

STAR ★

Event Display Development

A look at present, future and requirements

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U.S. DEPARTMENT OF
ENERGY

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Outline

- Intro
- STAR Web-based Event Display v1
- **Requirements, Planning, Design**
 - **Target Audience and Use-Cases**
 - **Requirements & Features**
 - **Technology Overview**
- STAR Web-based Event Display v2
- Summary, Outlook, Discussion

Intro: what needs to be visualized?

For the discussion on geometry modelling, see the presentation of J.Webb!



While all building blocks seem to be well-understood, precise Use-Cases and Requirements are very important for the Event Display development!

- **Detector Geometry**
 - raw detector geometry as produced by simulations package
 - serialized detector geometry as **exported** by experiment's framework
- **Raw Detector Data**
 - TPC hits (3D dots), EMC hits (blocks), Silicon pads (planes) – both raw and serialized
- **Reconstructed Objects**
 - Tracks, Vertices, V0s, EM showers
- **Service Information**
 - momentum, charge, energy deposition, coordinates, size

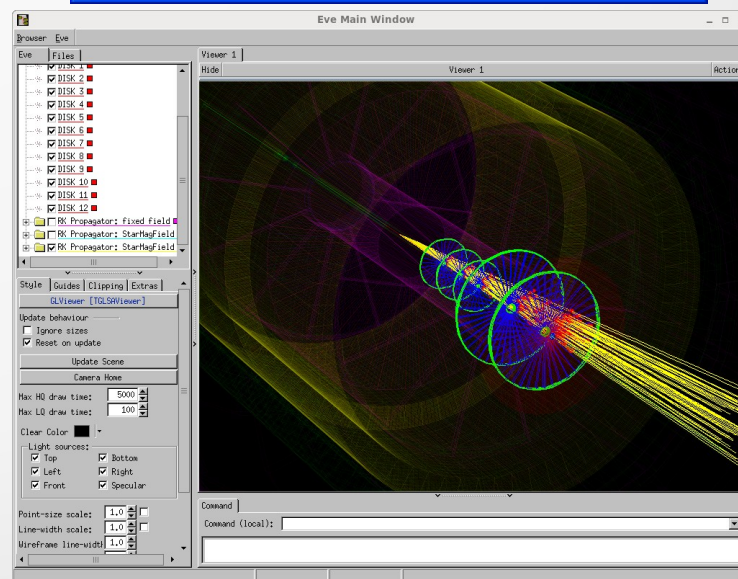
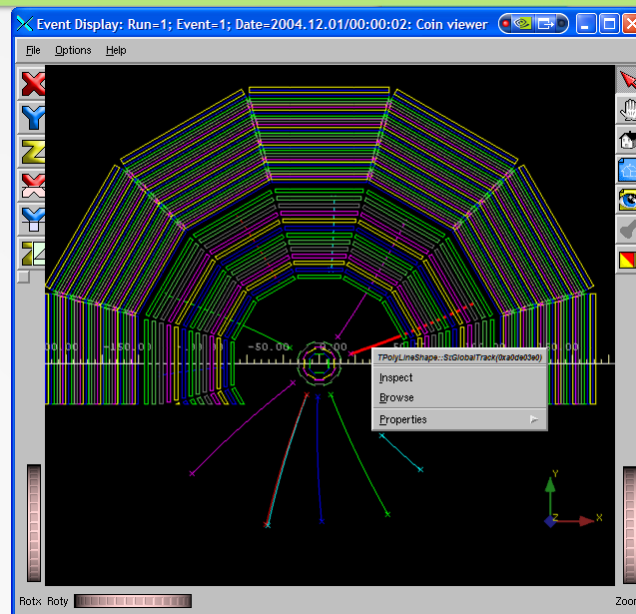
Existing Displays at STAR: desktop

- **Coin3D (Qt / OpenGL)**

- mature, feature-rich, desktop-based, cross-platform, tightly integrated with STAR software framework, full debugger support
- Mainly driven by the the need of MC and reconstruction experts
- aging, harder to maintain with years, so ROOT/TEve display becomes a viable alternative

- **ROOT / TEve (TGeo-based)**

- desktop-based event display based on ROOT / TEve
- Evolving need, aligned with the community direction
- reduced set of dependencies compared to Coin3D, native integration with ROOT
- TEve is backed by ROOT community



