EVE-7 and FireworksWeb: The next generation event visualization tools for ROOT and CMS

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Overview

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- Future work & plans
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See also: [1] *New web-based ROOT GUI*, Wed, 11 AM, Track 5
[2] *Web-based ROOT geometry viewer*, Wed, 12 PM, Track 5

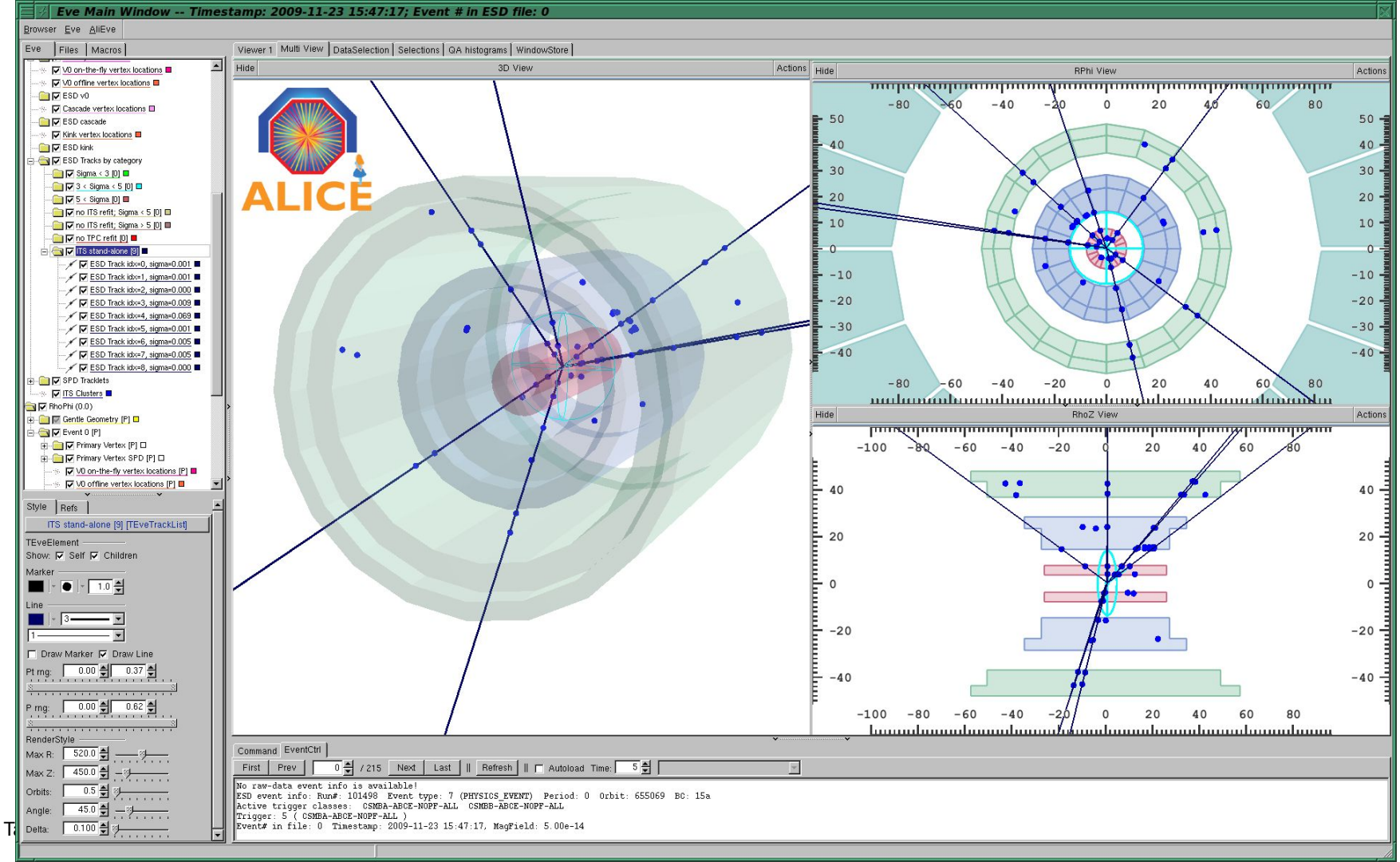
Introduction

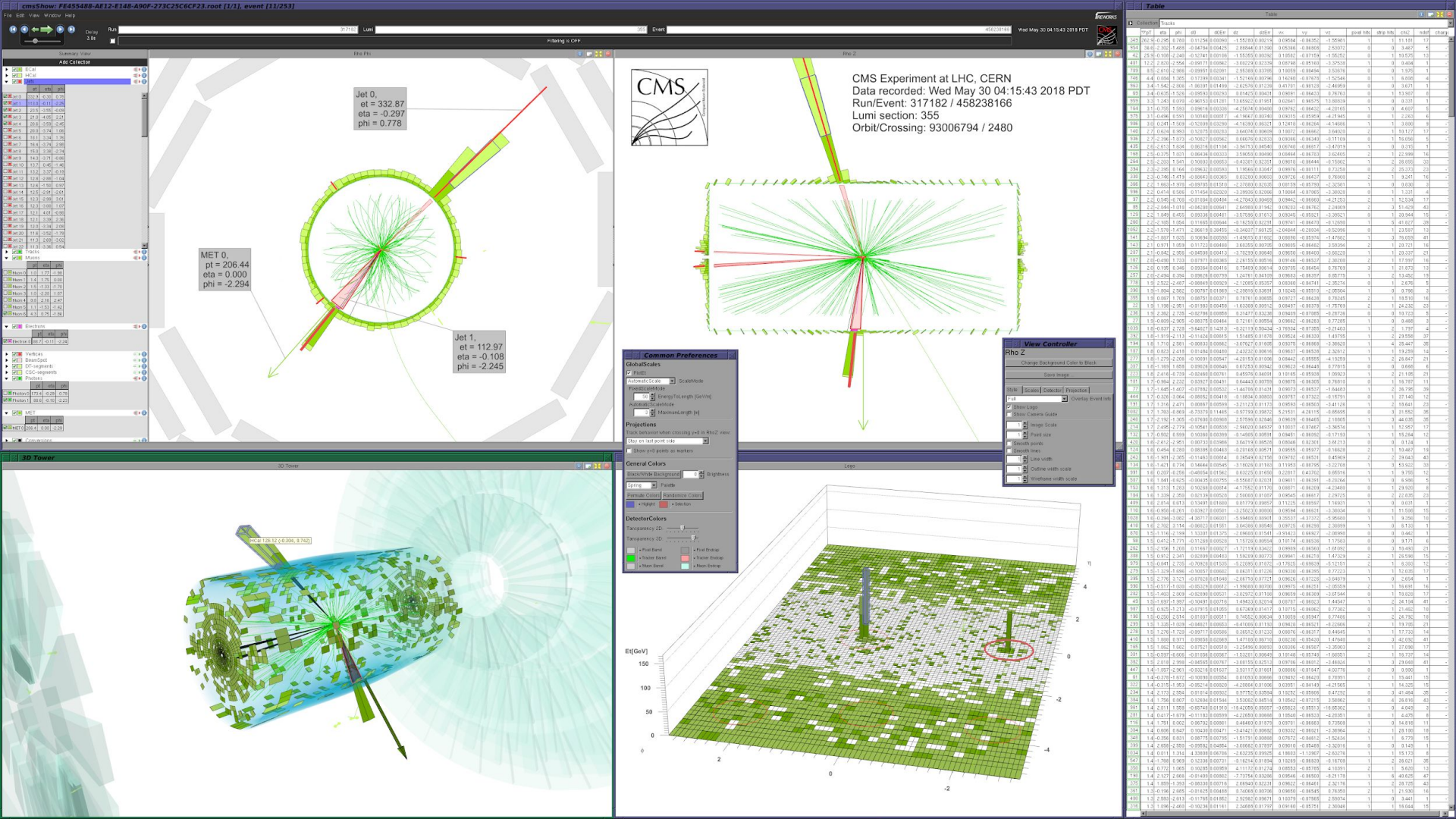
Brief history of EVE and Fireworks

- EVE development started in 2005 for ALICE
  - Split into ROOT-EVE and AliRoot-AliEve in 2007
    - Available as ROOT package graf3d/eve
  - *ROOT OpenGL interface was co-developed to support advanced EVE features*
- CMS chose EVE for physics-analysis event display in 2007
  - Prototype development 2008 / 09
  - Intense 5-developer effort in 2010 / 11
    - Full CMSSW support, geometry visualization, detailed views of all RECO objects
  - *Faithful representation of EDM objects - what you see is what analysis algorithms see, too!*
- Both EVE and Fireworks essentially in maintenance mode since 2011

Usage of EVE beyond ALICE and CMS:

- Belle2, HyperK, ILC, JUNO, NA-62, T2K
- Several smaller experiments in neutrino, nuclear, and medical physics


