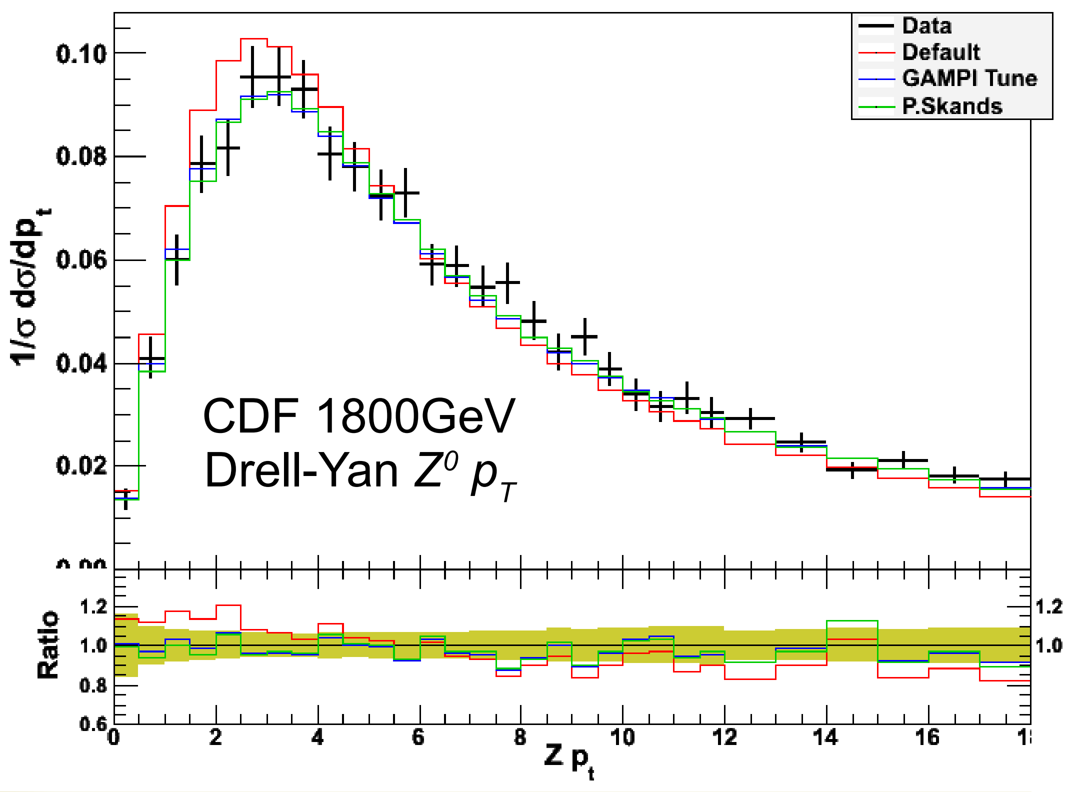
Genetic Algorithm tune(blue) has better description than the tune from Peter Skands(green). Other distributions are similar.



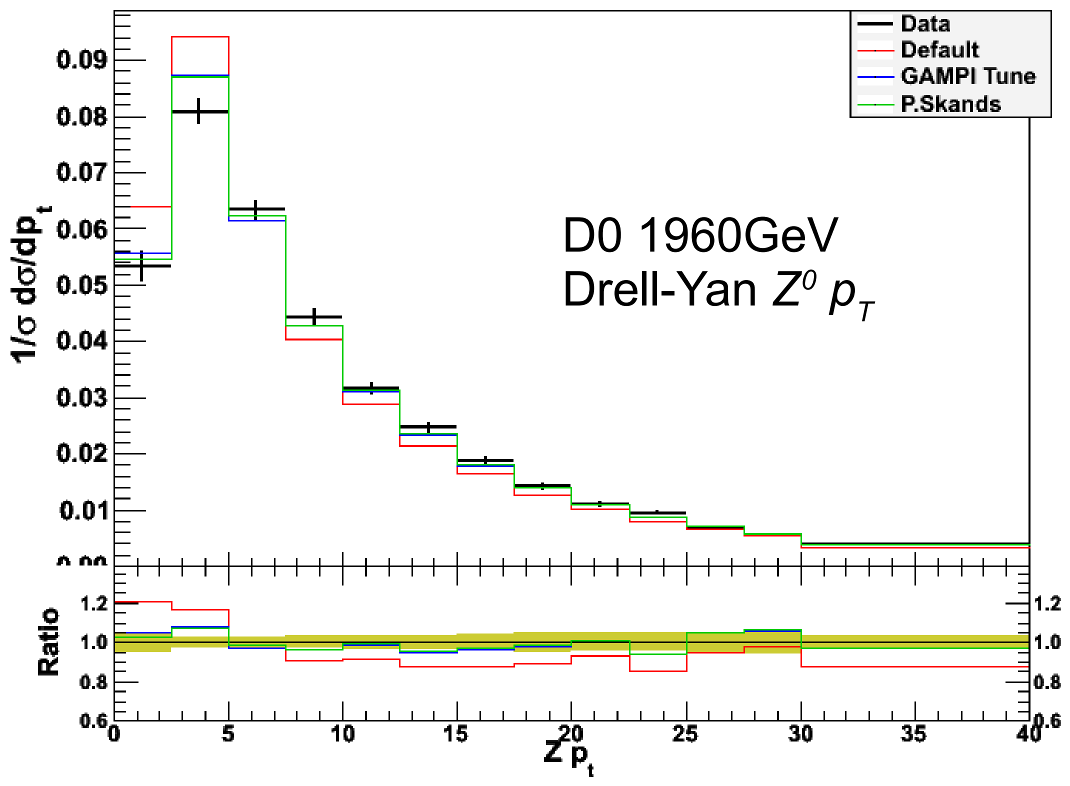
Mean p_T distribution agreement is also better than defaults. Low multiplicity region is slightly off from the measurement.

