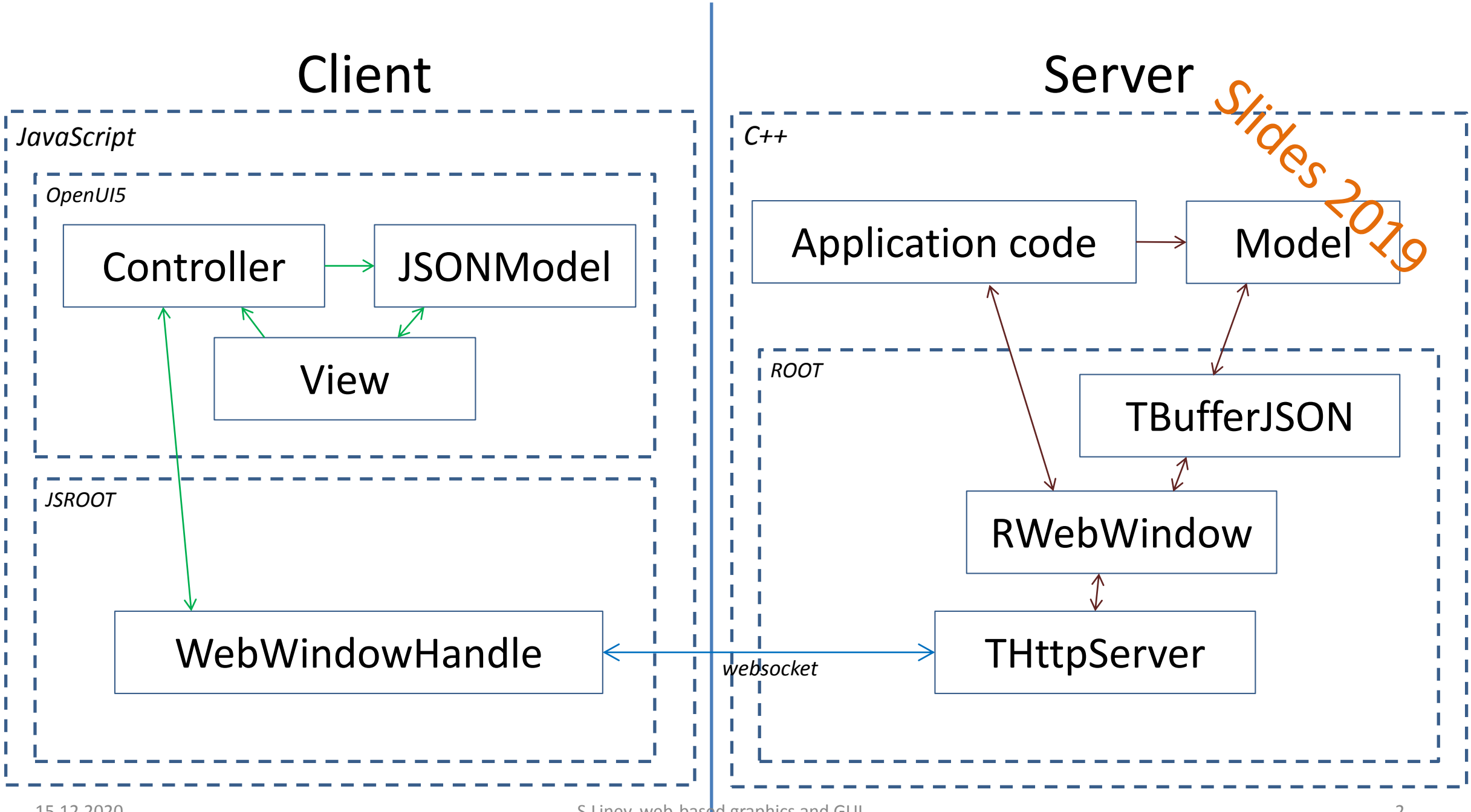
Web-based graphics and GUI

- Highlights from the past year
- Where to go?

Sergey Linev

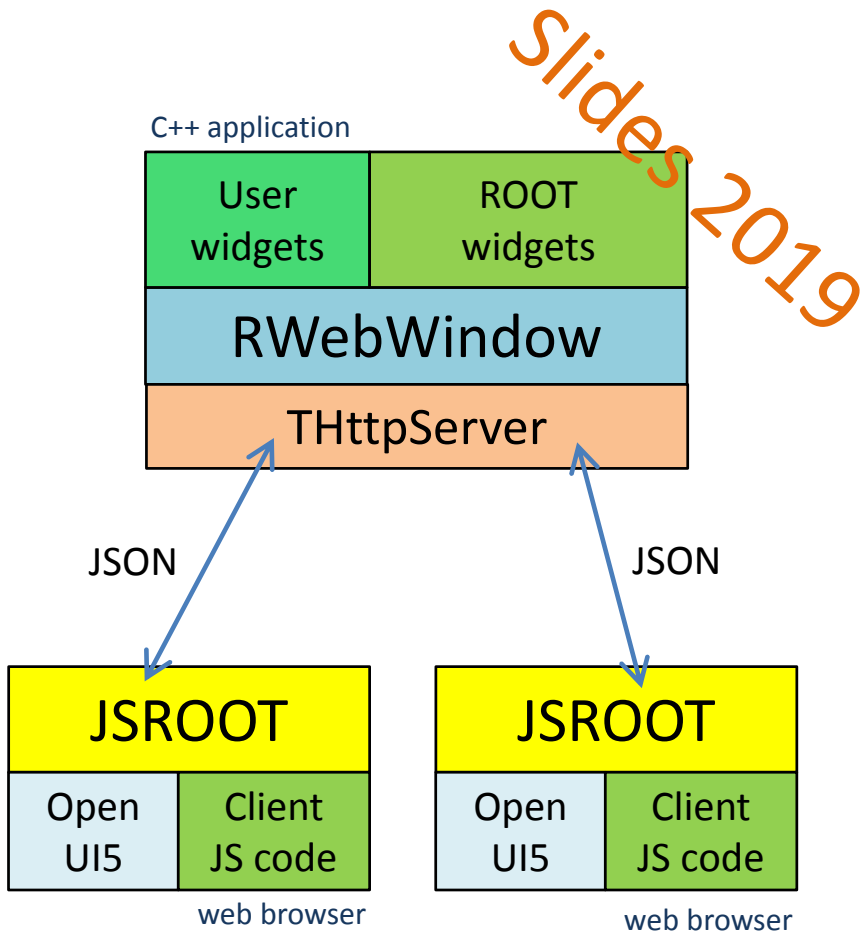
15.12.2020


Client
Server
slides 2019
JavaScript
C++
OpenUI5
Controller
JSONModel
View
Application code
Model
ROOT
TBufferJSON
JSROOT
RWebWindow
WebWindowHandle
THttpServer
websocket

RWebWindow

- Gateway to web-based displays in ROOT

- Launch web browser(s)
  - special support for Chrome and Firefox
  - headless mode, used for batch mode
- Local web displays
  - Chromium Embedded Framework **CEF**
  - Qt5 *QWebEngine* – also chrome-based
- Communication via websockets
- Openui5 support
  - any other GUI framework can be used
- Offline support
  - client code can be used without running ROOT



RWebWindow plans

- Connection sharing between widgets
  - prototyped now with RFileDialog in RBrowser
  - ~1 month

done!

Slides 2019

- Integration with JupyterLab
  - reuse web services
  - ~2 months

only JSROOT integration

- MDI inside single web-browser page (optional)
  - handle many different widgets (canvases, browsers, fitpanel) in same browser window
  - example: https://root.cern/js/latest/api.htm#url_syntax_flexible_layout
  - use same connection, same context, do not reload JS again
  - ~3 months

not touched

RWebWindow – batch mode

Slides 2019

- Already working:
  - Google Chrome, but requires http
  - Mozilla Firefox, also requires http
- Can be implemented:
  - Node.js - based solution
    - text/SVG/WebGL rendering is not trivial
    - use external tools like ImageMagic?
  - CEF
    - uses X11, can be replaced by other implementation
    - requires custom compilation, extremely large and introduces many dependencies
- Main unresolved issue for 2020
- Work estimation: ~3-6 months

RWebWindow – batch mode

Solved!

- Already working:
  - Google Chrome~~, but requires http~~ without http!
  - Mozilla Firefox~~, also requires http~~ skipped, but hope to get soon
- Can be implemented:
  - Node.js - based solution working!
    - text/SVG/WebGL rendering with system-provided libs
    - ~~use external tools like ImageMagic?~~ not necessary!
  - CEF is also working now!
    - uses X11 by default, can be replaced by Ozone
    - requires custom compilation, can be solved by LCG builds

- Main ~~unre~~**solved** issue for 2020
- Work estimation: ~2 months

ROOT components using webgui

- TCanvas

- RCanvas
- RBrowser
- REve
- RFitPanel
- RGeomViewer

RCanvas

- Full redesign of TCanvas class
- No gPad!
  - threads safety
- RDrawable
  - graphical primitive
  - attributes
  - reference data object
- RPadBase
  - maintain list of primitives

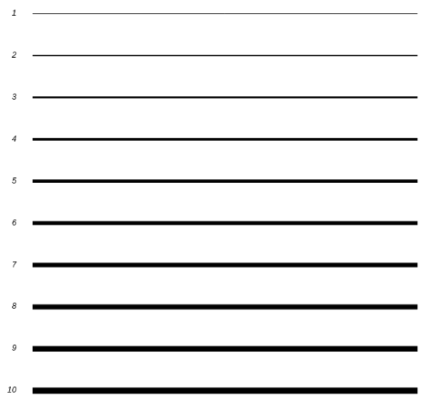
Slides 2019

```
#include "ROOT/RCanvas.hxx"
#include "ROOT/RHistDrawable.hxx"

using namespace ROOT::Experimental;

void draw_rh1()
{
   RAxisConfig xaxis(25, 0., 10.);
   auto pHist = std::make_shared<RH1D>(xaxis);
   pHist->Fill(5);

   auto canvas = RCanvas::Create("Canvas Title");
   auto draw1 = canvas->Draw(pHist);
   draw1->AttrLine().SetColor(RColor::kRed).SetWidth(2);

   canvas->Show();
}
```