Eve Main Window -- Timestamp: 2009-11-23 15:47:17; Event # in ESD file: 0
Browser Eve AliEve
Eve Files Macros
Viewer 1 Multi View DataSelection Selections QA histograms WindowStore
Hide 3D View Actions
Hide RPhi View Actions
Hide RhoZ View Actions
ALICE
Style Refs
ITS stand-alone [9] [TEveTrackList]
Command EventCtrl
First Prev Next Last Refresh Autoload
No raw-data event info is available!
ESD event info: Run#: 101498 Event type: 7 (PHYSICS_EVENT) Period: 0 Orbit: 655069 BC: 15a
Active trigger classes: CSMBA-ABCE-NOPF-ALL CSMBB-ABCE-NOPF-ALL
Trigger: 5 (CSMBA-ABCE-NOPF-ALL)
Event# in file: 0 Timestamp: 2009-11-23 15:47:17, MagField: 5.00e-14


cmsShow: FE455488-AE12-E148-A90F-273C25C6CF23.root [1/1], event [11/253]
Rho Phi
Jet 0,
et = 332.87
eta = -0.297
phi = 0.778
MET 0,
pt = 206.44
eta = 0.000
phi = -2.294
Jet 1,
et = 112.97
eta = -0.108
phi = -2.245
Rho Z
CMS
CMS Experiment at LHC, CERN
Data recorded: Wed May 30 04:15:43 2018 PDT
Run/Event: 317182 / 458238166
Lumi section: 355
Orbit/Crossing: 93006794 / 2480
Common Preferences
View Controller
Rho Z
Table
3D Tower
Lego
Et[GeV]

Motivation for EVE-7 & FireworksWeb

- EVE is 15 years old, ROOT-GL even older
  - Despite (or is it *Because of?*) all the progress, supporting native OpenGL still isn't easy.
  - OSX support is getting harder with every release.
  - SLC 6 / CentOS 7 ... our OSes are lagging years behind desktop versions.
  - People still run event display over ssh and this requires some deep tweaks lately.
  - This causes trouble for both EVE in general and for Fireworks.
- OpenGL is getting replaced with Vulkan over the next couple of years.
  - Implementing a low-level rendering engine was a good choice 20 years ago.
  - Modern rendering engines completely insulate application from the low-level graphics.
- ROOT-7 is replacing native GUI & graphics with web browser front-end.
  - EVE has to either grow along or die …

CMS has committed to support development of EVE-7 and FireworksWeb.

EVE-7 and FireworksWeb

Project outline

- Mission statement: *Rewrite EVE and Fireworks for LHC Run 3 and beyond*.
  - Keep most of EVE functionality in place while modernizing the code
  - Move some functionality from Fireworks into new EVE-7:
    - Physics data: collections, items, item filtering, and table views - possible because of Cling and C++ lambdas
    - Geometry browser
- Development Focus / Driver: FireworksWeb prototype!
  - First production release before Run 3.
    - Support at least the physics-analysis / event-scanning use case.
- Keep all advanced features, including:
    - Simultaneous (multiple) selection across physics items in table and graphical views
    - Non-linear projections (RPhi and RhoZ views with fish-eye blowup of vertex region)
    - Window management -- group views into independent top-level windows
    - Visualization of digits
    - Calorimeter visualization including Fireworks lego view
- Performance considerations
  - Optimize network traffic, data representations and workload on server and client