Existing Displays at STAR: Live Display

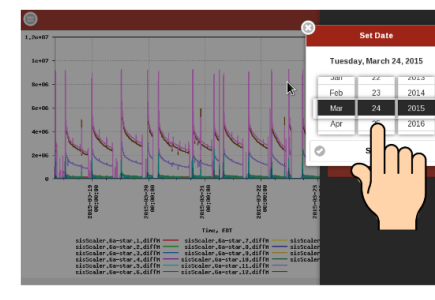
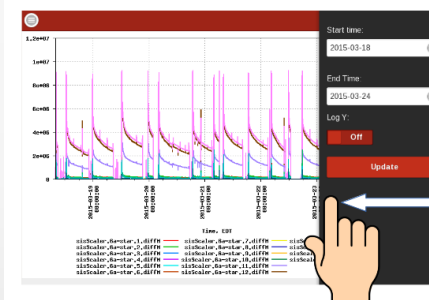
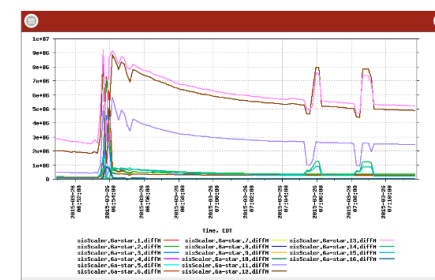
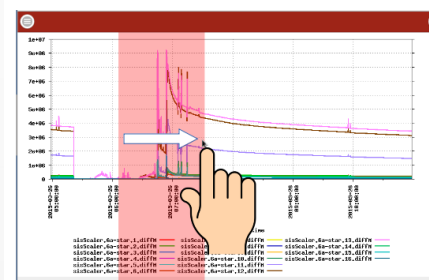
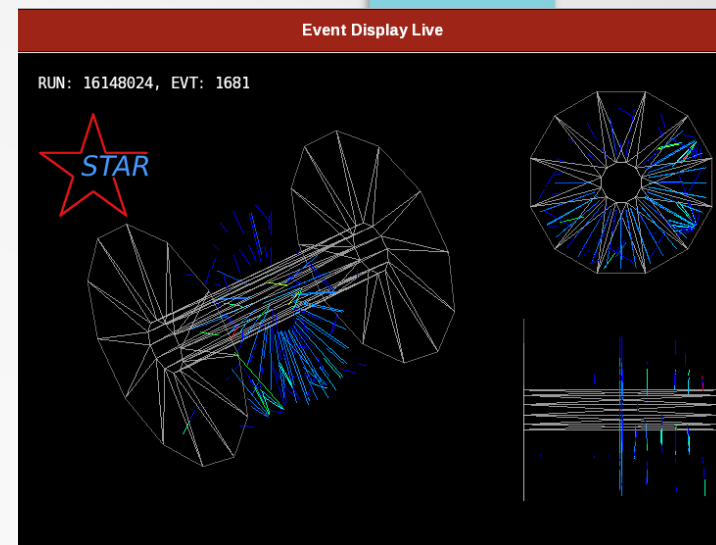
- **Live Event Display v1** (WebGL, since ~2010)
 - web-based event display based on Three.js and WebGL – no software to install at client side!
 - support fast event and geometry load, optimized for performance
 - used by Online crew, professors and PR managers

- **v1 is a part of STAR Online Services**

- web versions of RunLog, ShiftLog, DAQ monitor, Db Plots, Phonebok, Shift Crew, Expert List, Event Display(s), Metadata Collectors etc

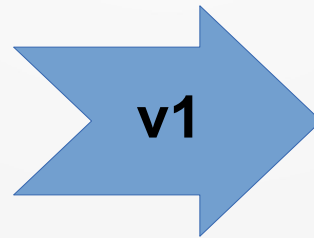
<https://online.star.bnl.gov/aggregator/>

...also available via Google Play as an app!



STAR: Event Display v1

existing tool at hand



STAR Event Display v1

Live data from the DAQ / Event Pool, or pre-recorded events

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Event Display

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Run: 15063011, Event: 582276, EvtTime: Tue Mar 04 2014 03:32:32 GMT-0500 (EST)

*** SELECT GEOMETRY ***

Camera 1

*** 2D/3D MODE ***

Scene rotation: OFF

Events: Pre-recorded Reco

ZOOM OUT SAVE IMAGE ZOOM IN

DETECTOR GEOMETRY

BASICS

BOTTOM PLANE

XY-AXES

BLUE BEAM

YELLOW BEAM

VERTEX TRACKER

PIXEL TRACKER

IST TRACKER

TIME PROJECTION CHAMBER

BARREL TPC

TRACKS

TPC tracks

HITS

Barrel EMC hits

merged meshes, vertices optimized for speed

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STAR Collaboration (c) 2013-2016