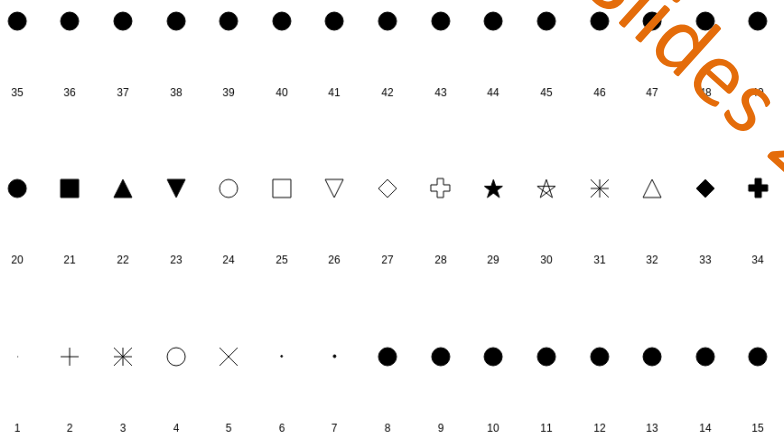
$ROOTSYS/tutorials/v7/draw_rh1.cxx

RCanvas

root $ROOTSYS/tutorials/v7/text.cxx

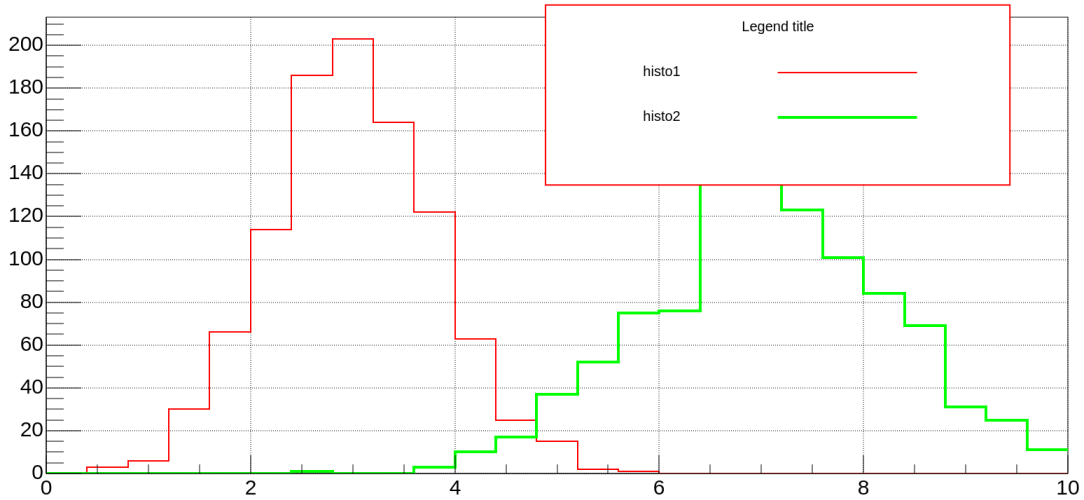


root $ROOTSYS/tutorials/v7/lineWidth.cxx

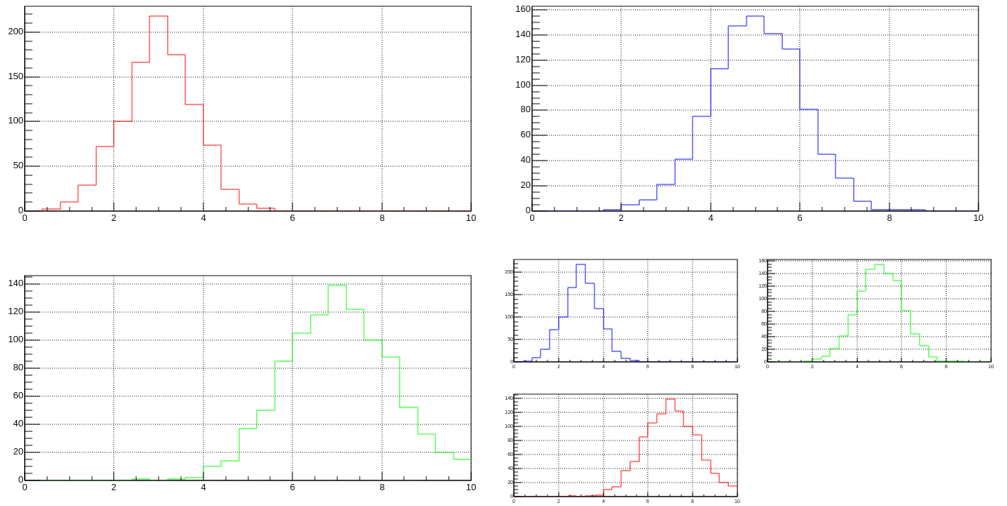


root $ROOTSYS/tutorials/v7/markerStyle.cxx

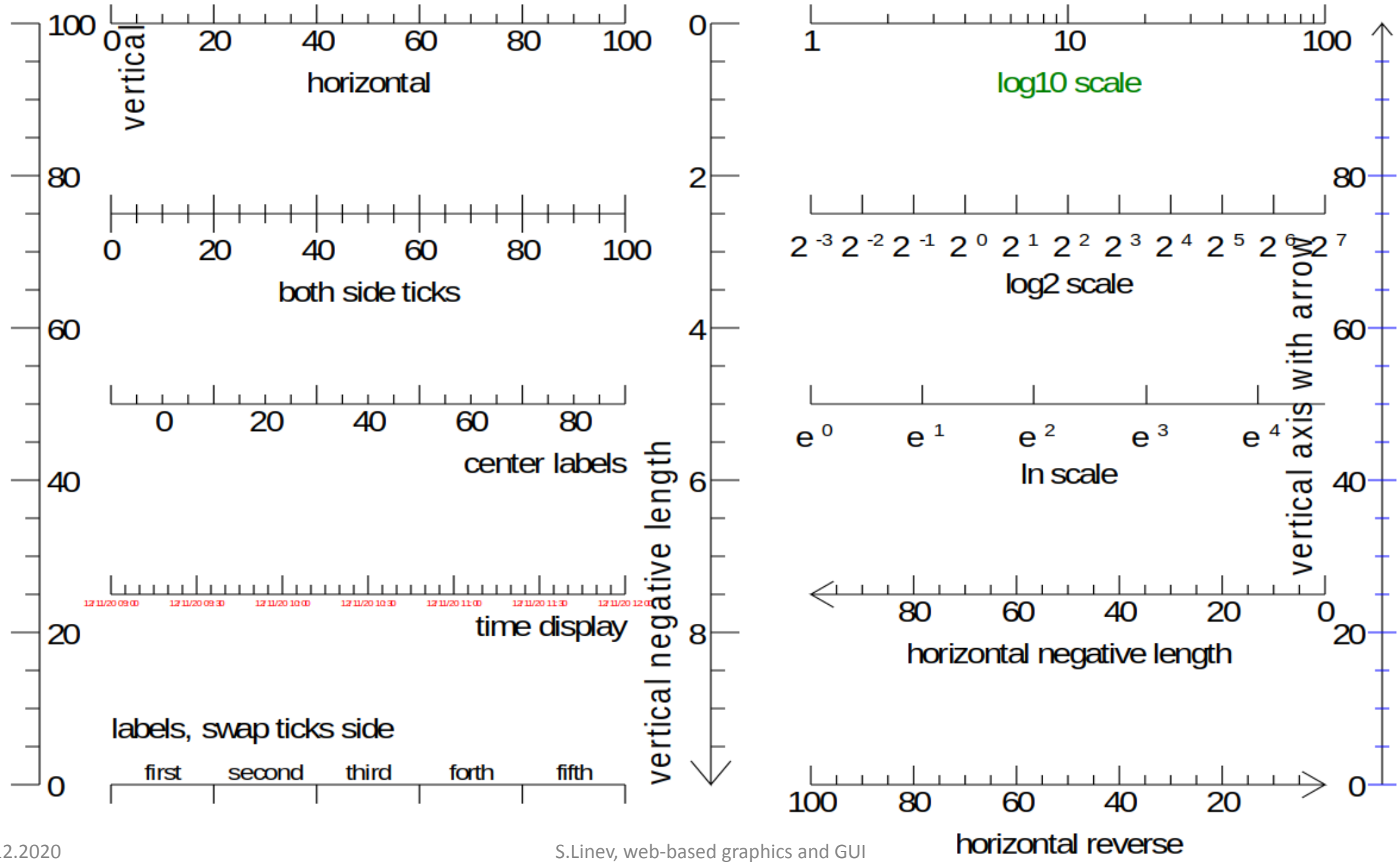
Slides 2019



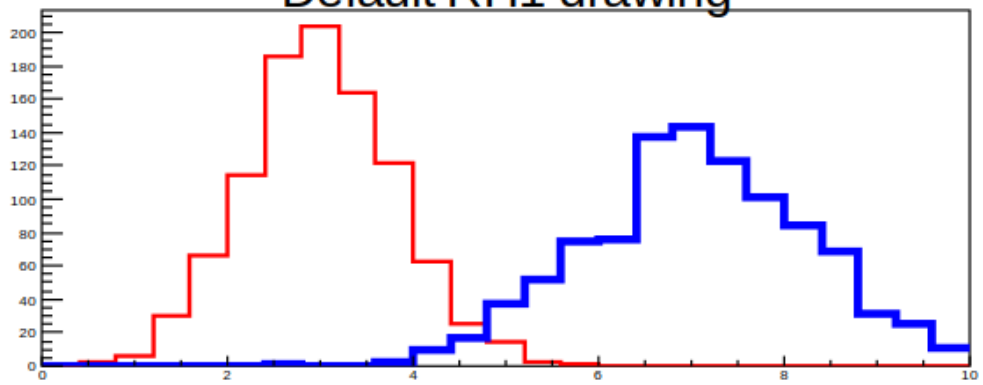
root $ROOTSYS/tutorials/v7/draw_legend.cxx



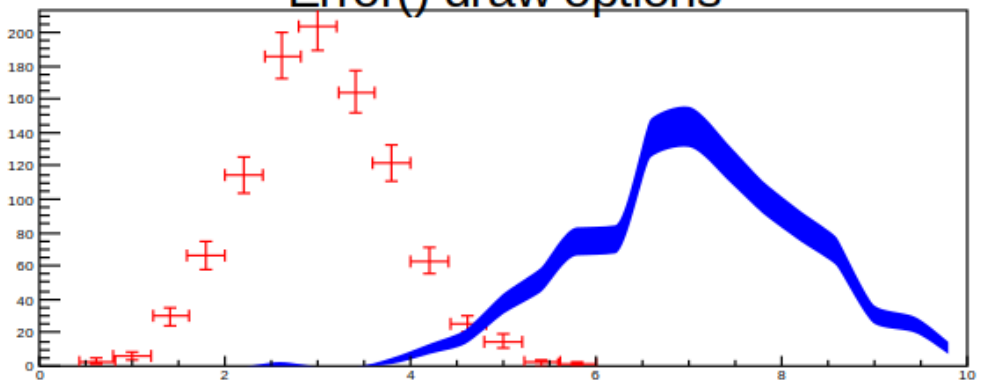
root $ROOTSYS/tutorials/v7/draw_subpads.cxx


vertical
horizontal
both side ticks
center labels
time display
labels, swap ticks side
first
second
third
forth
fifth
vertical negative length
log10 scale
log2 scale
ln scale
vertical axis with arrow
horizontal negative length
horizontal reverse