Components

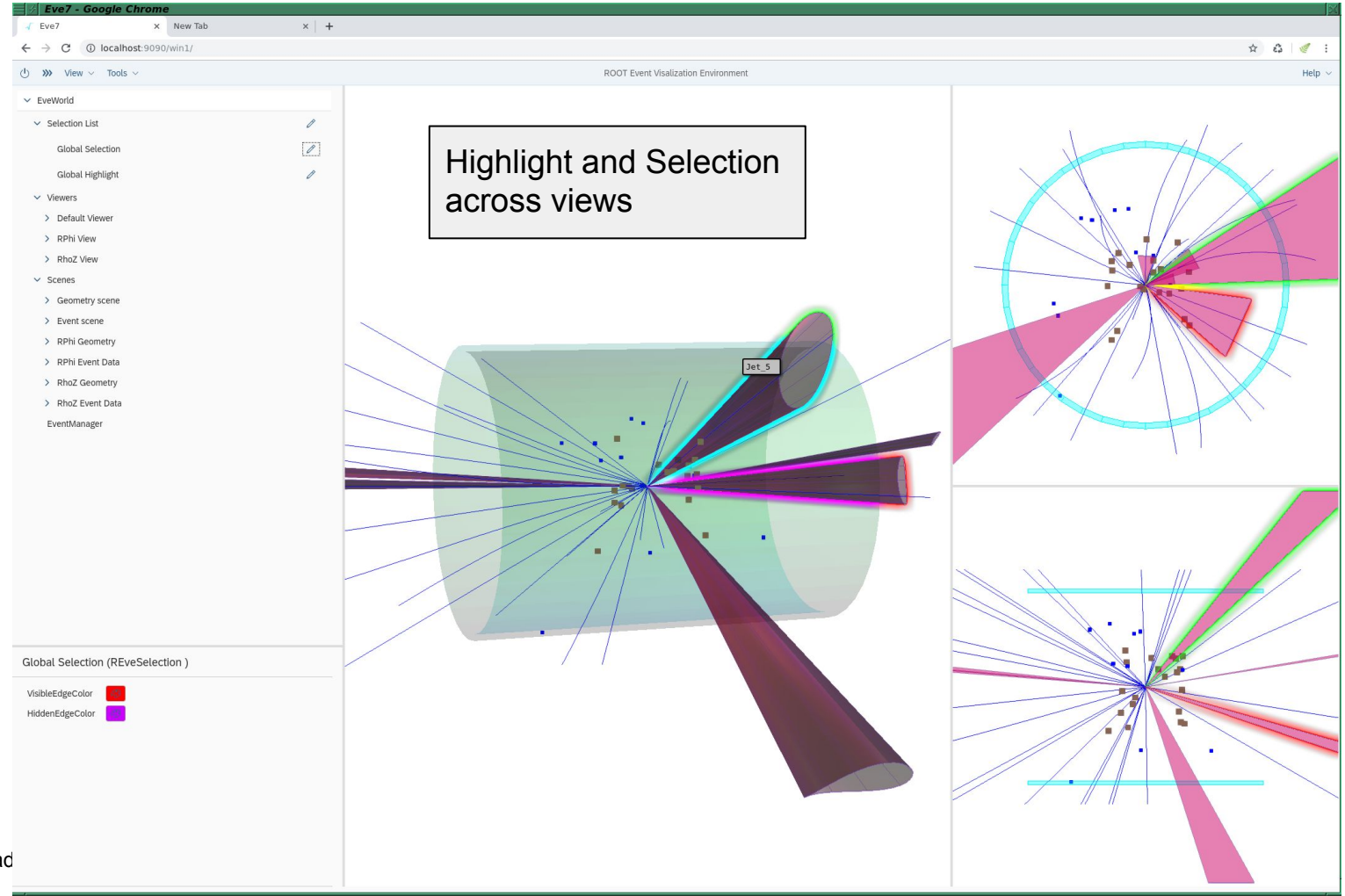
- Server / core: ***C++***
  - REveManager is the entry point holding hierarchy of Scenes / Directories of EVE objects
  - EVE objects support *streaming into JSON + binary data* for rendering
    - Graphical view & table configuration, selection, etc. are all *implemented as EVE objects*
    - *Client commands are C++ calls* on EVE elements *executed via Cling*
  - Data served through RWebWindow and ROOT's built-in civetweb web server
- Client side: *JavaScript*
  - **JSRoot**: initialization, colors, some 3D primitives & attributes, integration of OpenUI5
    - In the future also tree browser, file dialogs and geometry viewer
  - **OpenUI5**, the standard Web-GUI for ROOT
  - **Three.js**: 3D rendering