Zoomable, rotating STAR classic Event Display view

<http://online.star.bnl.gov/aggregator/livedisplay/>

EIC Meeting, JLAB, May 1st, 2017

v1: Geometry Support

Full set of classic Geant 3 geometrical shapes supported

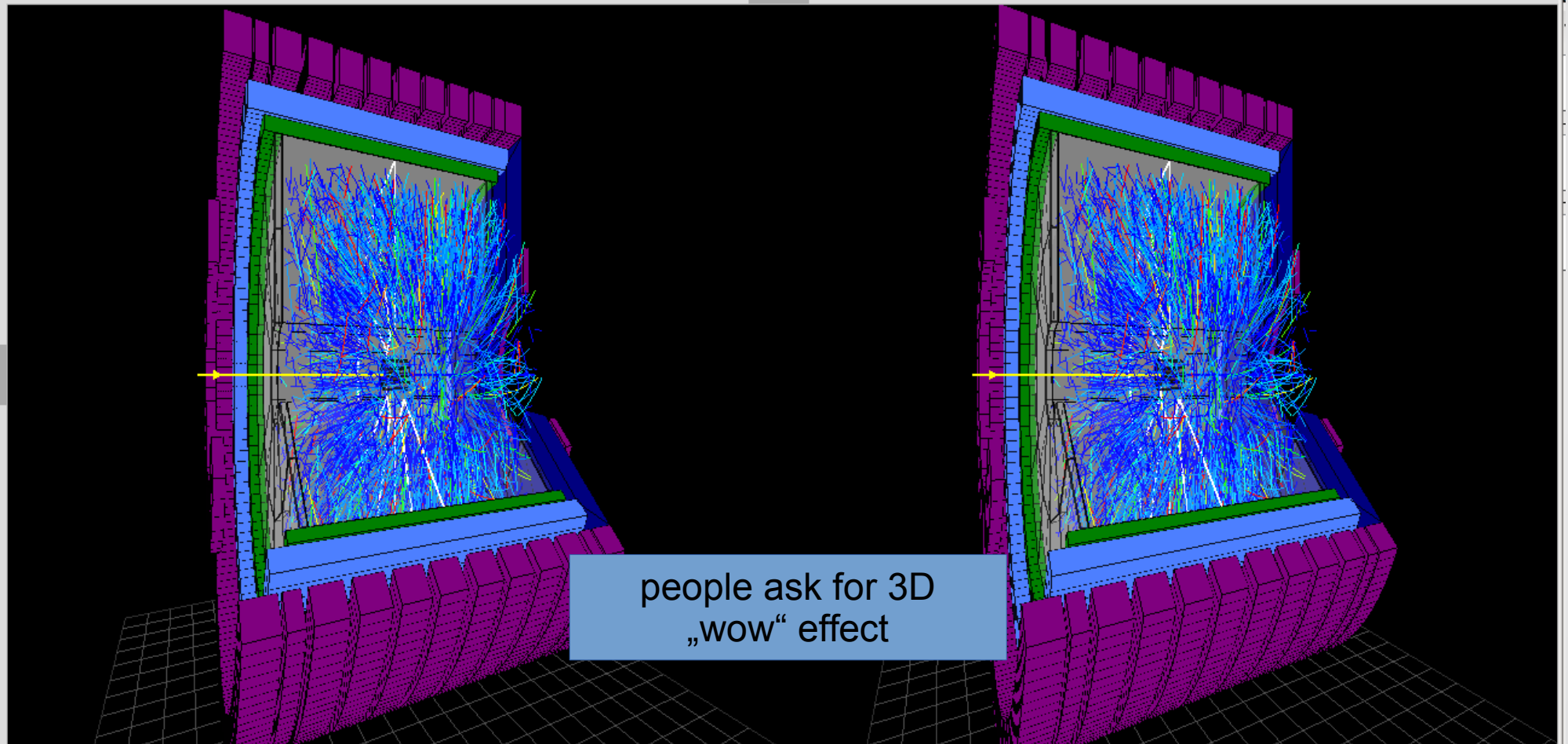
The screenshot displays the STAR Event Display interface. At the top left is the STAR logo, and at the top right is the Brookhaven National Laboratory logo. The main title is "Event Display". Below the title, the run information is "Run: 17055015, Event: 3, B: -0.5". A central 3D visualization shows the detector geometry with particle tracks. A blue box with white text "simple shapes optimized for speed" is overlaid on the 3D view. To the right, there are two 2D projections: a top-down view of the detector and a side-view projection. On the left, a control panel includes a "Split Detector Geometry" dropdown, "Camera 1" selection, "*** 2D/3D MODE ***" indicator, "Scene rotation: OFF", "Events: OFF", and buttons for "ZOOM OUT", "SAVE IMAGE", and "ZOOM IN". Below these are sections for "DETECTOR GEOMETRY", "BASICS" (BOTTOM PLANE, BLUE BEAM, YELLOW BEAM), "VERTEX TRACKER" (PIXEL TRACKER, IST TRACKER), "TIME PROJECTION CHAMBER" (BARREL TPC), and "SUBSYSTEMS" (TOF, EMC, MAGNET). At the bottom of the control panel are "TRACKS" and "HITS" sections. The bottom of the interface features the U.S. Department of Energy logo and the text "STAR Collaboration (c) 2013-2016".