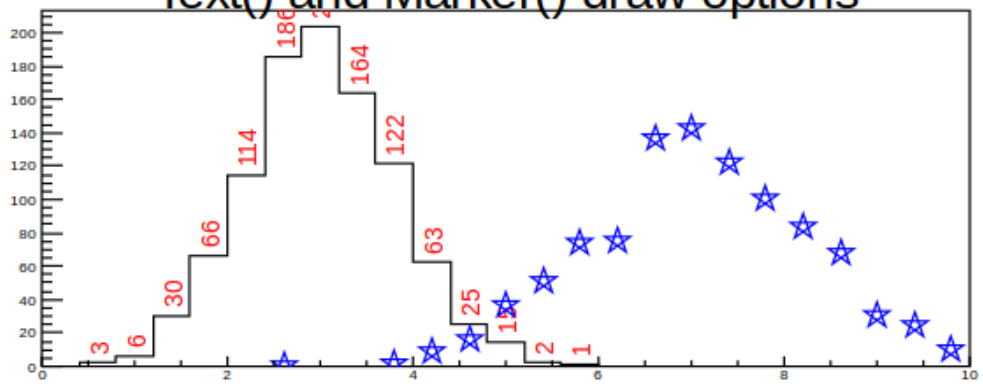
Default RH1 drawing



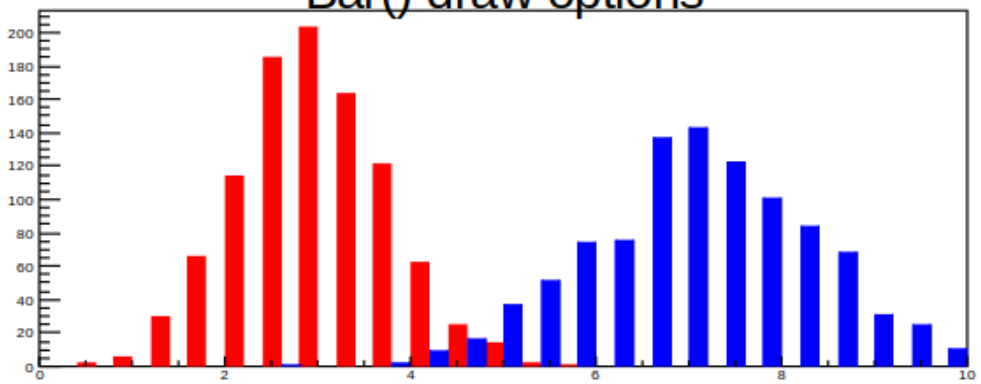
Error() draw options



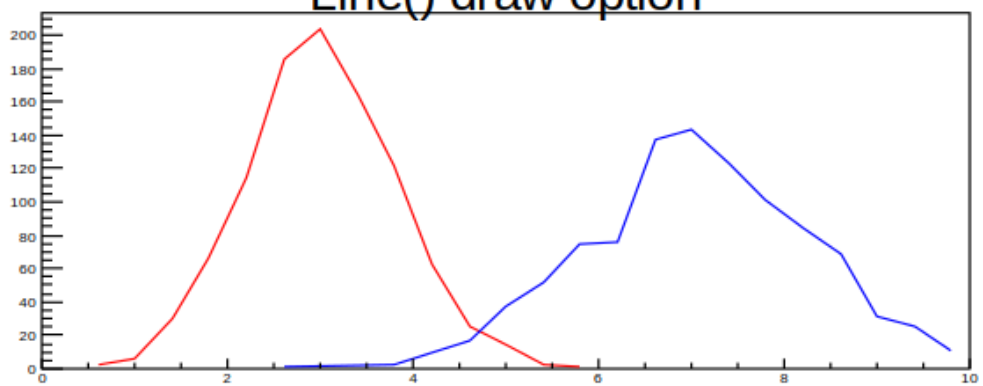
Text() and Marker() draw options



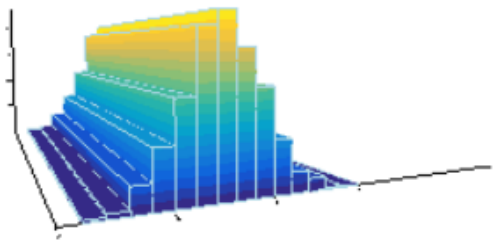
Bar() draw options



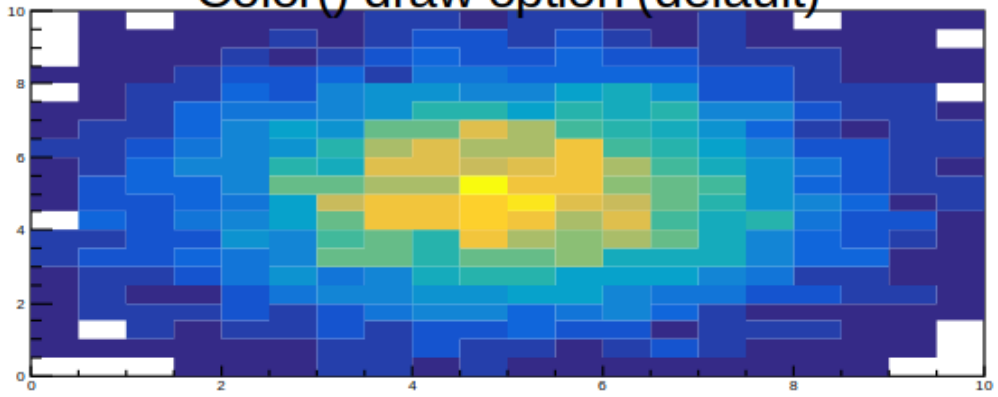
Line() draw option



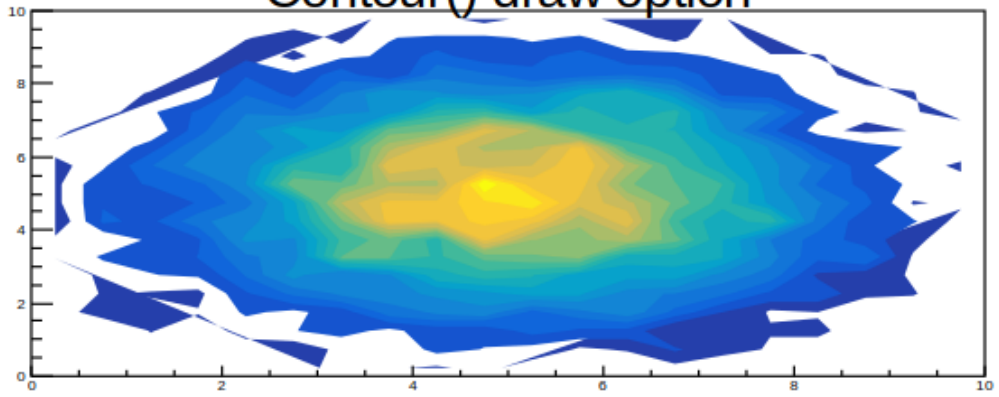
Lego() draw option



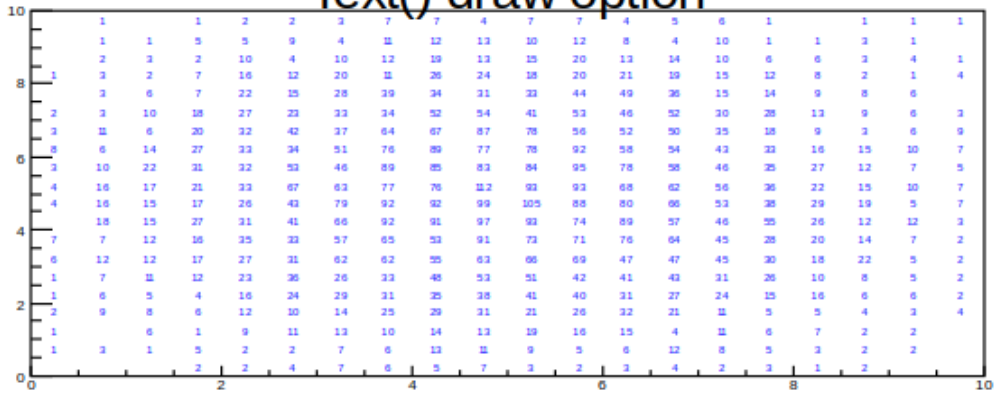
Color() draw option (default)



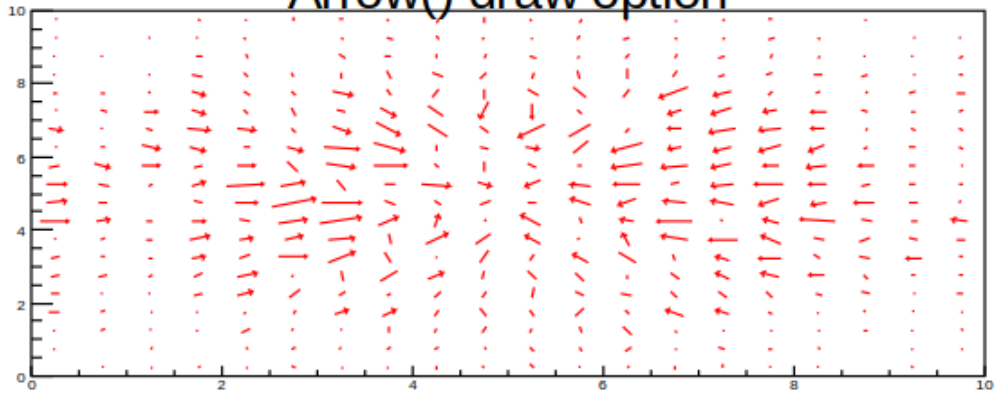
Contour() draw option



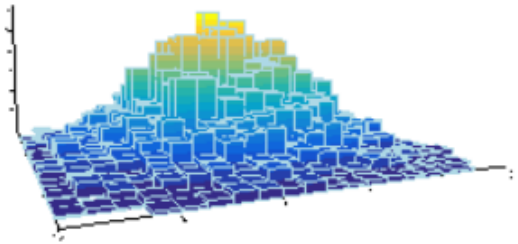
Text() draw option



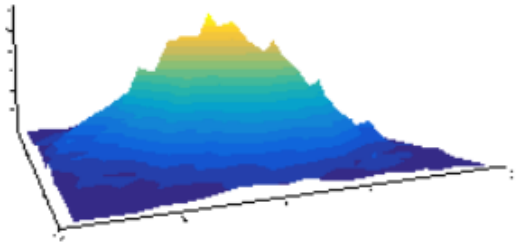
Arrow() draw option



Lego() draw option



Surf() draw option



RCanvas

Slides 2019

- Separate data (e.g. histogram) from view attributes
- Data can be shared via std::shared_ptr
  - provide I/O support, but only inside RCanvas
- Any attribute is optional
  - value can be provided with CSS-like syntax
  - default values provided in attribute classes
- Exactly same code for visual and batch mode

RCanvas plans

Slides 2019

- Basic classes: RDrawable, RPadBase, RAttrBase, RColor, ...
  - review API, ~2 months, mostly done!
- RStyle, CSS parsing
  - ~1 month, first prototype is there
- RHistDrawable (C++ & JS)
  - ~2 months, server-side pre-rendering is implemented!
- RGraphDrawable (C++ & JS)
  - ~1 month, not done – missing RGraph
- RPalette, RFrame, RLegend, RLatex, other primitives
  - ~3 months, many are done or prototyped!