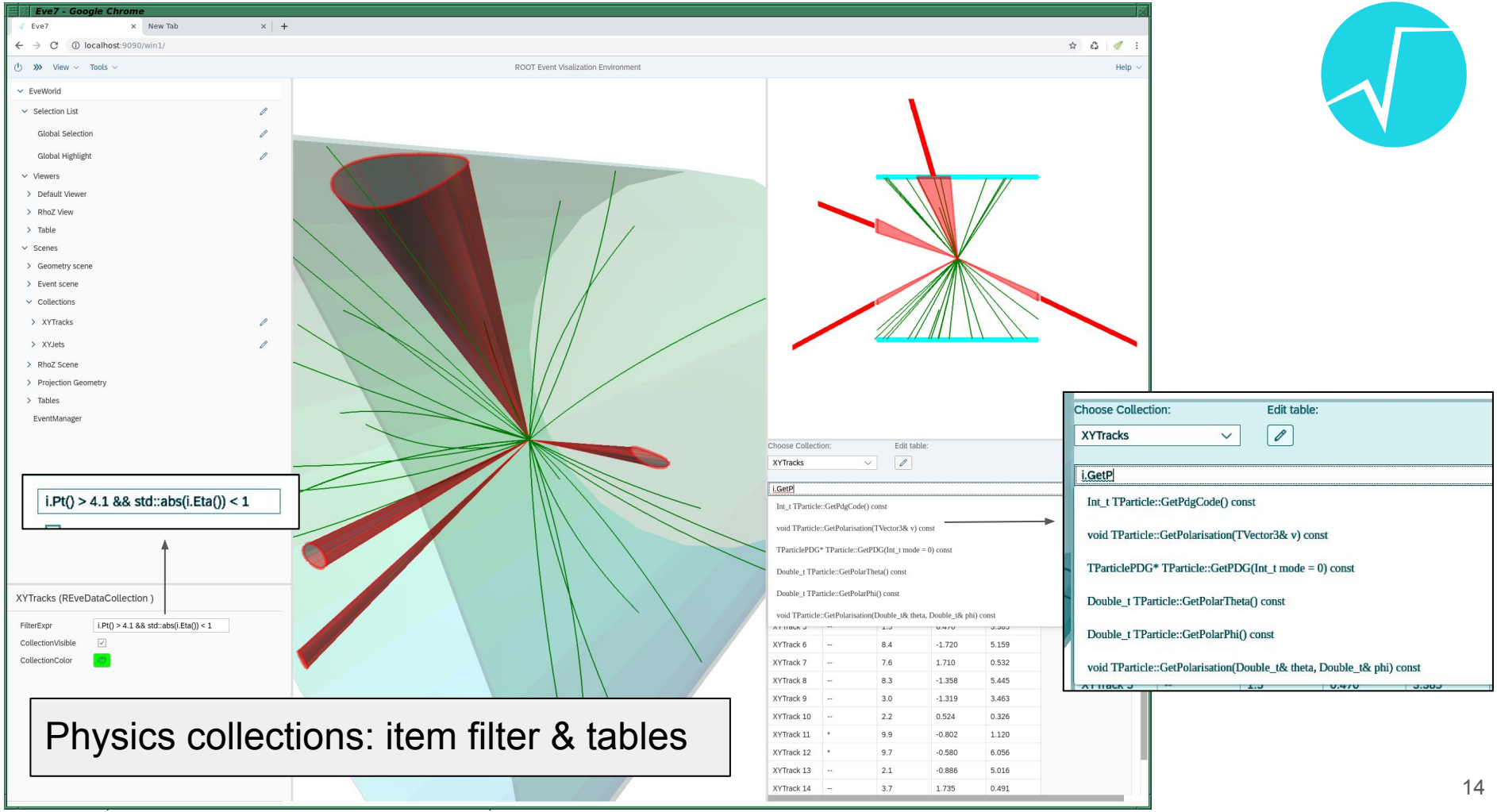
Server-Client communication

- Existence of C++ server is crucial for the main goal of EVE-7 & Fireworks:
  To visualize exactly the same data as is seen by analysis / reconstruction algorithms.
  - Allow users to use C++ expressions that call functions on actual physics data objects to:
    - set up filter expressions on physics objects, and
    - display correct values in table views, even for non-trivial expressions specified at runtime.
- Communication is bidirectional and stateful → *WebSocket* protocol is used.
- Multiple client connections are supported:
  - This is required to be able to show different views in different browser tabs / windows.
    - Each client subscribes only to views that are being shown in its window.
    - Selection and highlight are synchronized across all clients.
  - Likewise, **multiple users** can connect to the same server and view the same event.
- Full object data is sent only when a new event is loaded.
  - Within an event, only objects that get changed as a result of user actions are streamed.
  - Payload for event with 1,000 tracks (3D + 2 projected views) is O(1MB) spread over 6 messages

Status as of Nov. 2019

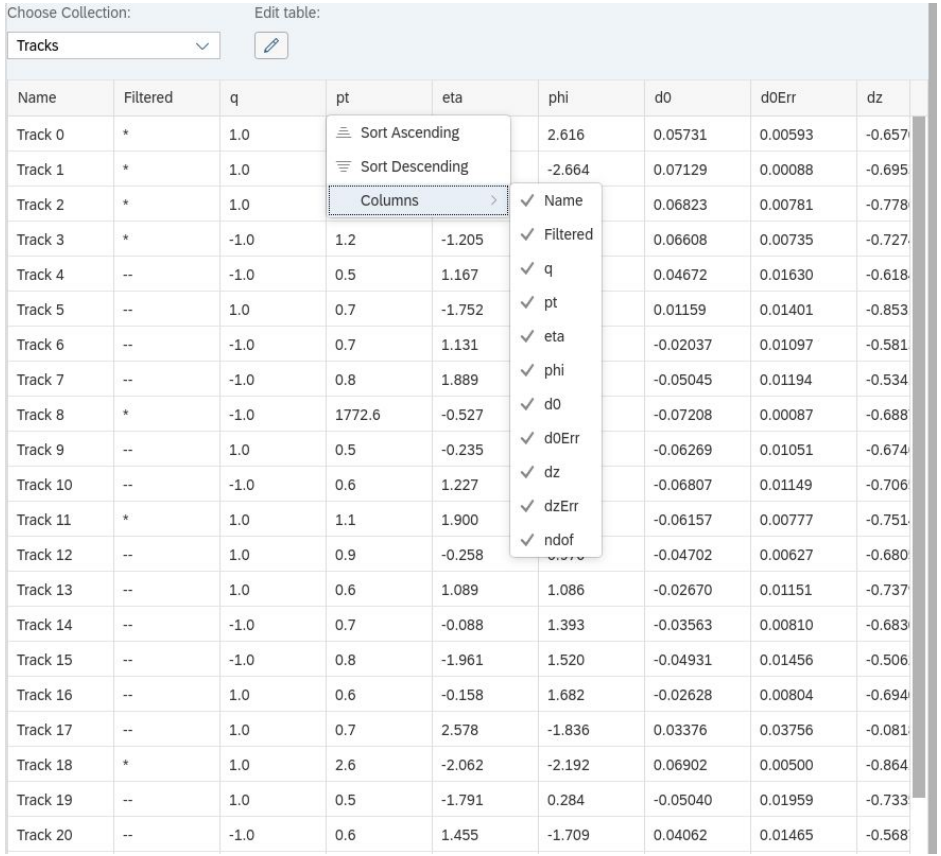
- **Prototype & technology demo**
  - Testing of various aspects, including performance, server / client communication over WAN
  - Will require (quite) some cleanup / restructuring before production release
- Supported / implemented features & screenshots
  - *EVE-7:*
    - Visual objects: pointsets, linesets, tracks, ellipsoid, jets, all TGeoShapes (including CSG)
    - Support for physics collections and physics items
    - Handling of scene changes (user interaction) and destruction (going to another event)
    - Selection and highlight mechanism works across graphical views and different representations
    - *Screenshots:* Cross view highlight & selection (pg. 12), Collections (pg. 13), Tables (pg. 14)
  - *FireworksWeb:* uses all EVE-7 features and has most Fireworks concepts imported.
    - Plugin system for adding physics collections
    - Collection editors (color, visibility, and physics item filter)
    - Proxy builders for tracks, PF candidates, jets, MET, electrons, vertices, muons, and CSC segments
    - Event navigation through CMS EDM data file (but no event filtering yet)
    - Uses custom client GUI elements for event info and event control
    - *Screenshots:* Overview (pg. 15), Table with CMS reco::Track class (pg. 16)