Events and Geometry are provided in custom JSON-based format – for fast processing
<http://online.star.bnl.gov/aggregator/livedisplay/>

EIC Meeting, JLAB, May 1st, 2017

v1: 3D Support

Left-Right (LR) view for 3D TVs, Right-Left (RL) view for cross-eyed view

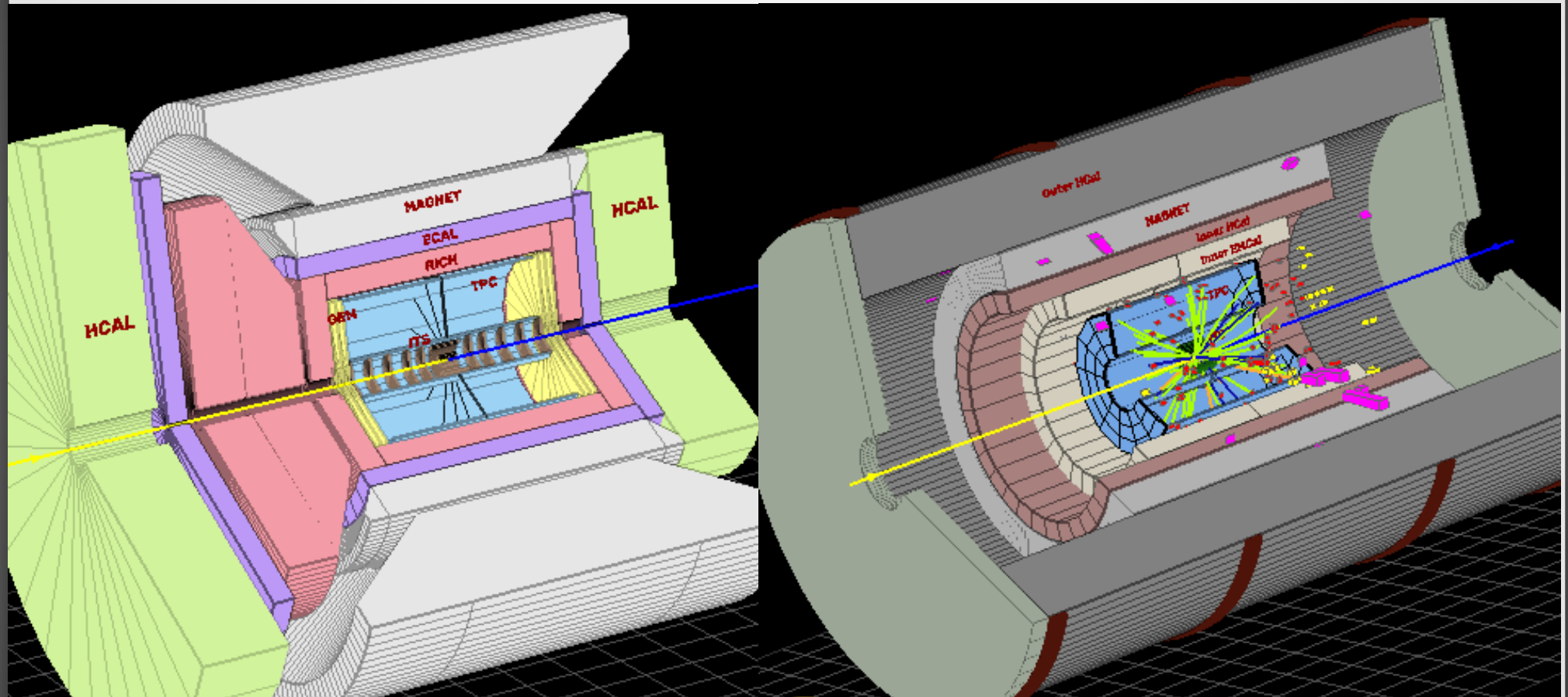


Google Cardboard, VR sets – we support all of them..