RCanvas testing

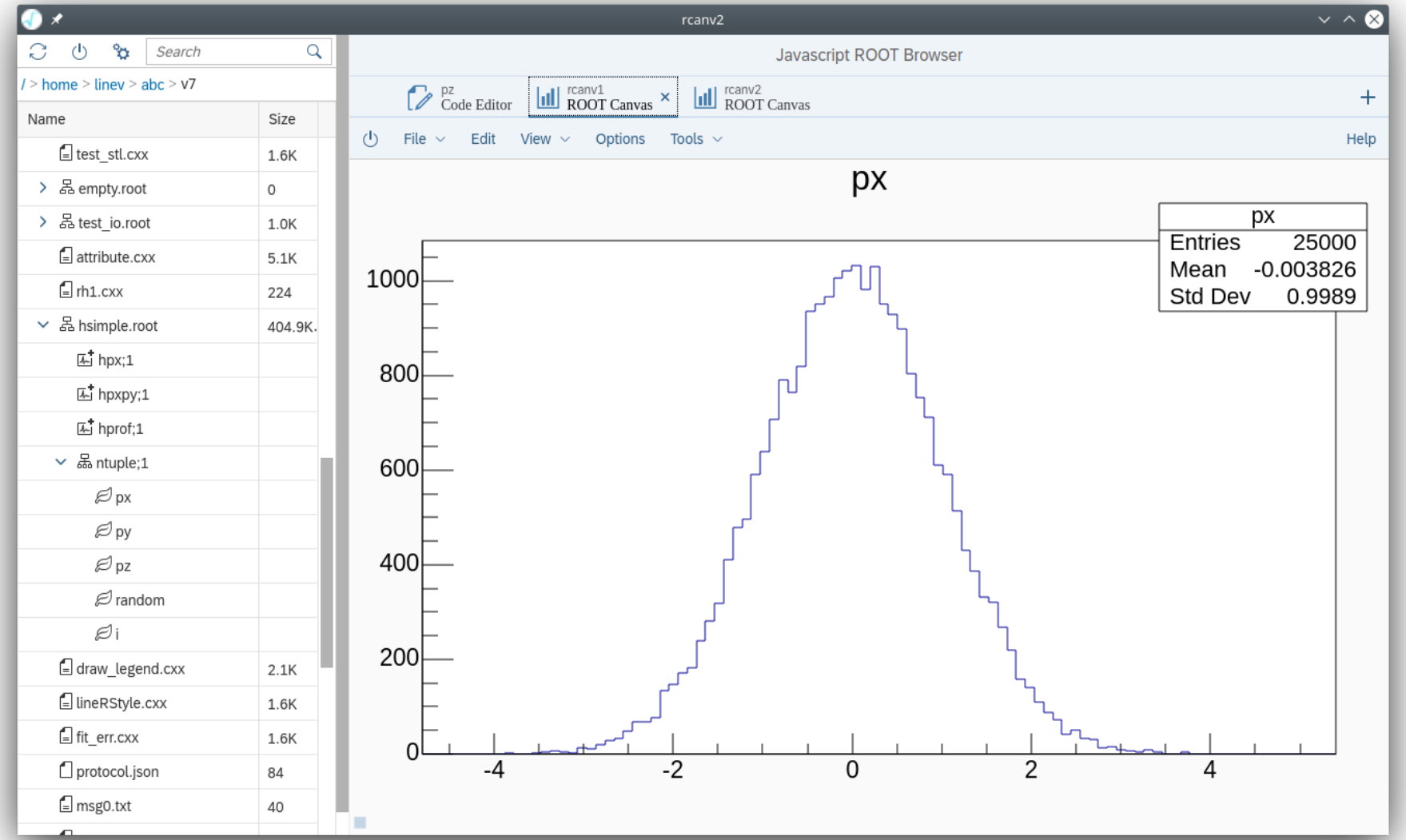
- Two kinds of tests are feasible:
  - batch jobs producing SVG images
    - either using headless browser mode (ROOT batch mode)
    - or run JavaScript code in Node.js
      - like https://github.com/linev/jsroot-test
    - ~1 month
  - interactivity tests
    - using tools like WebDriver
    - ~3 months
    - do not require deep knowledge of ROOT internals
      - good job for summer student

partially implemented

Slides 2019

not touched

RBrowser



root $ROOTSYS/tutorials/v7/browser.cxx

Slides 2019

- Browse:
  - file system
  - ROOT files
  - TTree
- Display objects with:
  - RCanvas (ROOT7)
  - TWebCanvas (ROOT6)
- Edit text files
  - openui5 code editor
- View images
- Scalable hierarchy browser
  - load only visible items
- RBrowsable adapter classes:
  - object management
  - iterators over sub-elements
  - support old TObject::Browse(TBrowser*)
  - custom client info

RBrowser plans

- RBrowsable
  - revise API
  - implement adapters for major ROOT classes
  - ~2 months