Eve7 - Google Chrome
Eve7
New Tab
localhost:9090/win1/
View
Tools
ROOT Event Visalization Environment
Help
EveWorld
Selection List
Global Selection
Global Highlight
Viewers
Default Viewer
RPhi View
RhoZ View
Scenes
Geometry scene
Event scene
RPhi Geometry
RPhi Event Data
RhoZ Geometry
RhoZ Event Data
EventManager
Global Selection (REveSelection)
VisibleEdgeColor
HiddenEdgeColor
Highlight and Selection across views
Jet_5

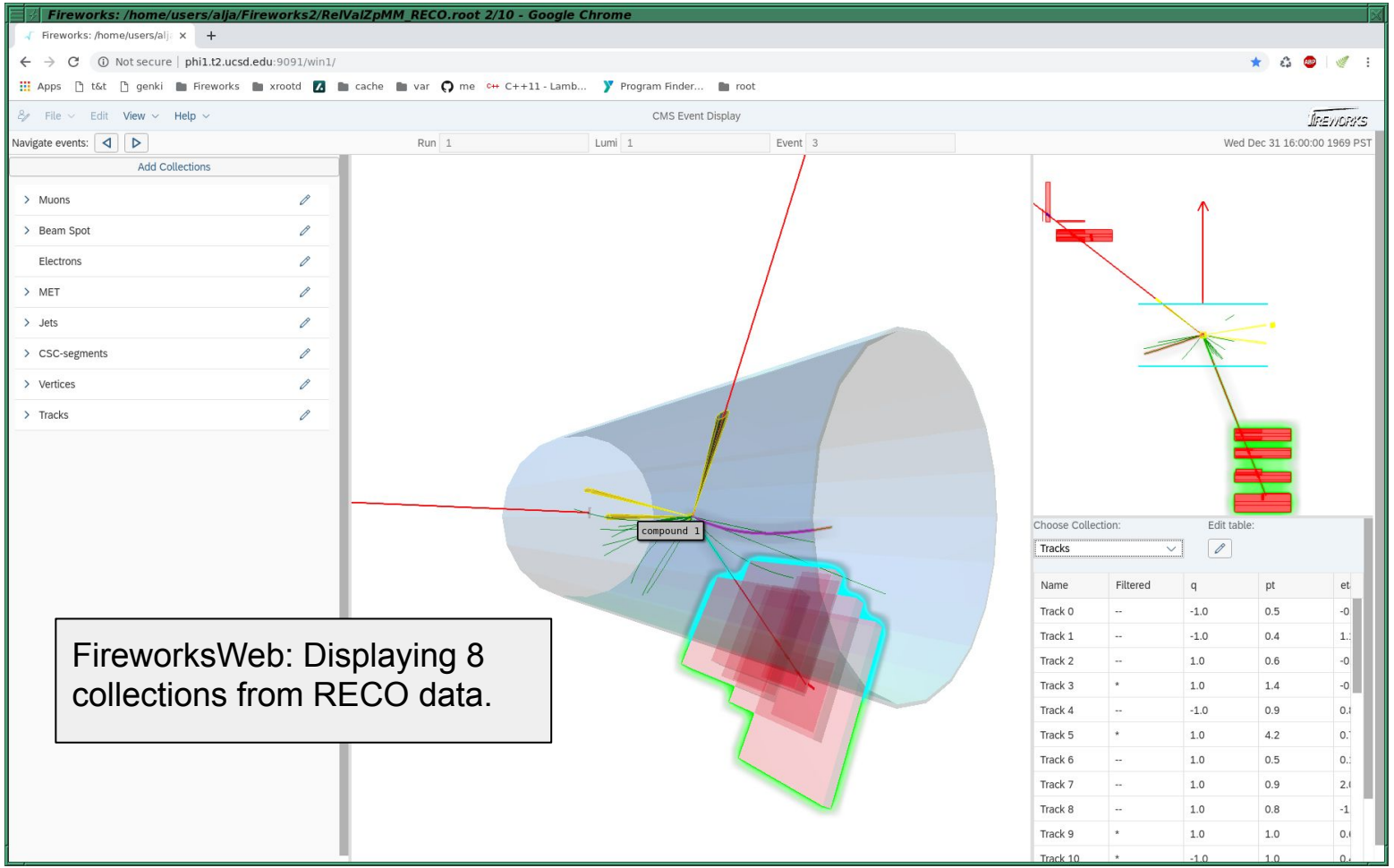


Physics collections: item filter & tables

Configurable OpenUI5 tables

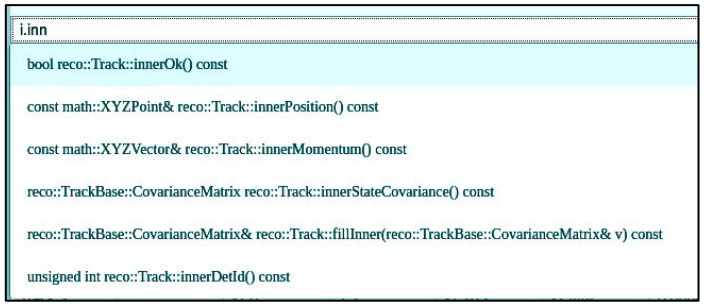


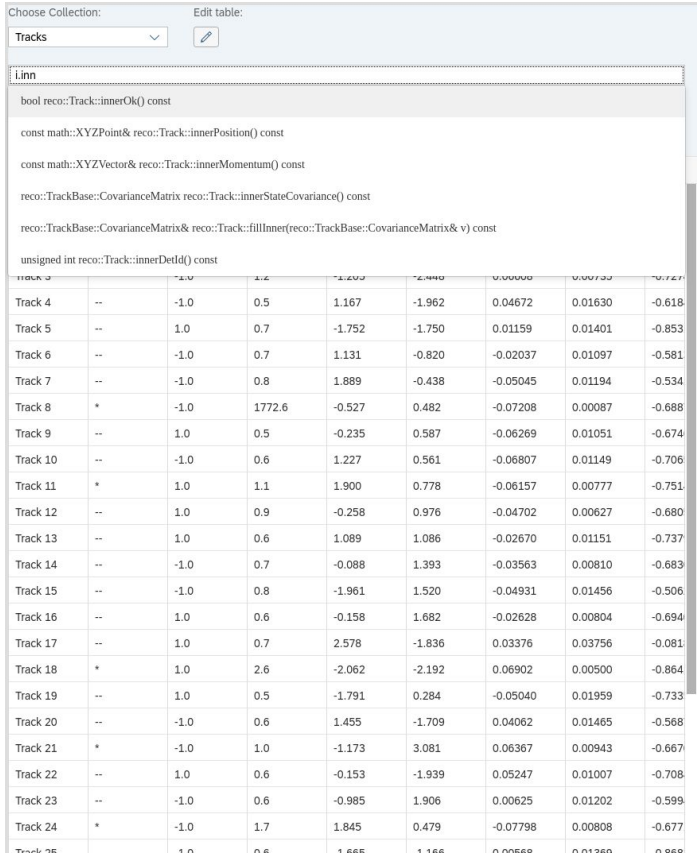
Name	Filtered	q	pt	eta	phi	d0	d0Err	dz
Track 0	*	1.0			2.616	0.05731	0.00593	-0.657
Track 1	*	1.0			-2.664	0.07129	0.00088	-0.695
Track 2	*	1.0				0.06823	0.00781	-0.778
Track 3	*	-1.0	1.2	-1.205		0.06608	0.00735	-0.727
Track 4	--	-1.0	0.5	1.167		0.04672	0.01630	-0.618