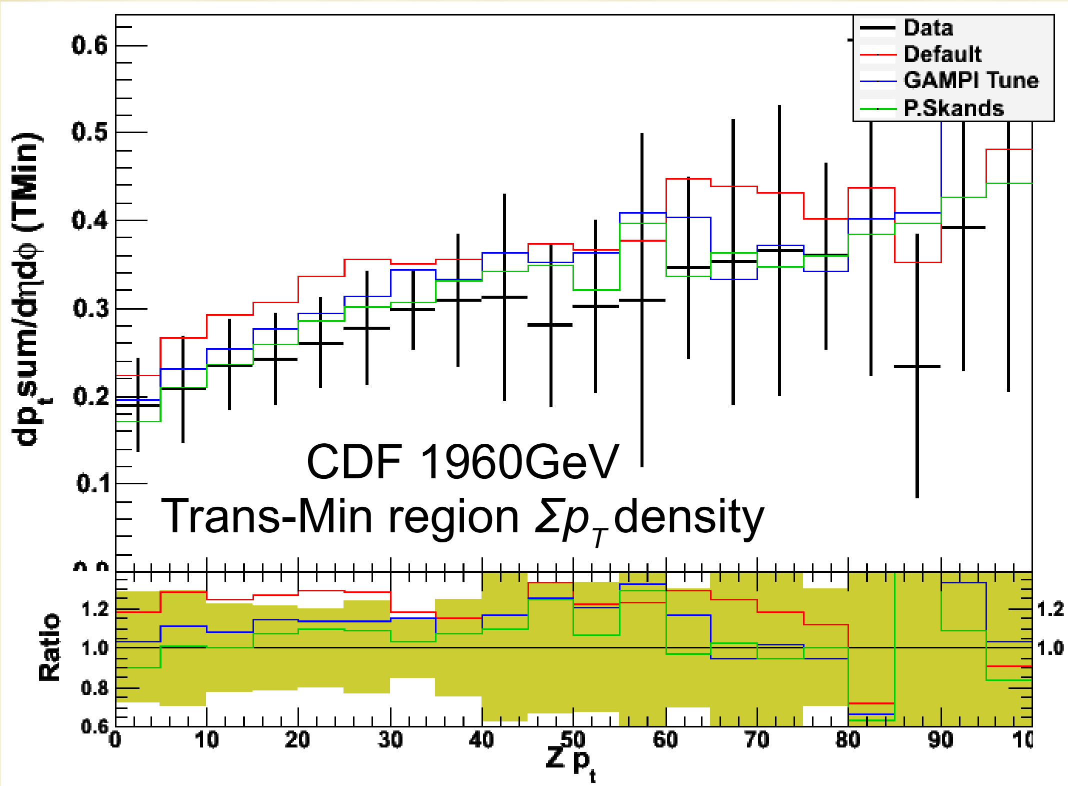


No significant difference between the tunes in p_T distribution

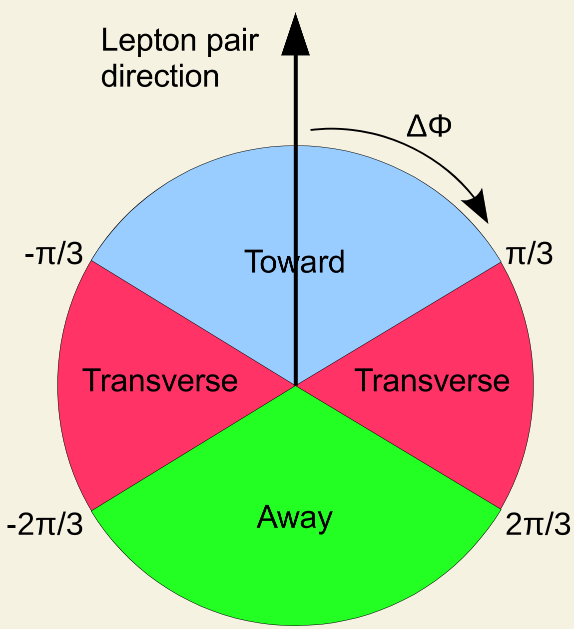


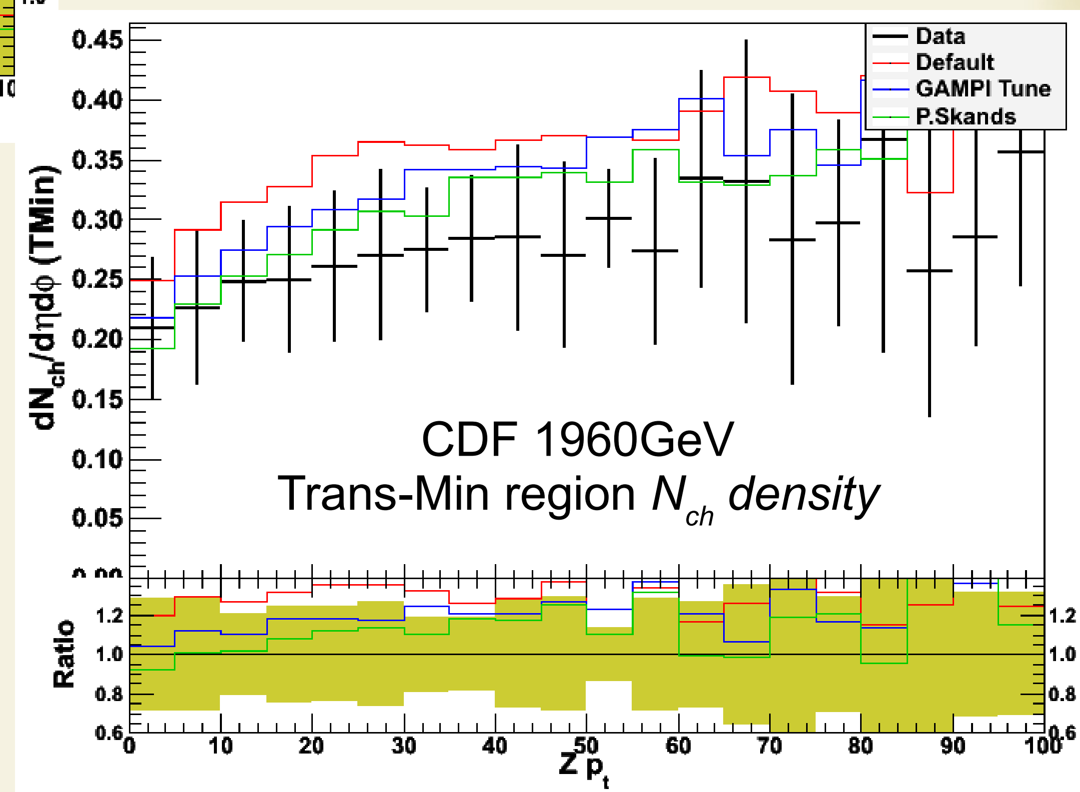
Slight improvement on the description of p_T of Z^0 in Drell-Yan events at 1800 and 1960 GeV