mostly done

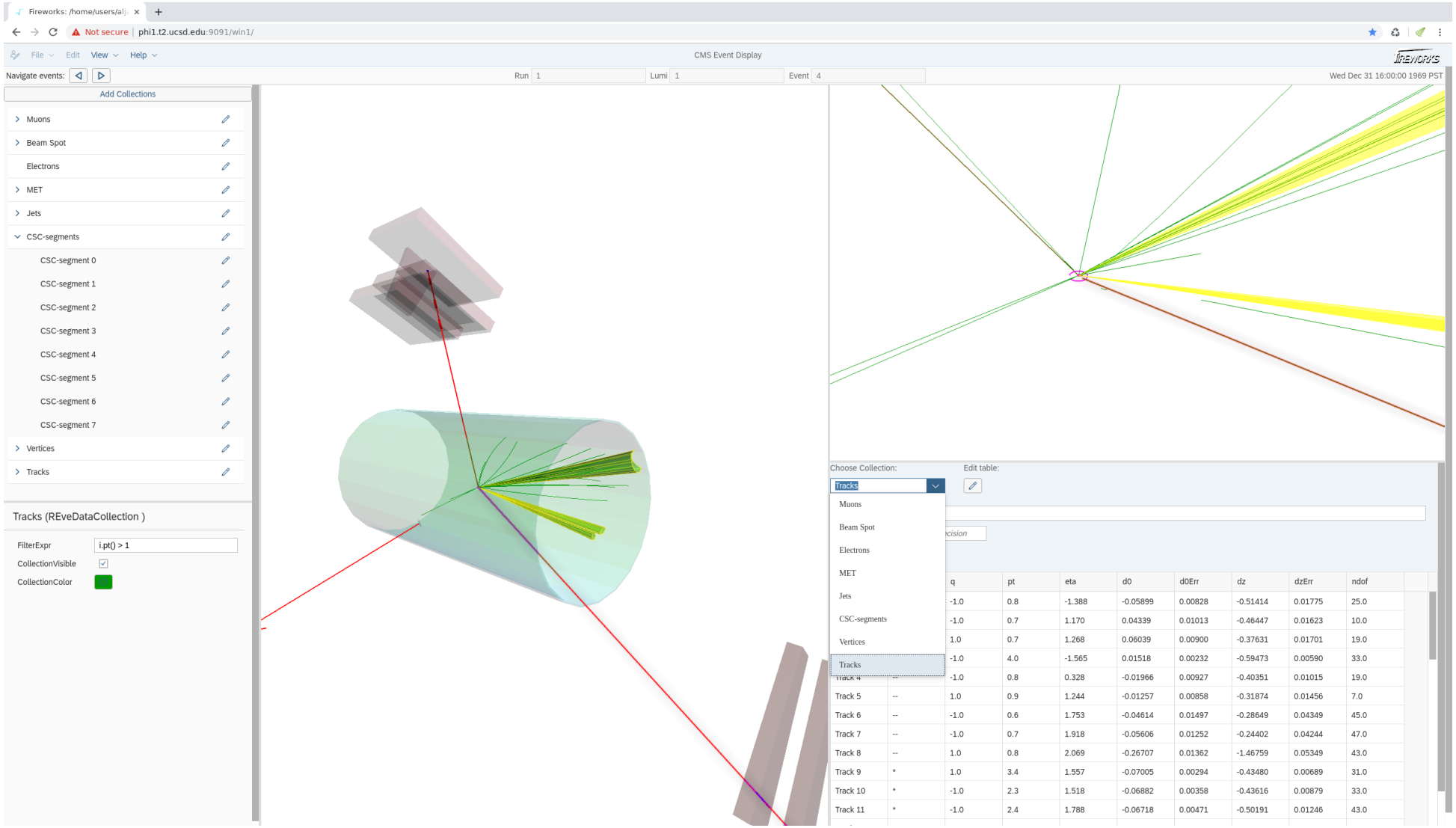
Slides 2019

- Provide RFileDialog
  - to be used in different components

done

- Overall work estimation: ~4 months

Eve7 and FireworksWeb

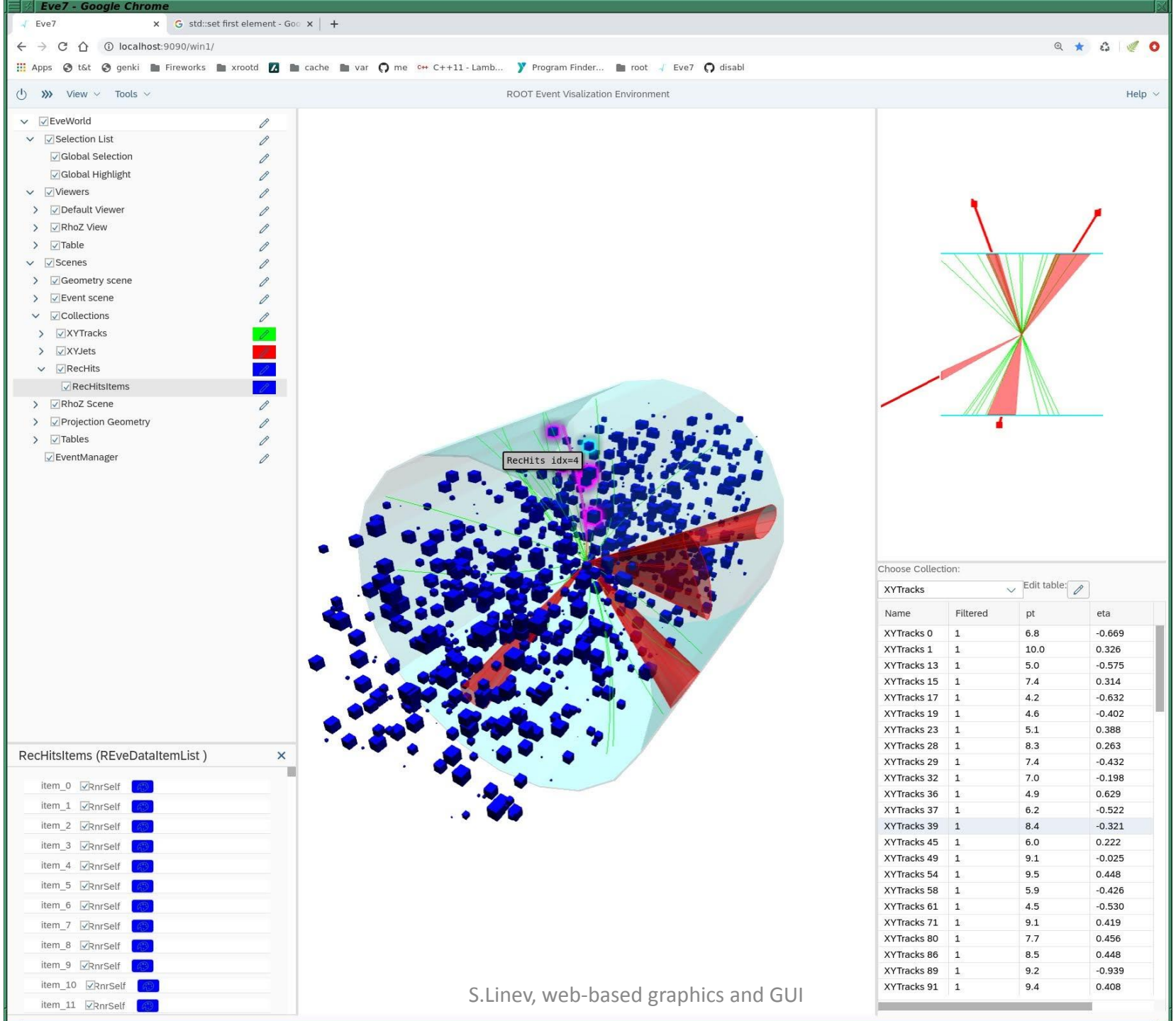


Slides 2019

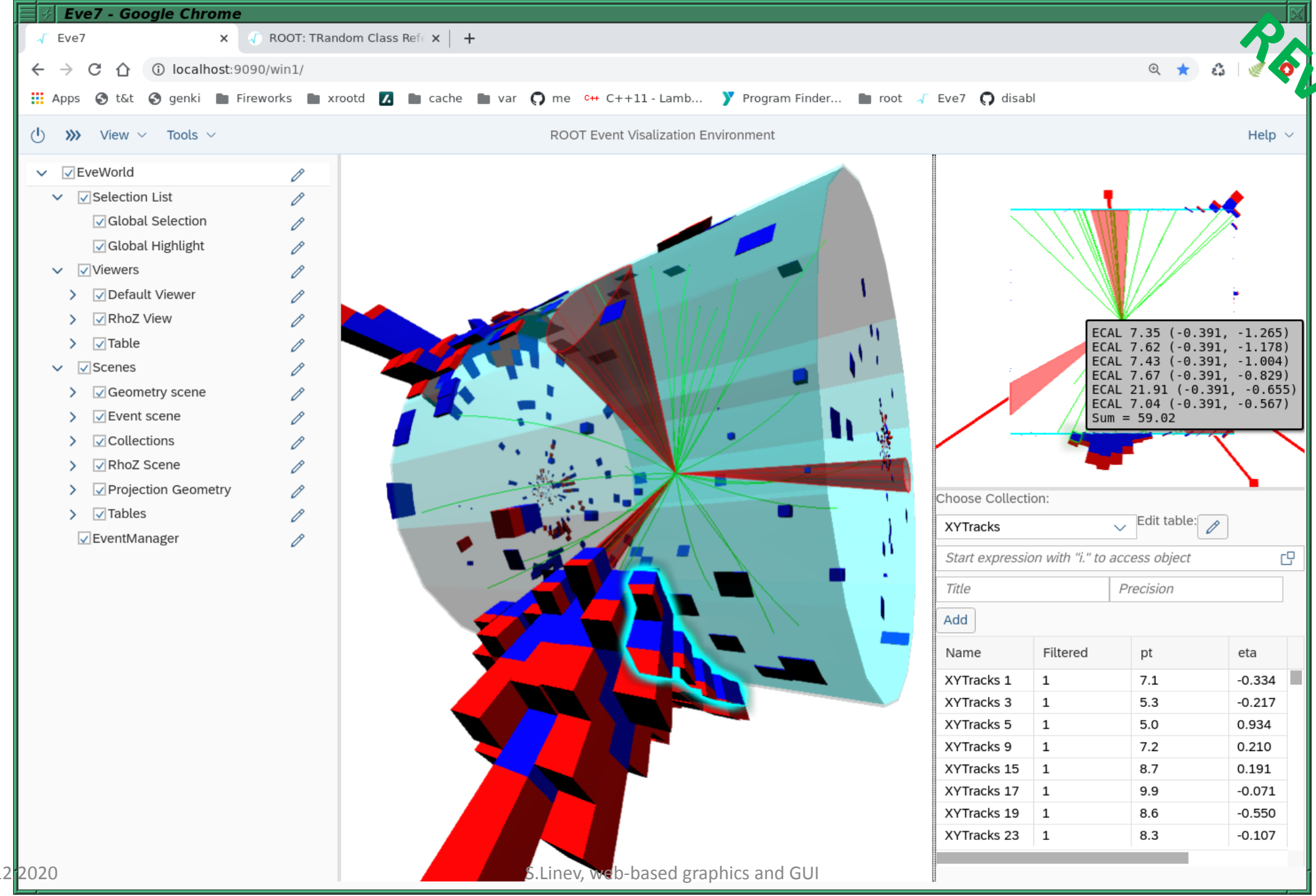
Online event display

- Hierarchy browser
- 3D views
- Projection views
- Table views
- Multiple clients
- Offline mode

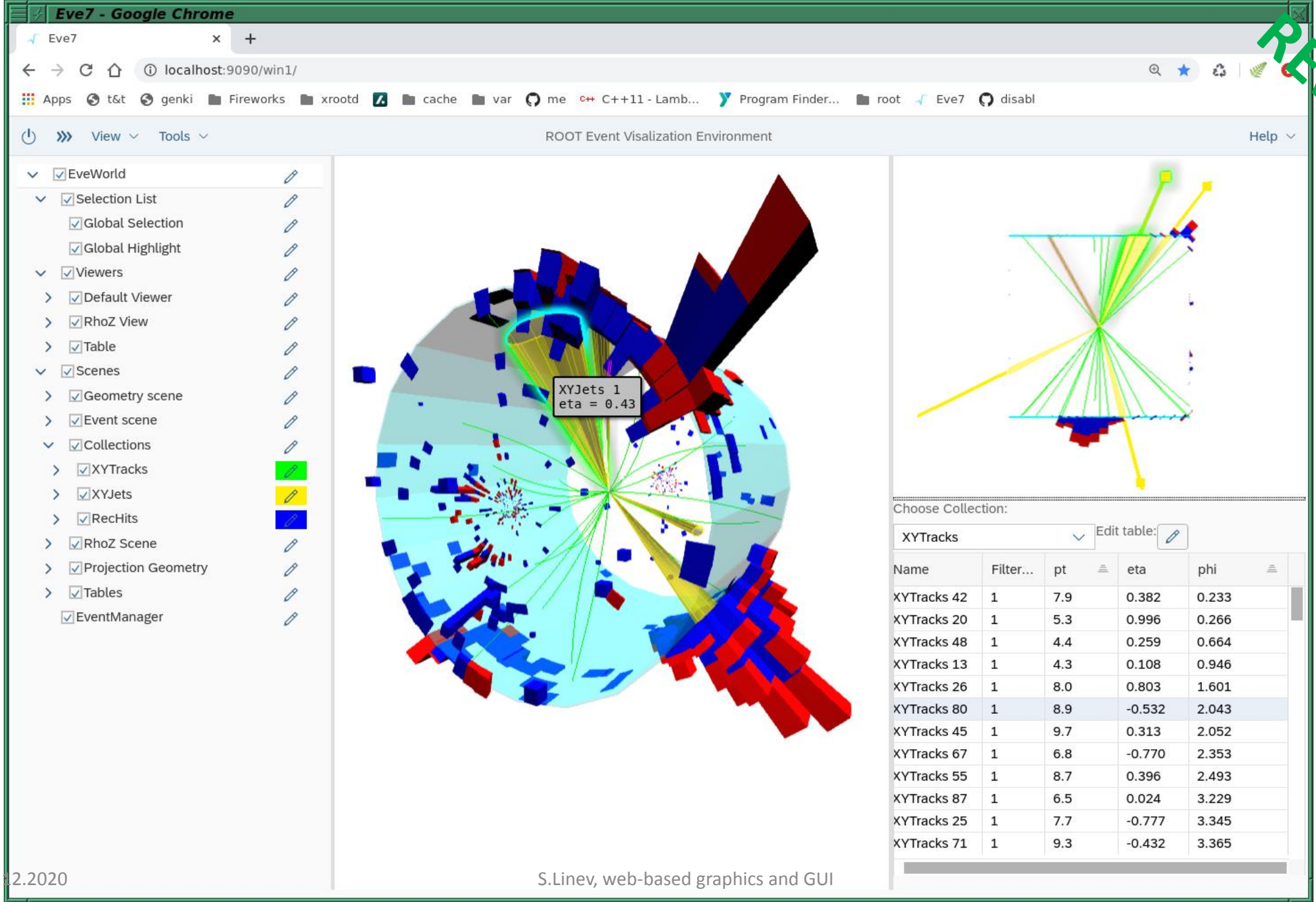
https://linev.github.io/eve7/


Eve7 - Google Chrome
Eve7
std::set first element - Goo
localhost:9090/win1/
Apps
t&t
genki
Fireworks
xrootd
cache
var
me
C++11 - Lamb...
Program Finder...
root
Eve7
disabl
View
Tools
ROOT Event Visalization Environment
Help
EveWorld
Selection List
Global Selection
Global Highlight
Viewers
Default Viewer
RhoZ View
Table
Scenes
Geometry scene
Event scene
Collections
XYTracks
XYJets
RecHits
RecHitsItems
RhoZ Scene
Projection Geometry
Tables
EventManager
RecHits idx=4
RecHitsItems (REveDataItemList)
item_0 RnrSelf
item_1 RnrSelf
item_2 RnrSelf
item_3 RnrSelf
item_4 RnrSelf
item_5 RnrSelf
item_6 RnrSelf
item_7 RnrSelf
item_8 RnrSelf
item_9 RnrSelf
item_10 RnrSelf
item_11 RnrSelf
Choose Collection:
XYTracks
Edit table:
Name
Filtered
pt
eta
XYTracks 0 1 6.8 -0.669
XYTracks 1 1 10.0 0.326
XYTracks 13 1 5.0 -0.575
XYTracks 15 1 7.4 0.314
XYTracks 17 1 4.2 -0.632
XYTracks 19 1 4.6 -0.402
XYTracks 23 1 5.1 0.388
XYTracks 28 1 8.3 0.263
XYTracks 29 1 7.4 -0.432
XYTracks 32 1 7.0 -0.198
XYTracks 36 1 4.9 0.629
XYTracks 37 1 6.2 -0.522
XYTracks 39 1 8.4 -0.321
XYTracks 45 1 6.0 0.222
XYTracks 49 1 9.1 -0.025
XYTracks 54 1 9.5 0.448
XYTracks 58 1 5.9 -0.426
XYTracks 61 1 4.5 -0.530
XYTracks 71 1 9.1 0.419
XYTracks 80 1 7.7 0.456
XYTracks 86 1 8.5 0.448
XYTracks 89 1 9.2 -0.939
XYTracks 91 1 9.4 0.408