Track 5	--	1.0	0.7	-1.752		0.01159	0.01401	-0.853
Track 6	--	-1.0	0.7	1.131		-0.02037	0.01097	-0.581
Track 7	--	-1.0	0.8	1.889		-0.05045	0.01194	-0.534
Track 8	*	-1.0	1772.6	-0.527		-0.07208	0.00087	-0.688
Track 9	--	1.0	0.5	-0.235		-0.06269	0.01051	-0.674
Track 10	--	-1.0	0.6	1.227		-0.06807	0.01149	-0.706
Track 11	*	1.0	1.1	1.900		-0.06157	0.00777	-0.751
Track 12	--	1.0	0.9	-0.258		-0.04702	0.00627	-0.680
Track 13	--	1.0	0.6	1.089	1.086	-0.02670	0.01151	-0.737
Track 14	--	-1.0	0.7	-0.088	1.393	-0.03563	0.00810	-0.683
Track 15	--	-1.0	0.8	-1.961	1.520	-0.04931	0.01456	-0.506
Track 16	--	1.0	0.6	-0.158	1.682	-0.02628	0.00804	-0.694
Track 17	--	1.0	0.7	2.578	-1.836	0.03376	0.03756	-0.081
Track 18	*	1.0	2.6	-2.062	-2.192	0.06902	0.00500	-0.864
Track 19	--	1.0	0.5	-1.791	0.284	-0.05040	0.01959	-0.733
Track 20	--	-1.0	0.6	1.455	-1.709	0.04062	0.01465	-0.568