<http://online.star.bnl.gov/aggregator/livedisplay/>

EIC Meeting, JLAB, May 1st, 2017

v1: New detectors are easy to implement

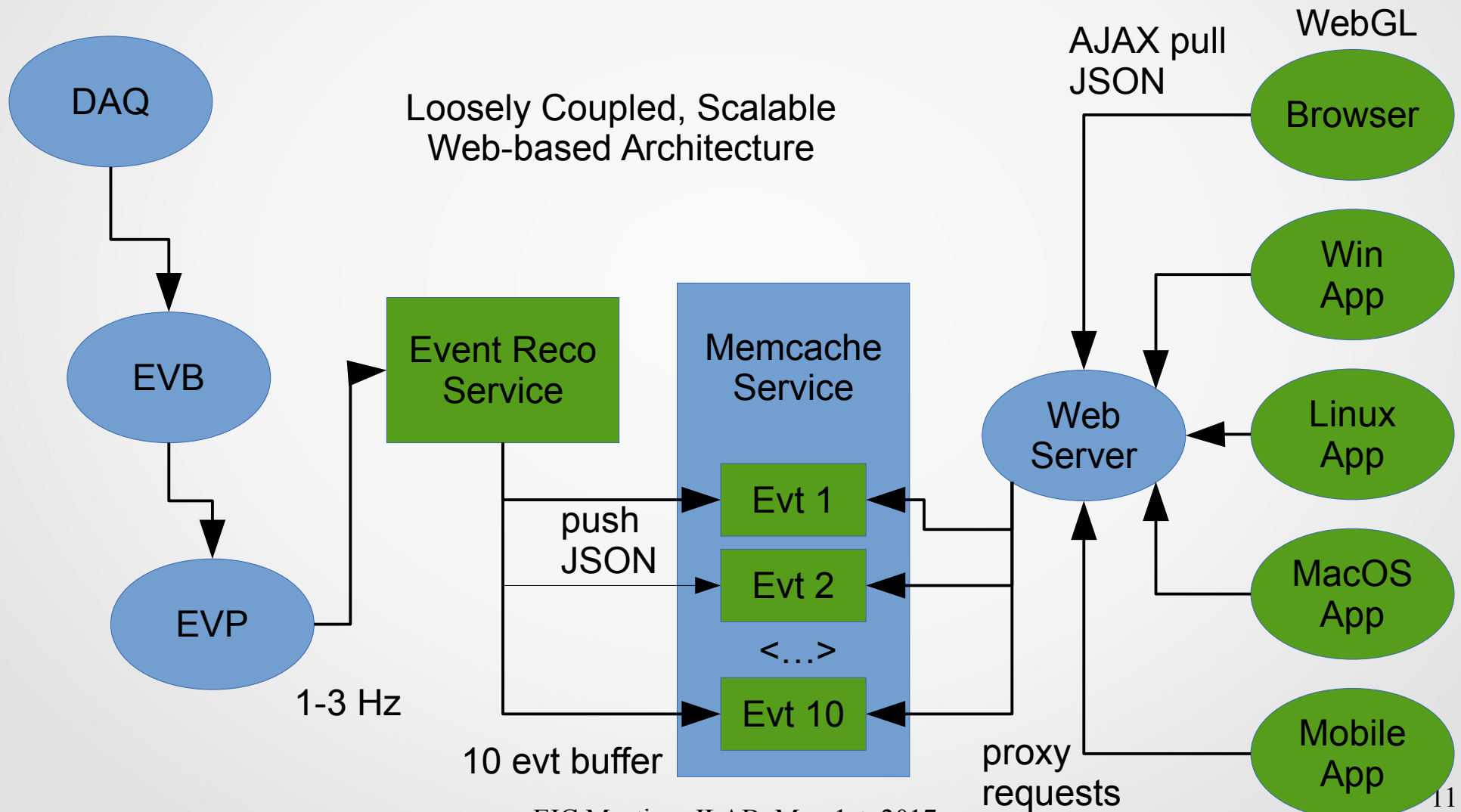


EIC detector concept, BNL
<http://www.eicug.org/display/>

SPHENIX detector, BNL
<https://www.sphenix.bnl.gov/display/>

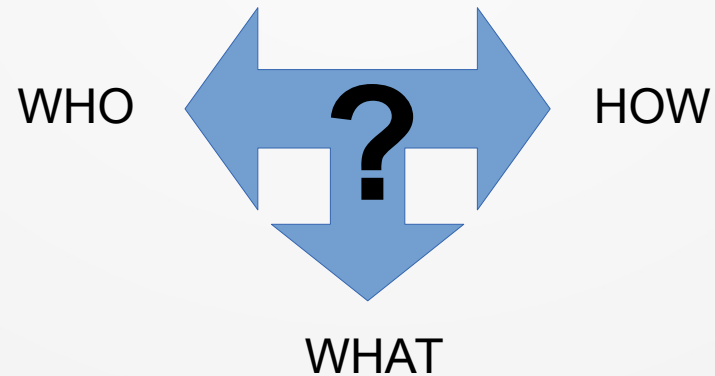
Component Diagram for v1

Online / Live Event Display

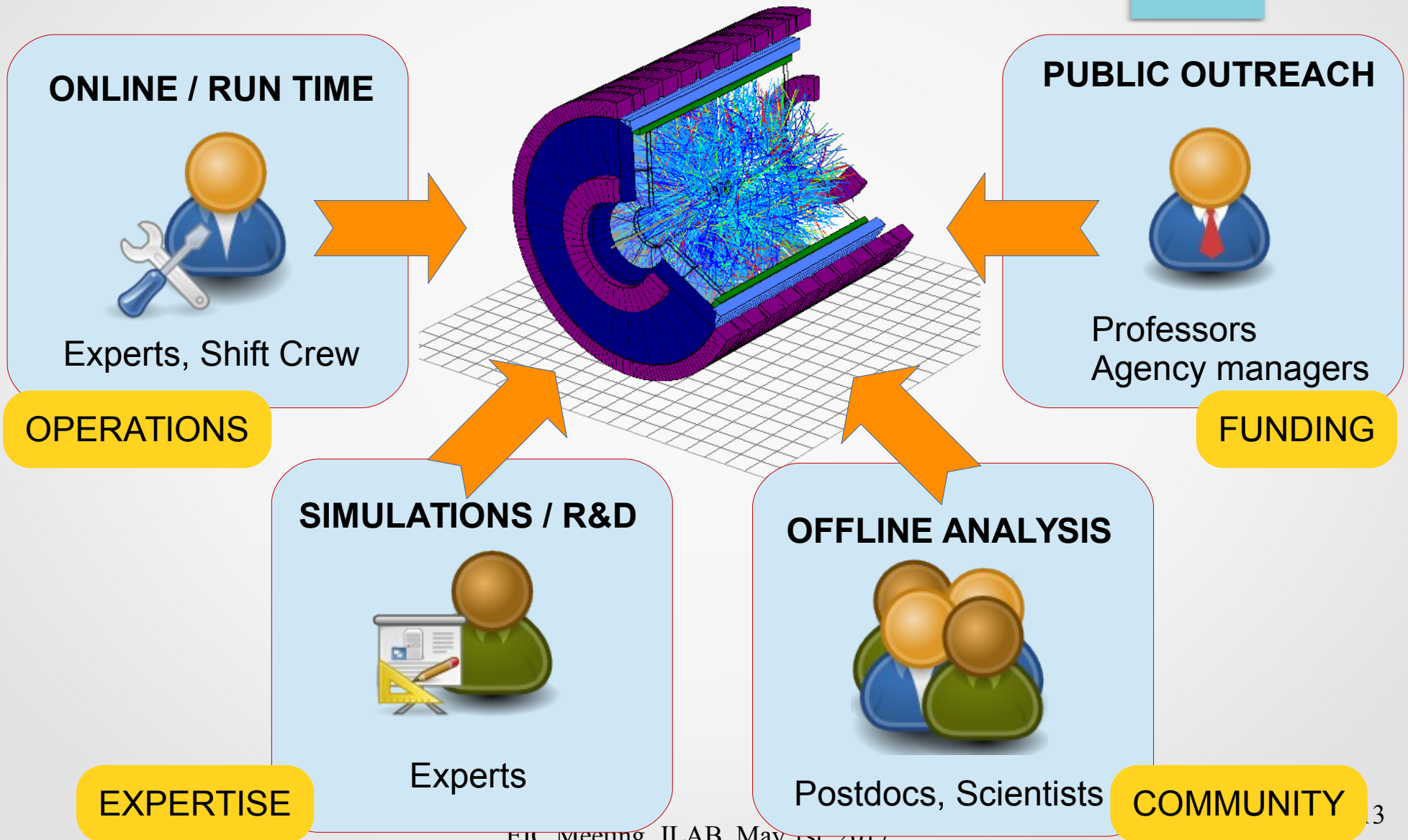


Next Gen Event Display

planning for the Event Display v2



Target Audience (who?)



Use-Cases (what?)

- **Simu & Reco Experts**
 - detector geometry design and visualization
 - mc event data visualization
 - service information visualization
- **Online Experts**
 - reco event visualization
 - early problem detection
- **Data Analysis crowd**
 - reco event visualization
 - detector internals visualization
 - illustrations for papers and posters
- **Public Outreach**
 - STEM teaching visuals (professors)
 - Illustrations for media, news, public events, agencies

Requirements (how?)

- **Simu & Reco Experts**

- precise geometry and reconstructables, precise camera positioning, MC framework-specific meta-data support, debugger integration, fast, high learning curve is okay

- **Online Experts**

- fast, interoperable, easily extensible, framework-independent, platform-independent, learning curve is irrelevant

- **Data Analysis**

- feature-rich, interactive, ability to produce high-resolution images, negligible learning curve is a must

- **Public Outreach**

- must cause „wow effect“, platform-independent, web-based, negligible learning curve is a must

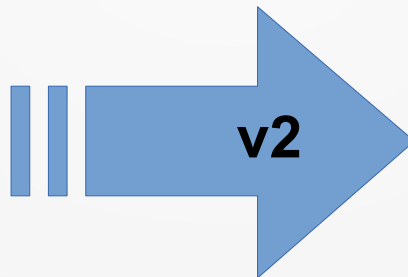
Planning: Summary

Based on the outlined use-cases and requirements:

- **Simu & Reco Experts** will likely still use *framework-specific* Event Displays most of the time due to the development needs - *access to the detailed meta-data of the specific simulations framework, which is virtually impossible to generalize* - backed by some compatible *generic* Event Display for interoperability purposes
- **Online, Data Analysis and Public Outreach groups** seem likely to be happy with a *generic* Event Display which must have the following properties: *framework-independent, platform-independent, easy to learn and use, fast*