REve 2020


Eve7 - Google Chrome
Eve7
ROOT: TRandom Class Ref
localhost:9090/win1/
Apps
t&t
genki
Fireworks
xrootd
cache
var
me
C++11 - Lamb...
Program Finder...
root
Eve7
disabl
View
Tools
ROOT Event Visalization Environment
Help
EveWorld
Selection List
Global Selection
Global Highlight
Viewers
Default Viewer
RhoZ View
Table
Scenes
Geometry scene
Event scene
Collections
RhoZ Scene
Projection Geometry
Tables
EventManager
ECAL 7.35 (-0.391, -1.265)
ECAL 7.62 (-0.391, -1.178)
ECAL 7.43 (-0.391, -1.004)
ECAL 7.67 (-0.391, -0.829)
ECAL 21.91 (-0.391, -0.655)
ECAL 7.04 (-0.391, -0.567)
Sum = 59.02
Choose Collection:
XYTracks
Edit table:
Start expression with "i." to access object
Title
Precision
Add
Name
Filtered
pt
eta
XYTracks 1 1 7.1 -0.334
XYTracks 3 1 5.3 -0.217
XYTracks 5 1 5.0 0.934
XYTracks 9 1 7.2 0.210
XYTracks 15 1 8.7 0.191
XYTracks 17 1 9.9 -0.071
XYTracks 19 1 8.6 -0.550
XYTracks 23 1 8.3 -0.107

REve 2020


Eve7 - Google Chrome
Eve7
localhost:9090/win1/
Apps
t&t
genki
Fireworks
xrootd
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C++11 - Lamb...
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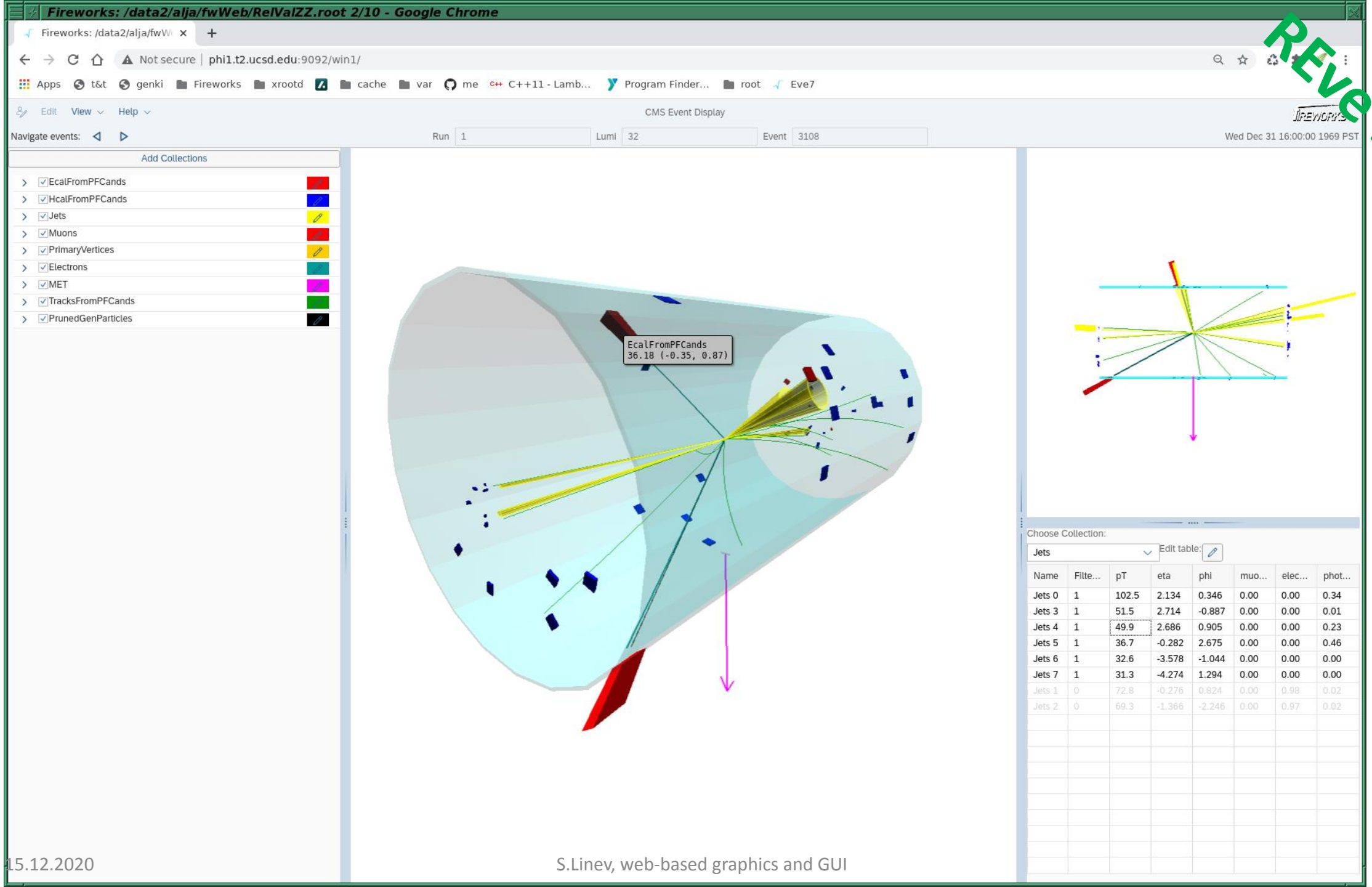
Event scene
Collections
XYTracks
XYJets
RecHits
RhoZ Scene
Projection Geometry
Tables
EventManager
XYJets 1
eta = 0.43
Choose Collection:
XYTracks
Edit table:
Name
Filter...
pt
eta
phi
XYTracks 42 1 7.9 0.382 0.233
XYTracks 20 1 5.3 0.996 0.266
XYTracks 48 1 4.4 0.259 0.664
XYTracks 13 1 4.3 0.108 0.946
XYTracks 26 1 8.0 0.803 1.601
XYTracks 80 1 8.9 -0.532 2.043
XYTracks 45 1 9.7 0.313 2.052
XYTracks 67 1 6.8 -0.770 2.353
XYTracks 55 1 8.7 0.396 2.493
XYTracks 87 1 6.5 0.024 3.229
XYTracks 25 1 7.7 -0.777 3.345
XYTracks 71 1 9.3 -0.432 3.365

REve 2020


Fireworks: /data2/alja/fwWeb/RelValZZ.root 2/10 - Google Chrome
Fireworks: /data2/alja/fwW
Not secure | phi1.t2.ucsd.edu:9092/win1/
Apps t&t genki Fireworks xrootd cache var me C++11 - Lamb... Program Finder... root Eve7
Edit View Help
CMS Event Display
Navigate events:
Run 1
Lumi 32
Event 3108
Wed Dec 31 16:00:00 1969 PST
Add Collections
EcalFromPFCands
HcalFromPFCands
Jets
Muons
PrimaryVertices
Electrons
MET
TracksFromPFCands
PrunedGenParticles
EcalFromPFCands
36.18 (-0.35, 0.87)
Choose Collection:
Jets
Edit table:
Name Filte... pT eta phi muo... elec... phot...
Jets 0 1 102.5 2.134 0.346 0.00 0.00 0.34
Jets 3 1 51.5 2.714 -0.887 0.00 0.00 0.01
Jets 4 1 49.9 2.686 0.905 0.00 0.00 0.23
Jets 5 1 36.7 -0.282 2.675 0.00 0.00 0.46
Jets 6 1 32.6 -3.578 -1.044 0.00 0.00 0.00
Jets 7 1 31.3 -4.274 1.294 0.00 0.00 0.00
Jets 1 0 72.8 -0.276 0.824 0.00 0.98 0.02
Jets 2 0 69.3 -1.366 -2.246 0.00 0.97 0.02