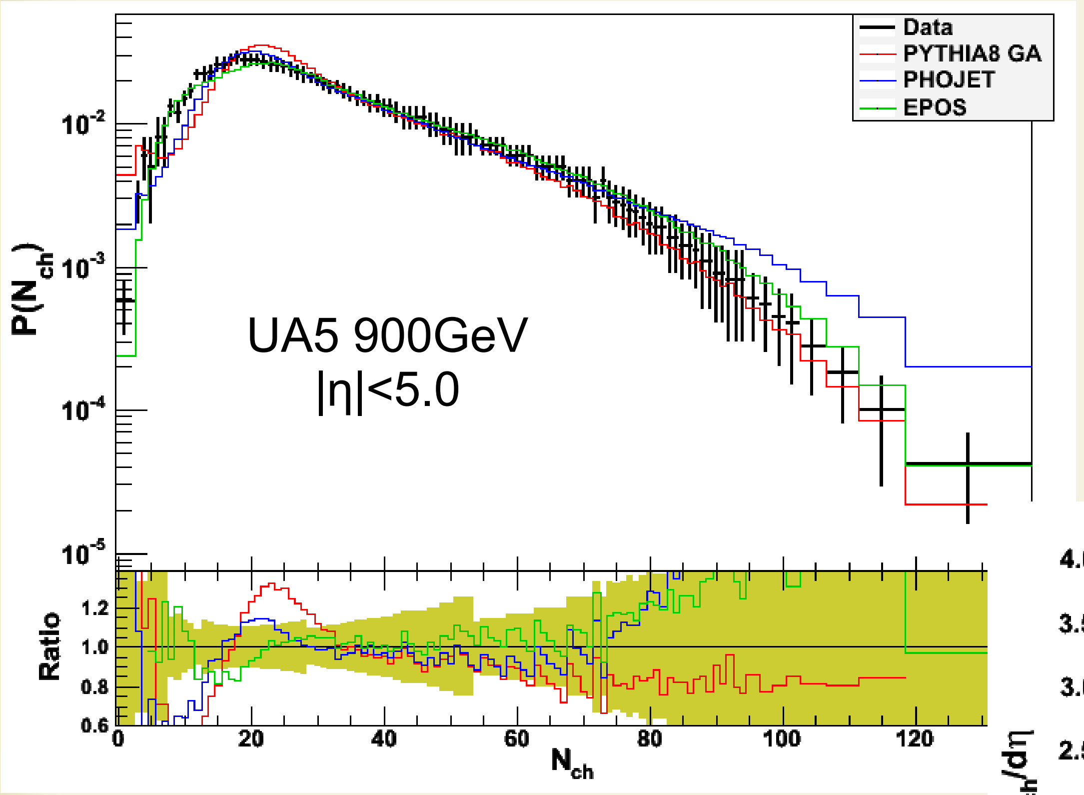


Descriptions of scalar sum density of p_T and N_{ch} density in the less active transverse region(Trans-min) in underlying event analysis in Drell-Yan events are improved. Trans-Max region is similar.