Event Display v2

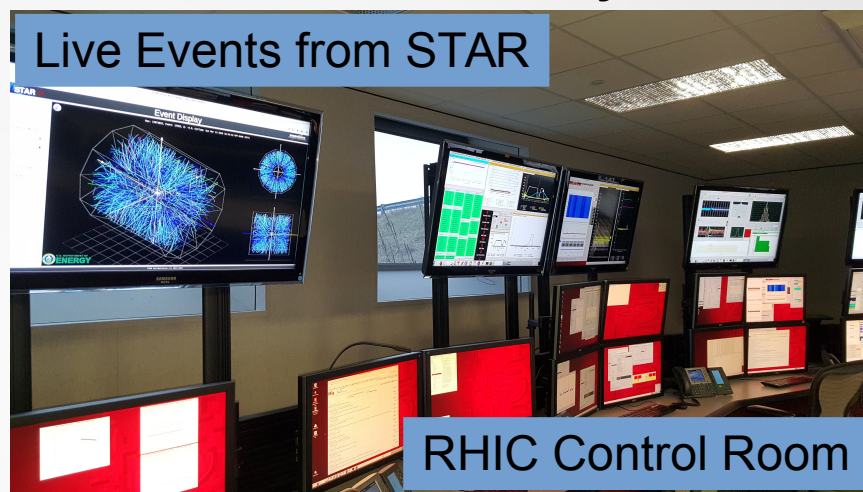
early development, functional prototype



Moving Towards Event Display v2

- **Based on the outlined requirements, we need to implement:**
 - browser-based display
 - wide Geometrical Shape types support
 - GDML / AGML import (common format)
 - increase interactivity: enhanced service information, volume manipulation
- **Why browser-based?**
 - future-proof codes, use newest JavaScript standard (ES6+)
 - forward compatible, universal user interfaces
 - general trend in the community towards web UIs as primary interfaces
 - Software as a Service (SAAS) paradigm is way to popular to ignore
 - answers all requirements listed earlier!

Some Use-Cases already covered!



Geometry Primitives

Name	Display	Geant 3	ROOT/TGeo	Geant 4	GDML	VecGeo
Box	Geo.box	BOX	TGeoBBox	G4Box	box	Box
Trapezoid, X	Geo.trd1	TRD1	TGeoTrd1	(=G4Trd)	(=trd)	(=Trd)
Trapezoid, X/Y	Geo.trd2	TRD2	TGeoTrd2	G4Trd	trd	Trd
General Trapezoid	Geo.trap	TRAP	TGeoTrap	G4Trap	trap	Trapezoid
Tube	Geo.tube	TUBE	TGeoTube	(=G4Tubs)	(=tube)	(=Tube)
Tube Segment	Geo.tubs	TUBS	TGeoTubeSeg	G4Tubs	tube	Tube
Cone	Geo.cone	CONE	TGeoCone	(=G4Cons)	(=cone)	(=Cone)
Cone Segment	Geo.cons	CONS	TGeoConeSeg	G4Cons	cone	Cone
Sphere	Geo.sphe	SPHE	TGeoSphere	G4Sphere	sphere	Sphere
Parallelepiped	Geo.para	PARA	TGeoPara	G4Para	para	Parallelepiped
Polygone	Geo.pgon	PGON	TGeoPgon	G4Polyhedra	polyhedra	Polyhedron
Polycone	Geo.pcon	PCON	TGeoPcon	G4Polycone	polycone	Polycone
Elliptical Tube	Geo.eltu	ELTU	TGeoEltu	G4EllipticalTube	eltube	(=scaled Tube)
Hyperboloid	Geo.hype	HYPE	TGeoHype	G4Hype	hype	Hype
Twisted Trapezoid	Geo.gtra	GTRA	TGeoGtra	G4TwistedTrap	twistedtrap	
Cut Tube	Geo.ctub	CTUB	TGeoCtub	G4CutTubs	cutTube	CutTube
Torus	Geo.torus		TGeoTorus	G4Torus	torus	Torus
Ellipsoid	Geo.ellipsoid	(SPHE)	(=scaled sphere)	G4Ellipsoid	ellipsoid	(=scaled Orb)
Elliptical Cone	Geo.elcone	(CONE?)	(=scaled cone?)			
Tetrahedra	Geo.tet		(=TGeoArb8?)			
Arbitrary 8 vertices	Geo.arb8		TGeoArb8			
Paraboloid	Geo.paraboloid		TGeoParaboloid			
Extrusion	Geo.xtru		TGeoXtru	G4ExtrudedSolid	xtru	(=GenTrap)
Simple Extrusion	Geo.sxtru					SExtru
Hollow Sphere	Geo.orb	(=SPHE)	(=TGeoSphere)	G4Orb	orb	Orb
Tw. Box	(=Geo.box)	(=GTRA?)	(=TGeoGtra?)	G4TwistedBox	twistedbox	
Tw. Gen. Trapezoid	(=Geo.trd2)	(=GTRA?)	(=TGeoGtra?)	G4TwistedTrd	twistedtrd	
Tw Tube Segment	(=Geo.tubs)			G4TwistedTubs		twistedtubs
Tessellated Solid	Geo.tessellated			G4TessellatedSolid		tessellated

Common subset is still to be agreed upon so Event Display must implement all shapes!