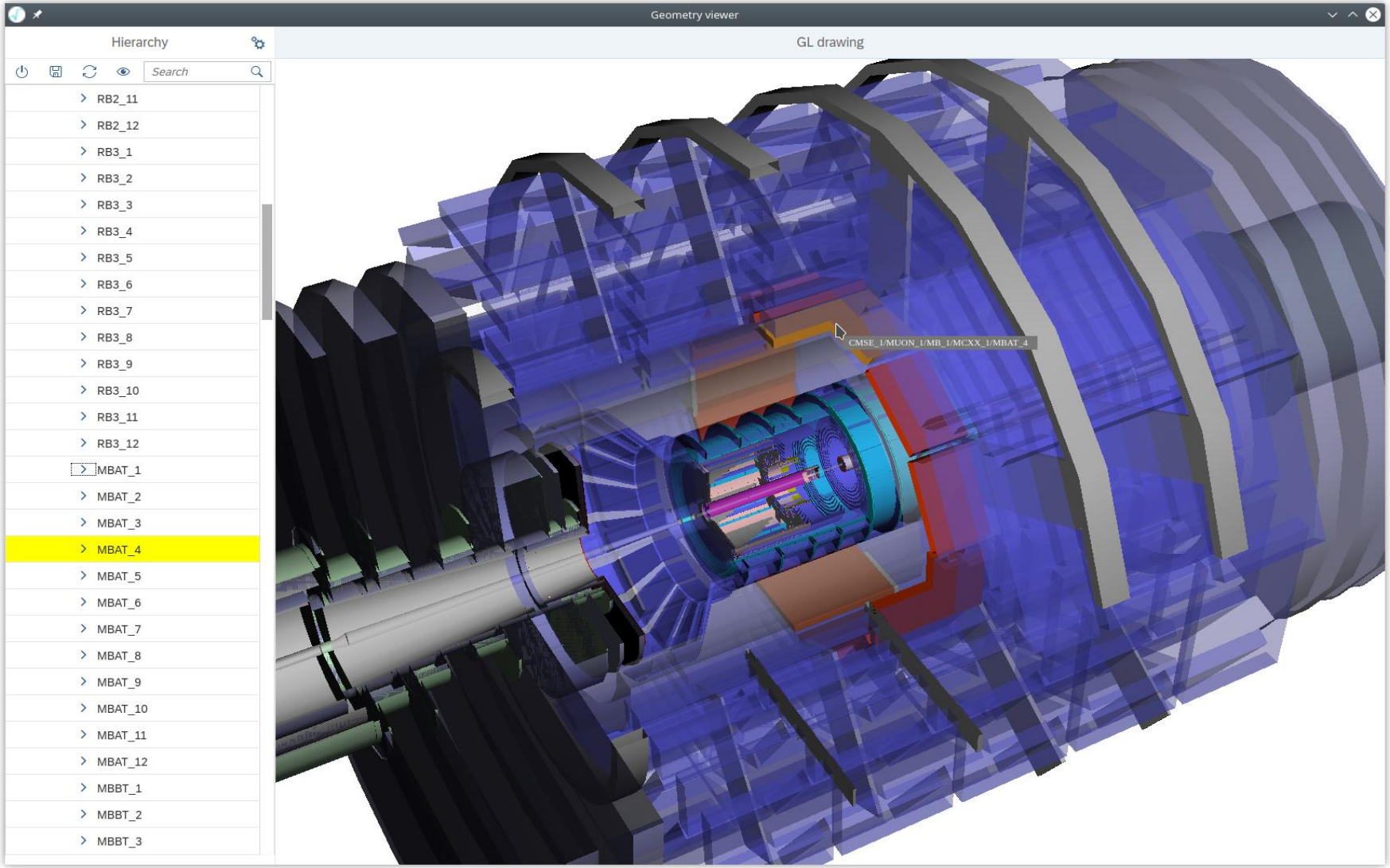
REve 2020

REve plans for 2021

- Setup FireworksWeb test servers at CERN, Fermilab, and UCSD for beta testing
  - Implement automatic play loop of event from CMS data file
  - Dio performance test with Chrome development tools
- Improve look and performance of physics collection item viewer
  - show/hide items table on collection tree node open/close
- Window management
  - add a possibility to create a new view (GL or table) in runtime through menu bar
- Introduce configuration. Add a possibility to:
  - created views
  - collections (filters, color attributes, proxy builder attributes)
  - table configurations (e.g. table column expressions)
- Explore new solutions of running event displays outside the firewall. Current workarounds are ssh tunnel or https with node certificate. Are there any other more convenient options?
  - web token (macaroons)
  - Web services, anything else?
- Integrate RenderCore as the second render engine to EVE-7
  - Faster rendering of tracks as polygons
  - High precision pickling for any size of viewing volume.
  - Rendering of High Granularity Calorimeter for CMS experiment with shaders.

- grate job of Alja and Matevz!

RGeomViewer



- Reuse eve7 and JSROOT code
- Browse hierarchy
- Search nodes
- Individual volume display
- Transparency
- Wireframes
- Offline mode

Slides 2019

root $ROOTSYS/tutorials/eve7/viewer.cxx

RGeomViewer plans

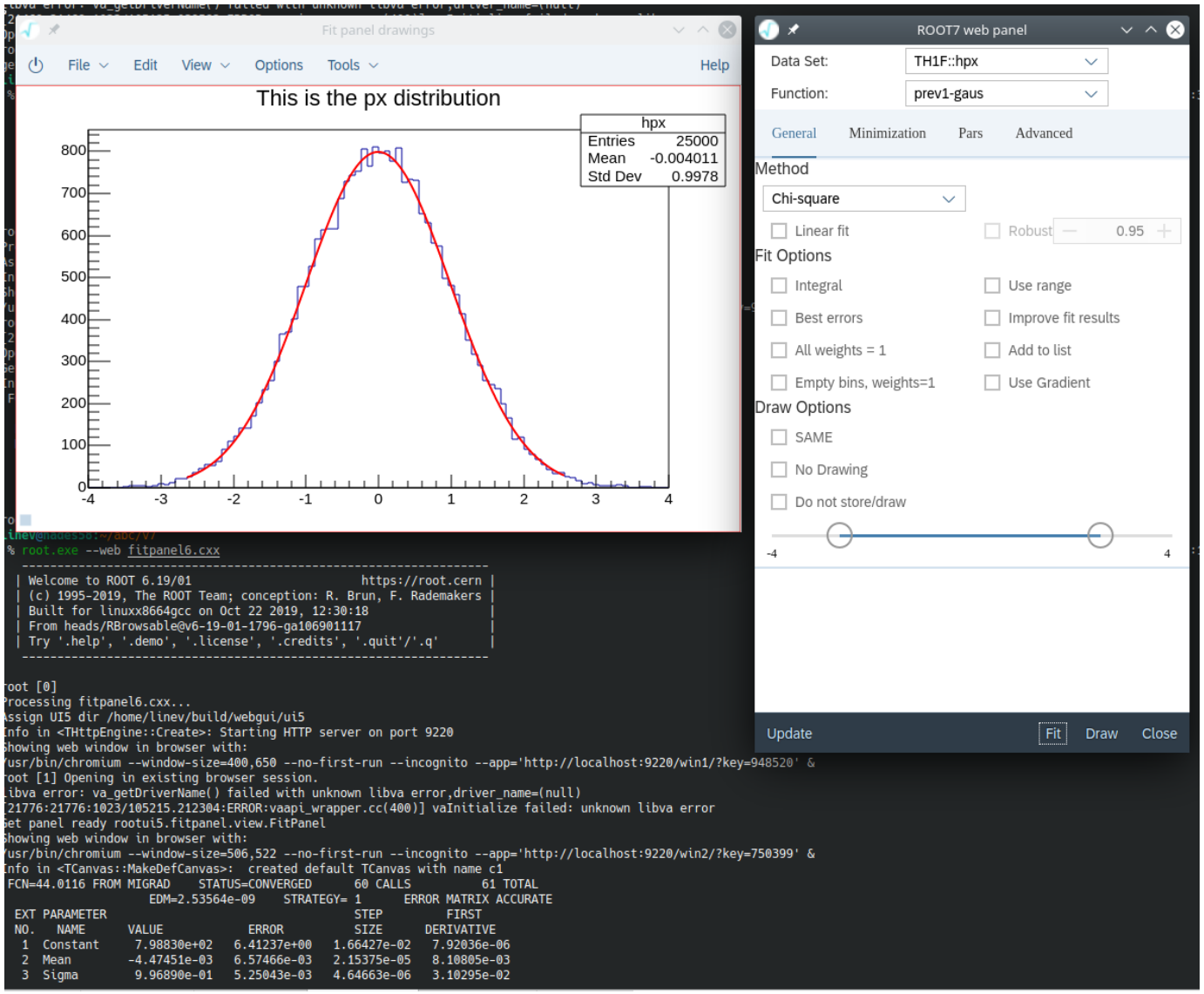
- Beta quality:
  - most functionalities are there
  - need more testing/debugging
- To do:
  - integrate with RBrowser
- Work estimation:
  - ~2 months

not touched

not touched

Slides 2019

RFitPanel



root --web $ROOTSYS/tutorials/v7/fitpanel6.cxx

Slides 2019

- Access fit functionality via web widget
  - very similar to original TFitPanel
  - use ROOT6 data classes for fitting
  - improve usability
- Example of model/view separation
  - model is C++ class
  - converted to/from JSON
  - used as is for view configuration
- Display fit results in TCanvas
  - x11 or web-based

RFitPanel plans

- Beta quality, needs to be tested

- Work estimation:
  - ~0.5 month to finalize all small issues

not touched

Slides 2019

Overall remarks

- Huge amount of work to complete
  - difficult promote to users before

Slides 2019

- That is our priority list?
  - RBrowser (~4 months)
  - RCanvas (~9 months)
  - rock-solid batch mode (3+ months)
  - the rest (6+ months)

80% done

JSROOT v5 -> v6

- Major incompatible code upgrade
- Use many ES6 features like Promises and partially Classes
- Skip IE support
- Resolve WebGL rendering in batch mode
- Resolve many internal workarounds
- Follow naming convention
- Provide better code documentation

- To be completed very soon – by 6.24 release

How motivate users to use webgui?

- Many different components already there
  - but nobody care
- While current solutions continues to work
  - no any reasons to try something else inside ROOT

ROOT components using webgui

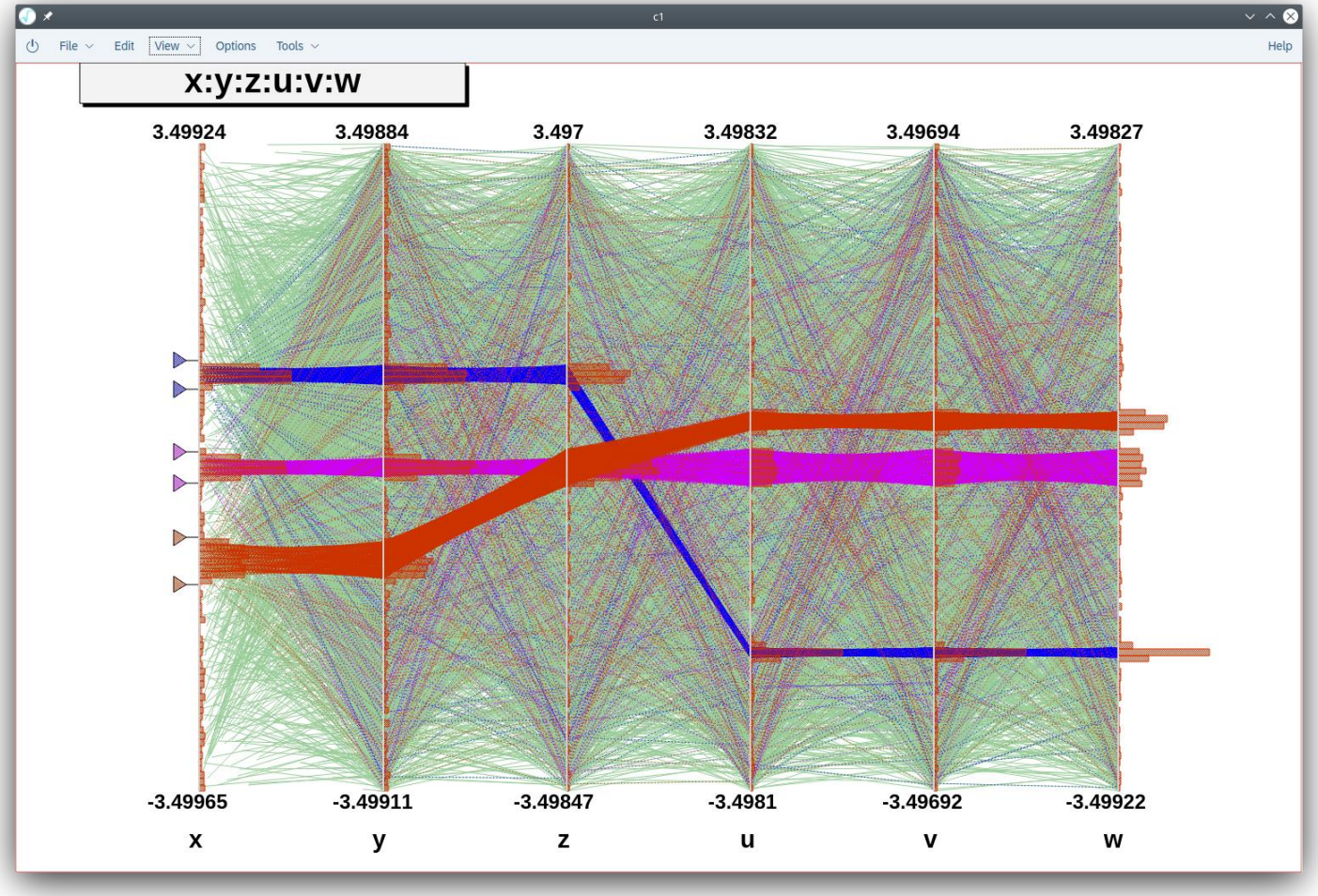
- TCanvas

- RCanvas
- RBrowser
- REve
- RFitPanel
- RGeomViewer

How motivate users to use webgui?