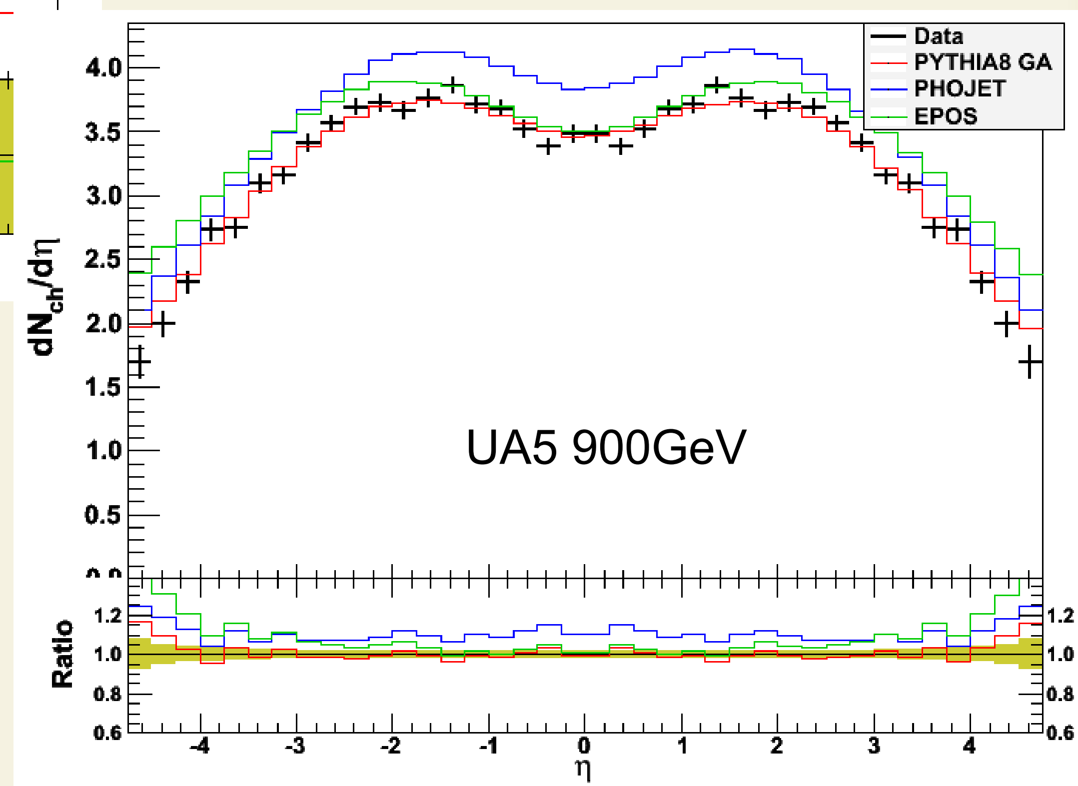




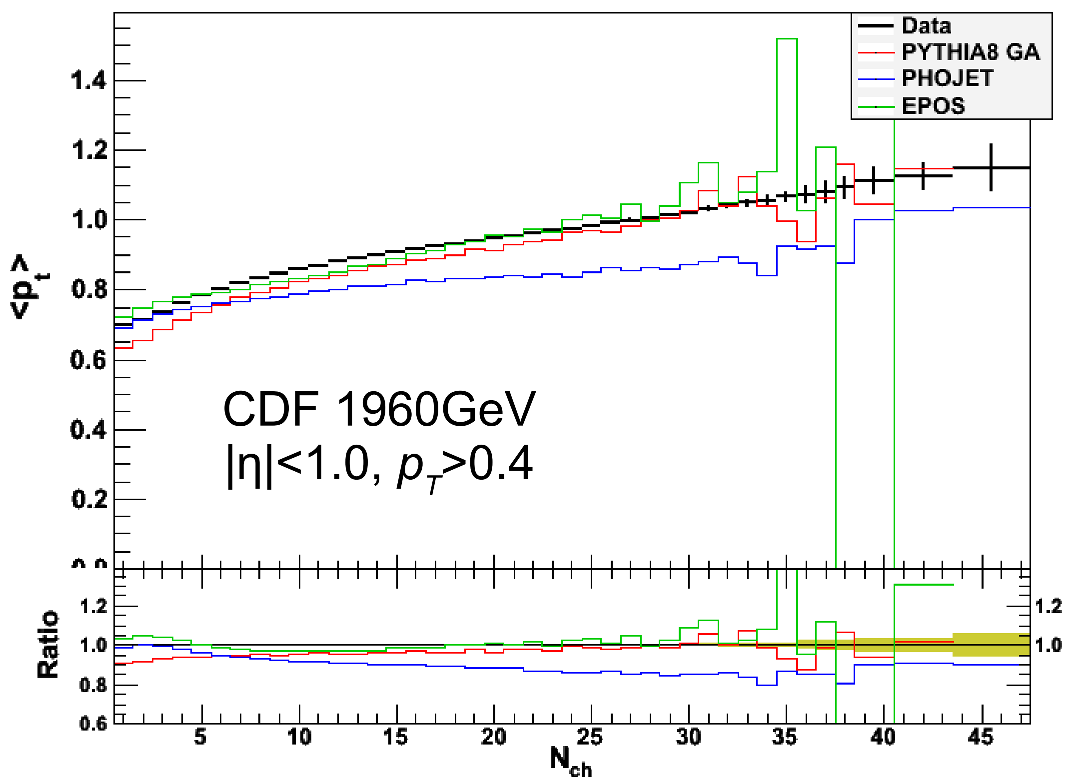
Comparing with Other Generators



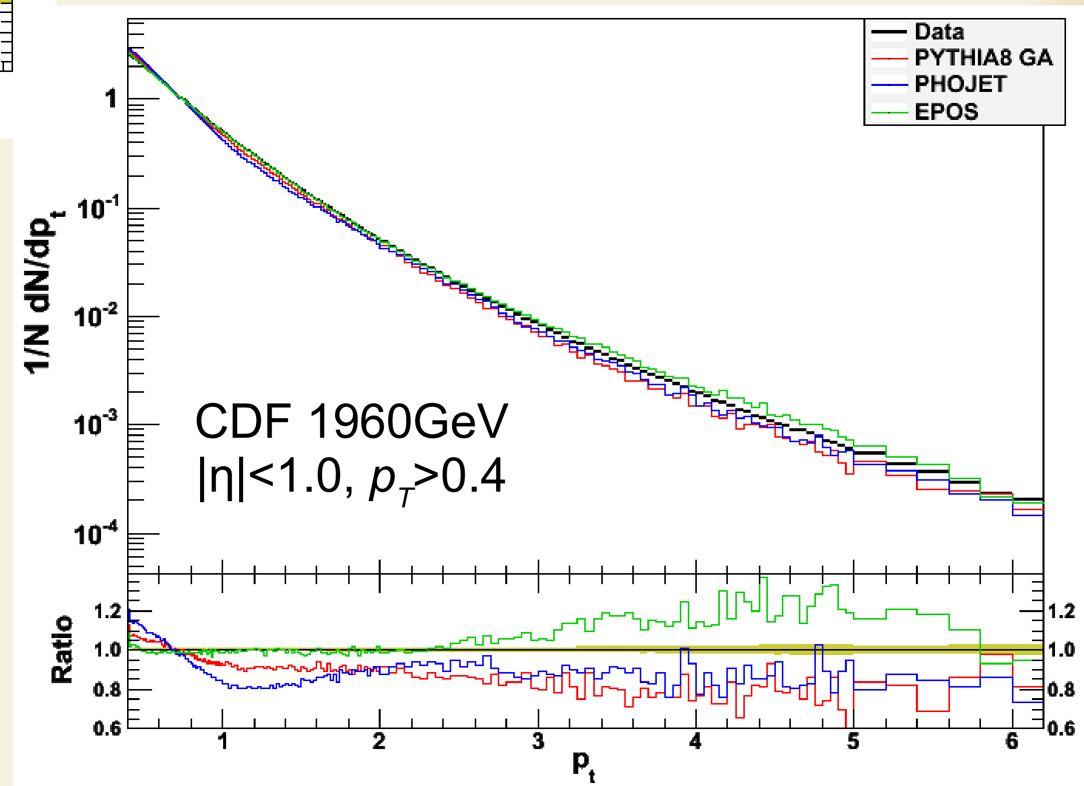
EPOS has closest reproduction of the charged particle multiplicity distribution slightly worsening at the tails. GAMPI tune is good at the tails however worsens in the low multiplicity where Phojet does slightly better job. But it fails in the tails