FireworksWeb: Displaying 8 collections from RECO data.

Interactive table content in Fireworks, screenshot looking at a class dictionary





Track 4	--	-1.0	0.5	1.167	-1.962	0.04672	0.01630	-0.618
Track 5	--	1.0	0.7	-1.752	-1.750	0.01159	0.01401	-0.853
Track 6	--	-1.0	0.7	1.131	-0.820	-0.02037	0.01097	-0.581
Track 7	--	-1.0	0.8	1.889	-0.438	-0.05045	0.01194	-0.534
Track 8	*	-1.0	1772.6	-0.527	0.482	-0.07208	0.00087	-0.688
Track 9	--	1.0	0.5	-0.235	0.587	-0.06269	0.01051	-0.674
Track 10	--	-1.0	0.6	1.227	0.561	-0.06807	0.01149	-0.706
Track 11	*	1.0	1.1	1.900	0.778	-0.06157	0.00777	-0.751
Track 12	--	1.0	0.9	-0.258	0.976	-0.04702	0.00627	-0.680
Track 13	--	1.0	0.6	1.089	1.086	-0.02670	0.01151	-0.737
Track 14	--	-1.0	0.7	-0.088	1.393	-0.03563	0.00810	-0.683
Track 15	--	-1.0	0.8	-1.961	1.520	-0.04931	0.01456	-0.506
Track 16	--	1.0	0.6	-0.158	1.682	-0.02628	0.00804	-0.694
Track 17	--	1.0	0.7	2.578	-1.836	0.03376	0.03756	-0.081
Track 18	*	1.0	2.6	-2.062	-2.192	0.06902	0.00500	-0.864
Track 19	--	1.0	0.5	-1.791	0.284	-0.05040	0.01959	-0.733
Track 20	--	-1.0	0.6	1.455	-1.709	0.04062	0.01465	-0.568
Track 21	*	-1.0	1.0	-1.173	3.081	0.06367	0.00943	-0.667
Track 22	--	1.0	0.6	-0.153	-1.939	0.05247	0.01007	-0.708
Track 23	--	-1.0	0.6	-0.985	1.906	0.00625	0.01202	-0.599
Track 24	*	-1.0	1.7	1.845	0.479	-0.07798	0.00808	-0.677

Further work & Plans

Development plan

- Short term - clean up existing code:
  - ROOT 6.20 release in December (EVE-7 is in ROOT since v6.16, Jan. 2019)
  - FireworksWeb technology preview release by the end of 2019 (FWLite based tarball)
- Plan for 2020:
  - EVE-7 ready as replacement for EVE
    - Most functionality supported, including physics collection / item handling.
  - FireworksWeb functional for Run3
    - Support CMS physics data-analysis & event scanning / trigger studies
- Beyond 2020:
  - EVE-7: optimization & beautification, and user support!
  - FireworksWeb - advanced functionality:
    - Running from full CMSSW framework & editing of CMS algorithm parameters
    - CMS geometry browser
    - Optimization for Heavy Ion runs

Conclusion

- EVE-7 and FireworksWeb rewrites are well underway.
- FireworksWeb as the driving force for the migration had positive influence:
  - Focus on most important core elements required for technology investigation
  - Port high-level functionality from CMS codebase into ROOT
  - Provide a framework for building of comprehensive physics-analysis event displays
- The main motivation for moving physics data representation into EVE-7 was to share this with other experiments.
  - It proved to be extremely useful for CMS physics ...
  - … and it will only make sense if other experiments actually use it.
- Early users / contributors are welcome at this point.
  - But beware there is another year of flux ahead.

See also: [1] *New web-based ROOT GUI*, Wed, 11 AM, Track 5
[2] *Web-based ROOT geometry viewer*, Wed, 12 PM, Track 5