- Immediate steps (6.24):
  - officially release TWebCanvas canvas
    - „root --web hsimple.C“ works since several years
  - include full-functional implementation TWebCanvasFull in ROOT
    - provides most of interactive features
    - only this class make sense for users for production use
    - can be „official“ QtRoot interface, which works on all Qt-supported platforms
  - personal reasons
    - reduce maintenance efforts in two repositories
- Minimal efforts from users to try
- The only way to convince them that technology works
- Improve many components which are also used with ROOT7

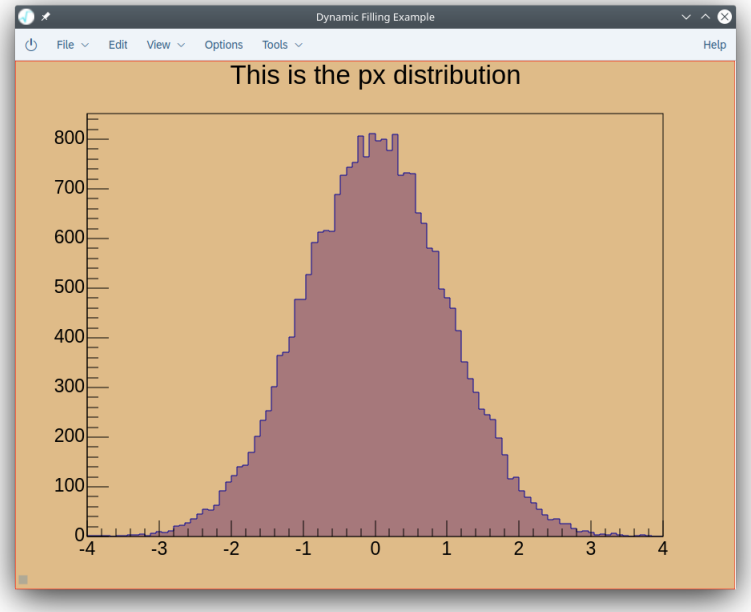
TWebCanvas



root --web $ROOTSYS/tutorials/tree/parallelcoord.C

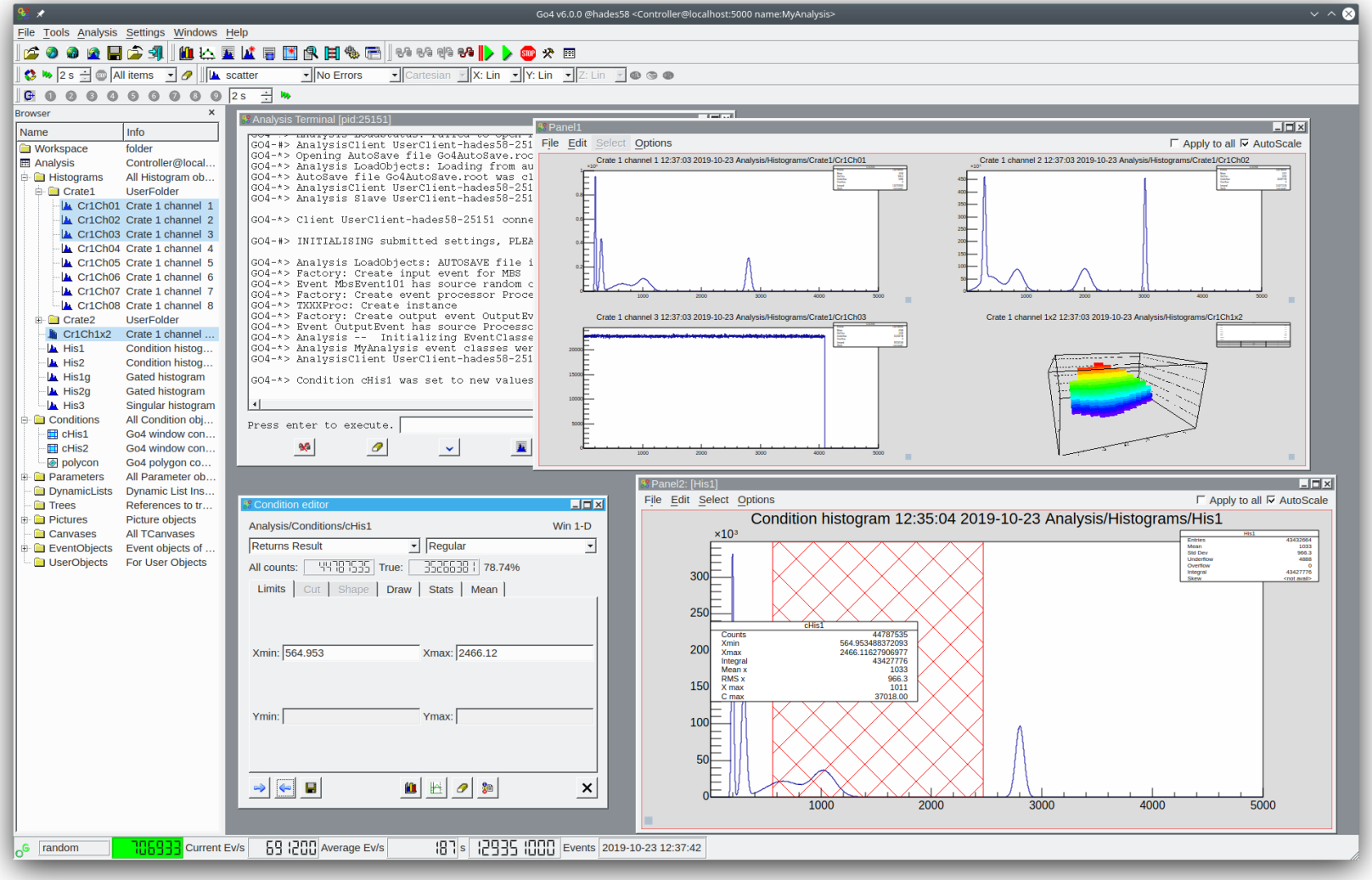
- Show TCanvas in browser
  - web-based TCanvasImp
- Reuse JSROOT code
- Limited support of TVirtualX
  - custom Paint() may work

Slides 2019



root --web $ROOTSYS/tutorials/hsimple.C

TWebCanvas with Qt5



- go4 v6.0
  - developed since 1999
  - http://go4.gsi.de
- Qt5-based GUI
  - QtROOT for ROOT graphics
  - since a while not working on Mac (missing x11 support)
- Solution:
  - embed TWebCanvas in QWebEngine
  - provide support for custom go4 classes
- Same code for:
  - Linux/Mac/Windows
- Any ROOT web widget can be embed in Qt5:
  - root --web=qt5 …

Slides 2019

How motivate users to use webgui?

- Short/mid-term steps (6.26):
  - promote ROOT6 classes usage with RCanvas
    - provide examples, test macros, tutorials
  - TObjectDrawable optionally brings CSS usage
    - not available in TWebCanvas
    - provide specialization for TH1/TGraph classes
  - Our benefits
    - let improve RCanvas/RStyle/RAttr classes without introducing RHist classes
  - Actually, RHist plotting is 90% reuse of JSROOT code for TH1/TH2/TH3 classes
    - improving v6, we automatically improve v7

How motivate users to use webgui?

- Mid-term steps (6.26 – 6.28)
  - review RAttr class – central of importance in whole design
  - review / improve RColor (better mapping to CSS)
  - release RCanavs and RBrowser (no Experimental)

Usability

- Can we compete with compact python code?
  - we can provide several small macros which solves typical user problem with single call:
    - create canvas, add histogram to canvas, display canvas
    - „replacement“ for TObject::Draw functionality
  - promote usage of „preconfigured“ CSS files
    - provide „experiment“ default styles for hist colors, axes ticks, grids, margins
    - extend CSS functionality

RCanvas example

```
#include "ROOT/RCanvas.hxx"
#include "ROOT/RHistDrawable.hxx"

using namespace ROOT::Experimental;

void draw() {
   // Create the histogram.
   RAxisConfig xaxis("x", 10, 0., 1.);
   RAxisConfig yaxis("y", {0., 1., 2., 3., 10.});
   auto pHist = std::make_shared<RH2D>(xaxis, yaxis);

   // draw histogram
   auto canvas = RCanvas::Create("Canvas Title");
   canvas->Draw(pHist);
   canvas->Show();
}
```

RStyle example

```
auto style = RStyle::Parse(
    "frame {"                    // select type frame for RFrame
    "   gridx: true;"            // enable grid drawing
    "   gridy: true;"
    "   ticksx: 2;"              // enable ticks drawing on both sides
    "   ticksy: 2;"
    "   x_labels_size: 0.05;" // below 1 is scaling factor for pad height
    "   y_labels_size: 20;"   // just a font size in pixel
    "   y_labels_color_name: green;"  // and name labels color
    "}");

canvas->UseStyle(style);

RDirectory::Heap().Add("style", style); // required to keep style alive
```

Usability

- Can we compete with powerful plot engines as matplot?
  - difficult from the beginning
  - focus on interactivity and multithreading
  - address special user needs
    - different log scales (done)
    - better axis labels and title positions (partially done)
    - custom fonts support
    - custom encoding supports (not only latin)
    - special draw style support (XKCD, see issue #6682)
    - …

Usability

- Integration with JupyterLab
  - use Jupyter web server
  - conceptually should work
  - luck of resources
  - priority?

Final summary

- I see no reasons to wait longer
- We are loosing potential users
- Modern techonlogies aging very fast