GAMPI Tune has excellent description of the Charged particle distribution. EPOS has good agreement in low *η* range over estimating at higher *η*. Phojet is about 10% above the data.

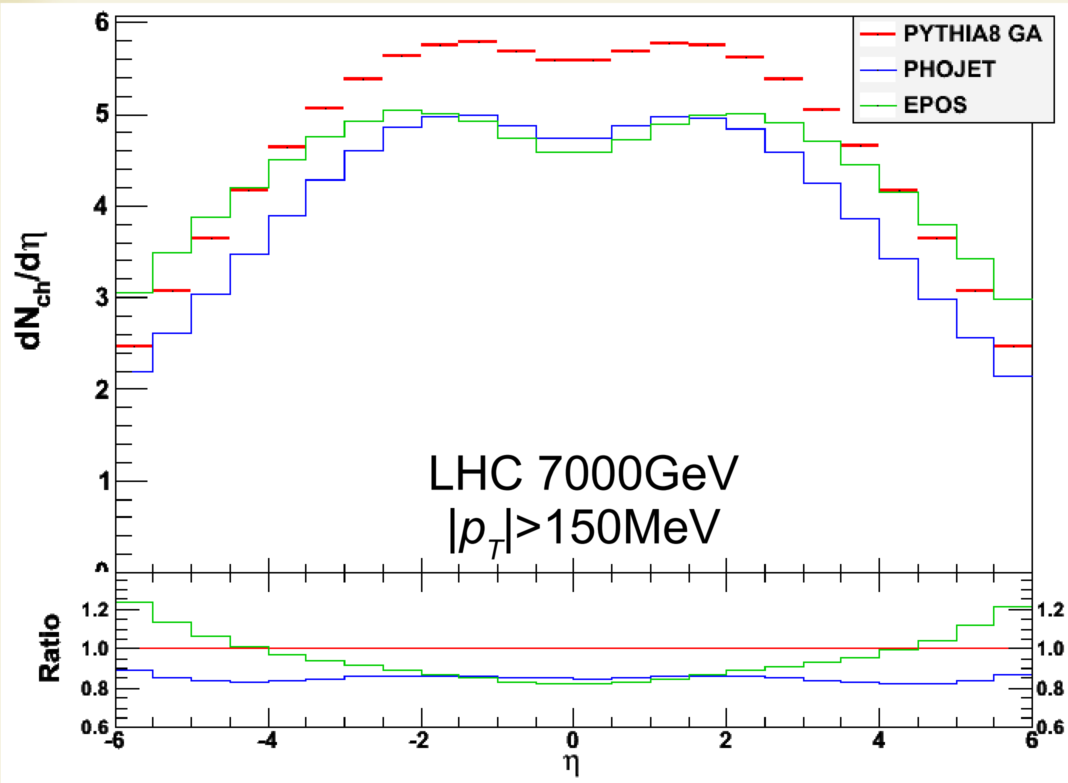


Shape of the mean p_T distribution of Phojet is flatter and disagrees with the data. EPOS and Pythia has acceptable agreement with the data.

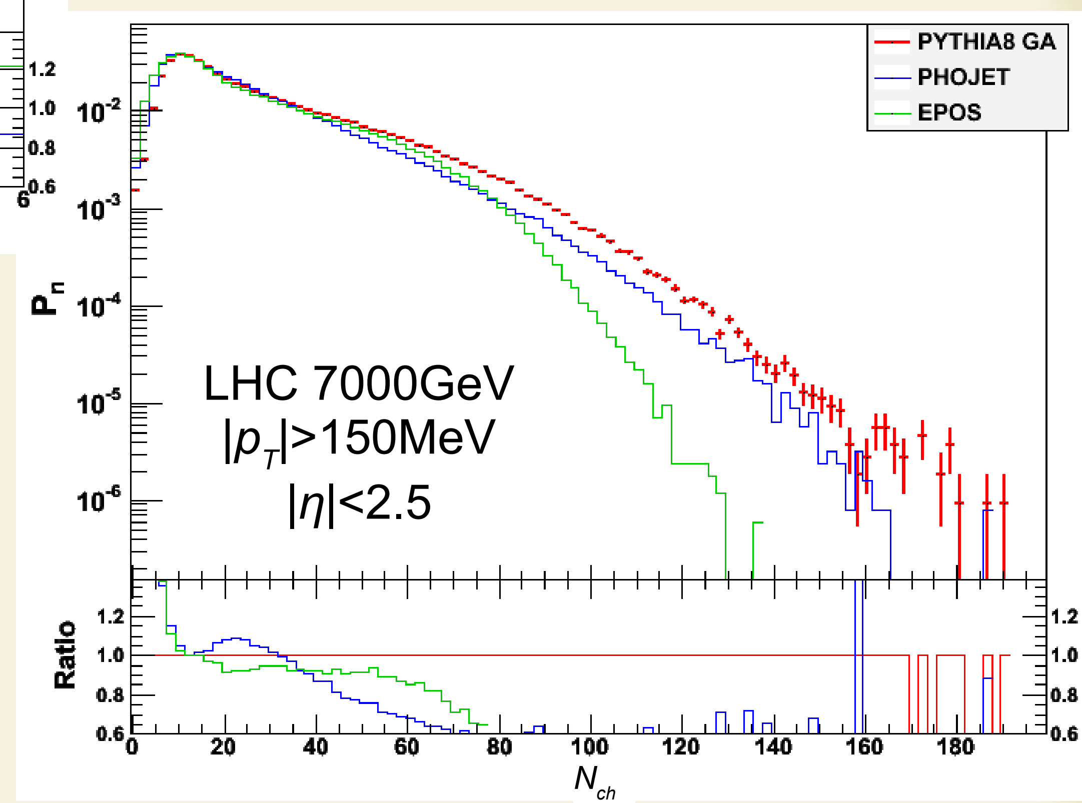


EPOS has a good description of the p_T distribution especially at low p_T. GAMPI tune and Phojet are comparable at the tails, however Pythia has a better description of low p_T

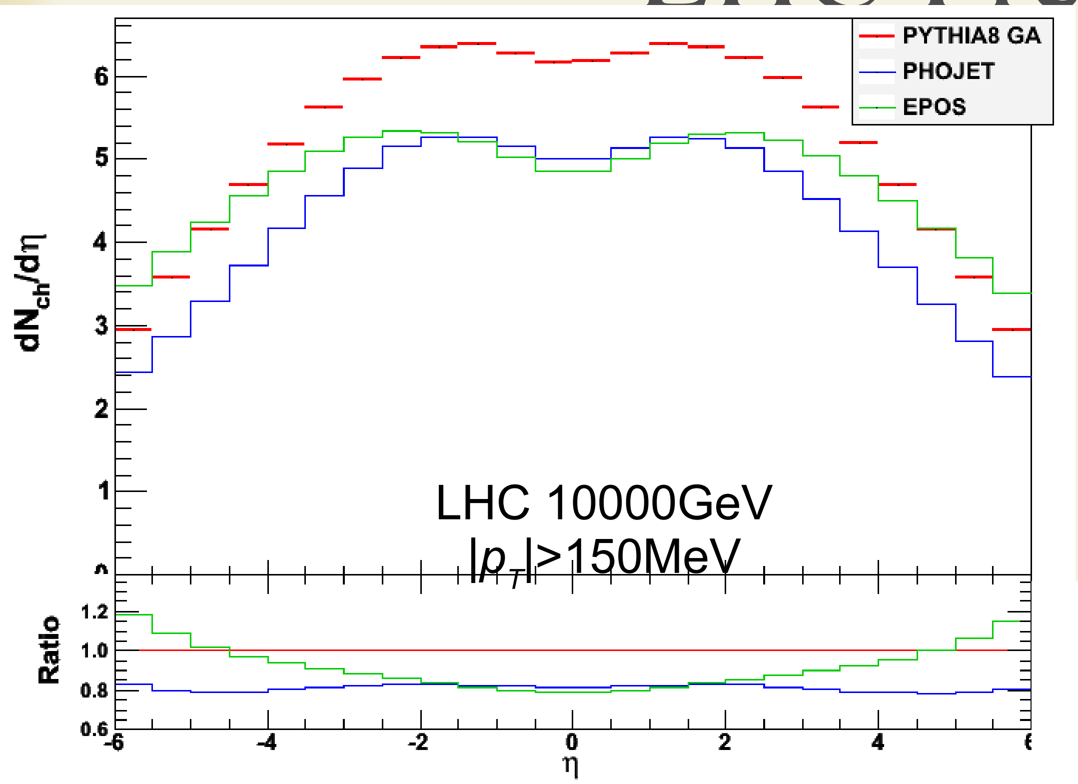
LHC Predictions



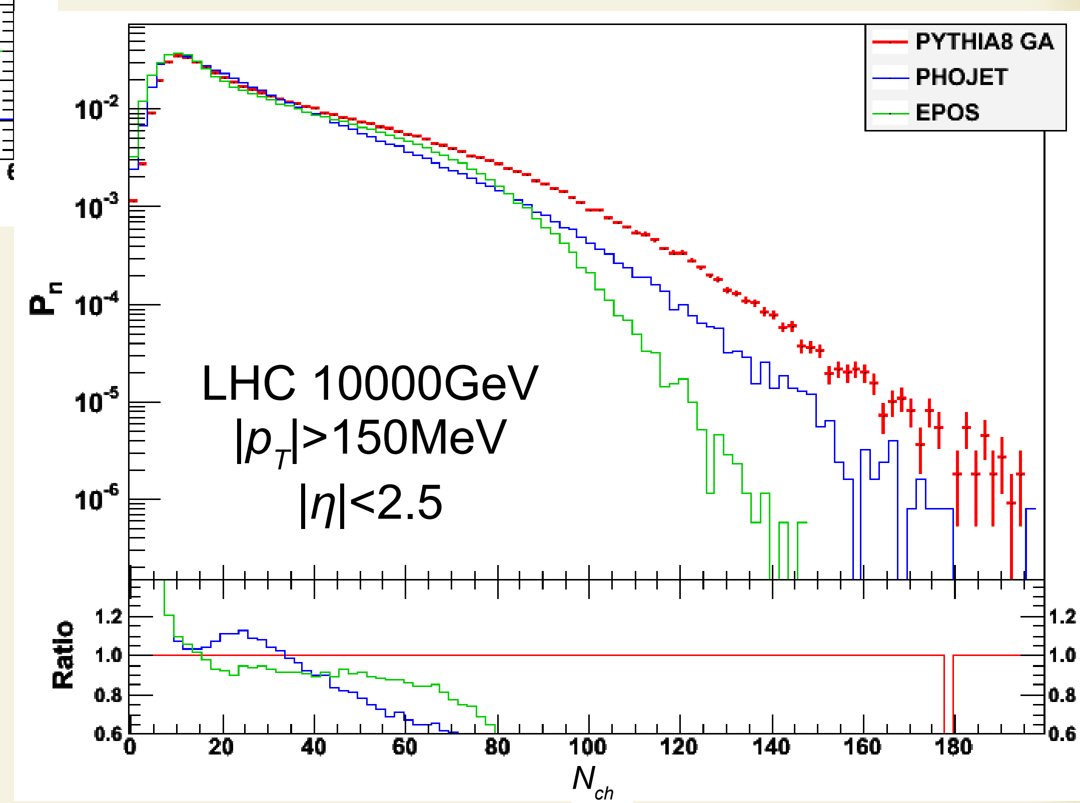
Generator level charged particle multiplicities at 7TeV, requiring at least one charged particle in both side of the detector in range 2.12<|η|<3.85



LHC Predictions



Differences become more apparent at 10TeV



Conclusions

- Trigger monitoring is an important and challenging task. OMD is versatile tool covering a small part of this task.
- Genetic algorithms can be used for Monte-Carlo tuning, finding tunes comparable to or better than alternative methods.
- Minimum bias events have to be modeled properly in order to make precise measurements at high energies.
- Predictions of soft interaction models are different at high energies.

THANK YOU

BACKUP

Trigger Conditions(UA5)

Data taken with trigger conditions which require at least one charged particle in pseudorapidity ranges $-5.6<\eta<-2.0$ and $2.0 <\eta< 5.6$. Method of maximum entropy used for the trigger and detector acceptance. Data contains only the primary particles. Errors in multiplicity data are strongly correlated.

There are two triggers for different data.2-Arm trigger is at least one hit in both η ranges $2.0<|\eta|< 5.6$ and selects mainly (Non single-diffractive(NSD) trigger. 1-Arm trigger requires hit only one arm to select highly asymmetric events like single diffractive(SD) events. Data are corrected for secondary tracks,trigger efficiency, geometrical acceptance losses. Plots here are using data for NSD events and symmetrized for -ve η.

Trigger Conditions (CDF)

Data 1960 was taken with minimum bias trigger which requires hits in both hemispheres in range $3.7< |\eta| <4.7$. Data is corrected for track detection and reconstruction efficiency, contamination from secondaries, particle decays and misidentification. Only primary tracks with $p_{t}>0.4GeV$ and $|\eta|\le1.0$ used.
1800 GeV and 630 GeV Multiplicity data and transverse momentum distribution trigger requires hits in $3.2< |\eta| < 5.9$ in both hemispheres. Only tracks with $p_{t}\ge0.4GeV$ and $|\eta|\le1.0$ There is no reference for corrections for secondaries. Only track reconstruction efficiency is corrected.

$dN/d\eta$ plot trigger requires hits in $3.2< |\eta| < 5.9$ in both hemispheres. Additionally only events which have at least 4 tracks in $|\eta| <3.0$ with at least one in both forward and backward hemispheres. Data is corrected for secondaries. Also pt spectrum extrapolated to 0. to take kinematical acceptance into account.

In simulation required two charged particles in the trigger η ranges to approximate trigger,then applied fudical cuts ($|\eta|<1.0$, $p_{t}\ge0.4$.

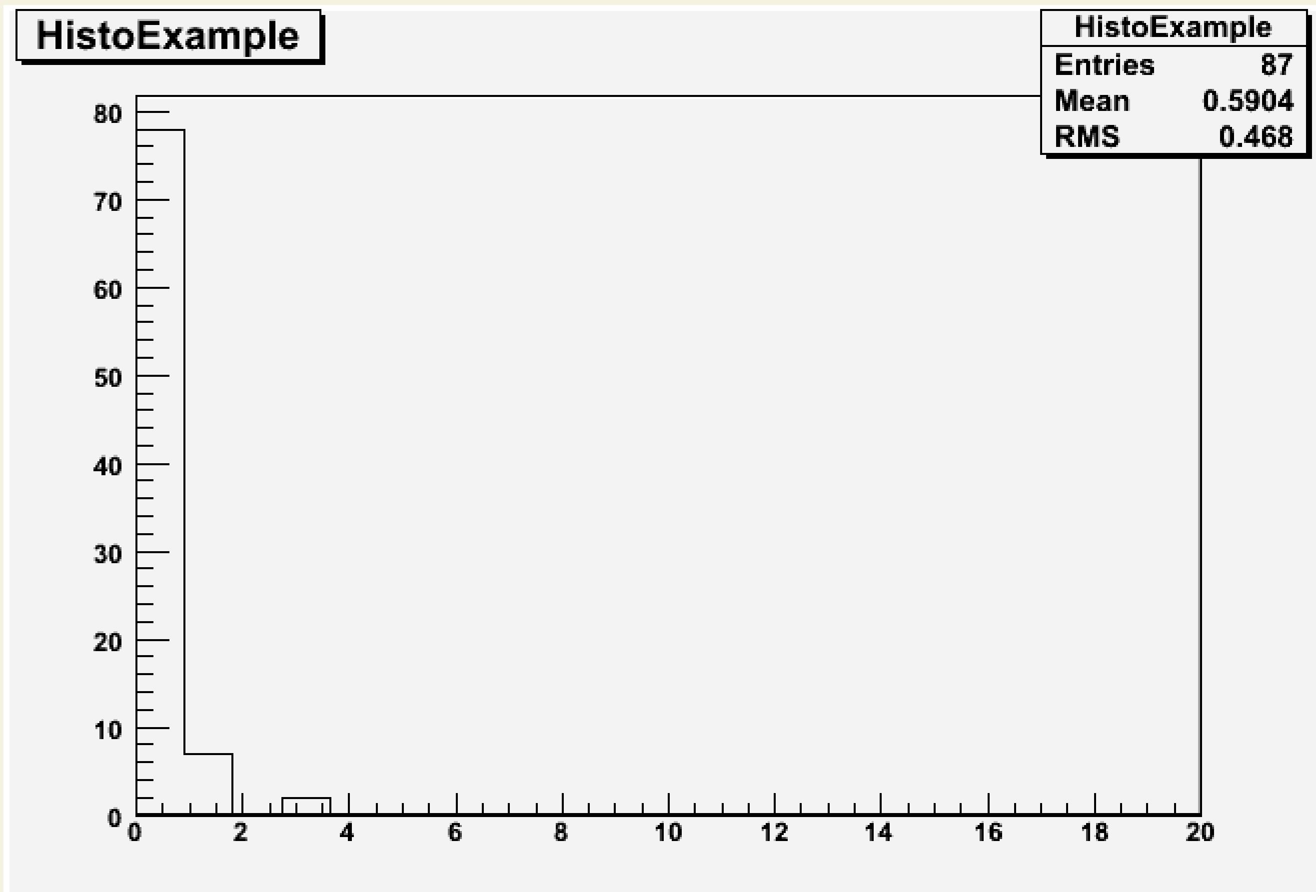
Drell-Yan and UE

D0 data is corrected for acceptances and efficiencies within Z masses of 40 to 200GeV. Used Z^{0} from the generator for plots.

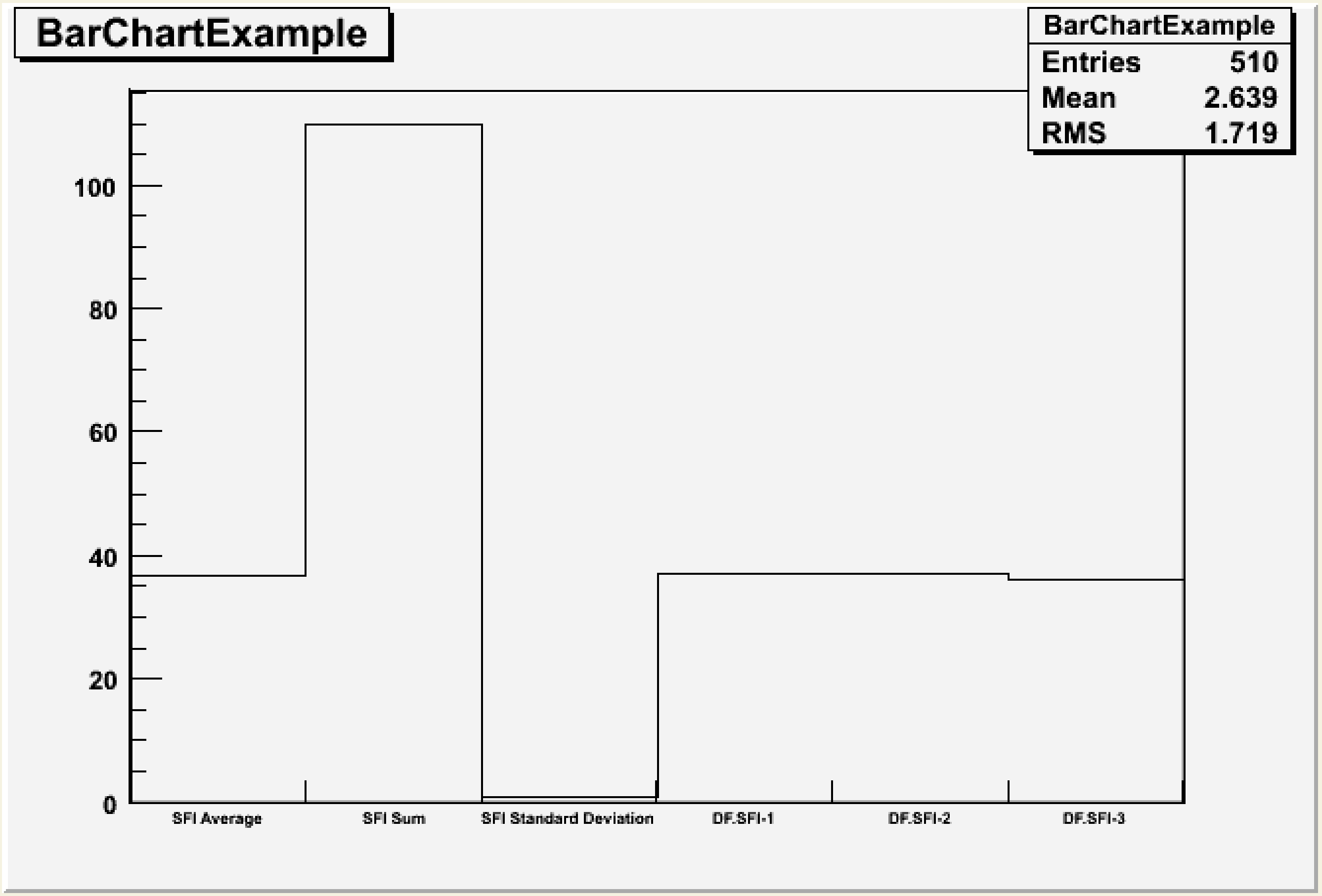
CDF Drell-Yan 1800GeV data used Z^{0} in the range 66 to 116GeV. directly from generator.

Underlying event data required an $e^{-}e^{+}$ each with $p_{t}>20.$ and $70<M_{inv}<110.GeV$, $|\eta_{Z_{0}}|<6.$. TransMax(Min) region is defined as transverse region with respect to $\theta_{Z_{0}}$ which has Max(Minimum) $\sum p_{t}$ or n_{ch}

Histogram styles (Histogram)



Histogram Styles (Bars)



Histogram Styles(2D)