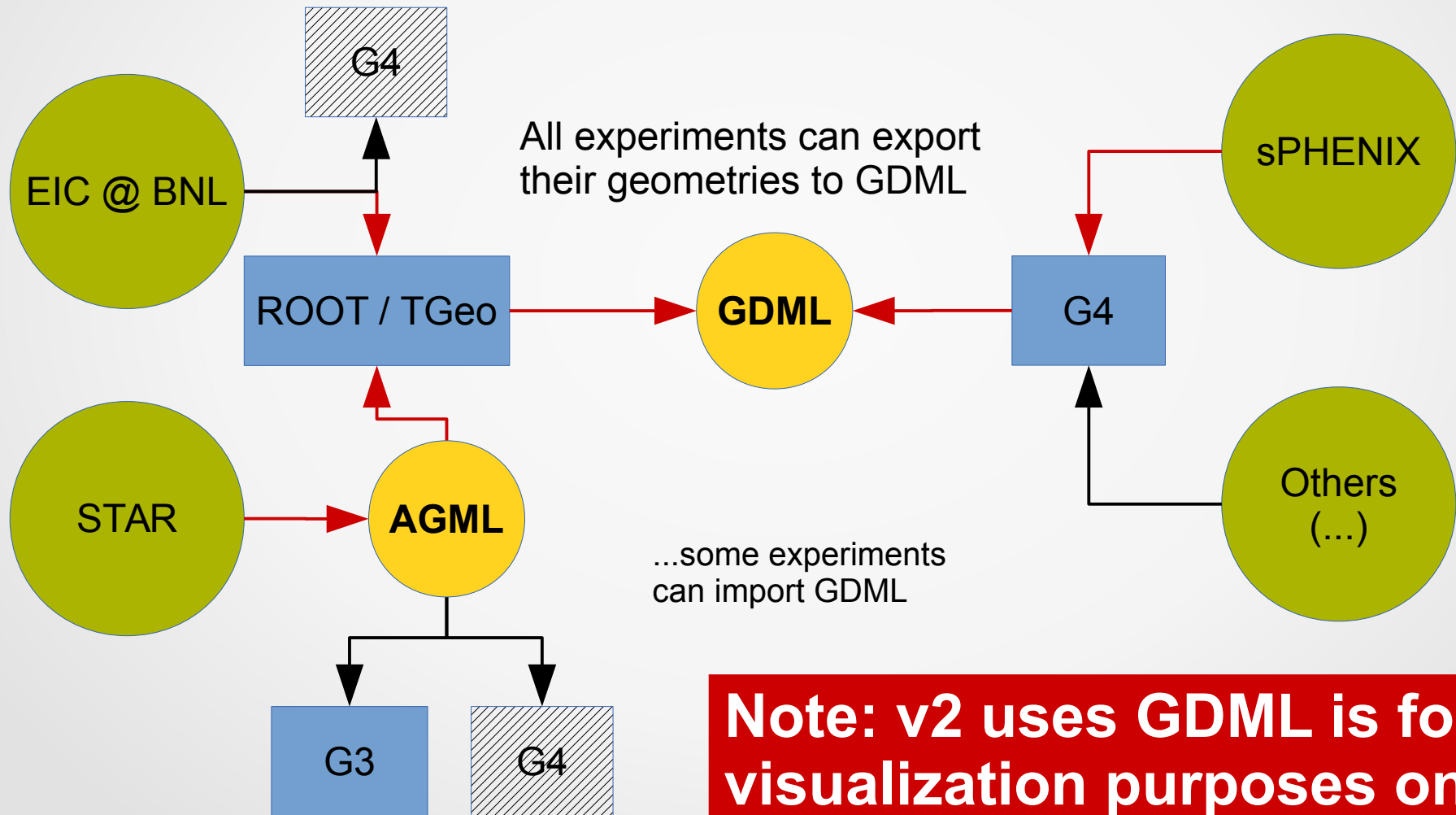
Recent v2 activity

- STAR Event Display Conversion started in April 2017:
 - **Source codes** being rewritten according to JS ES6 standard. Transpile with babel, package with webpack, NW.js, Cordova
 - **Geometry Shapes** => standalone library, depends on Three.js
 - basic G3 subset revised, coordinate system fixed and validated
 - **NEW** G3+TGeo+G4+GDML+VecGeom shapes added (100%)
 - **NEW** Boolean solids support
 - **NEW GDML import** => standalone library (dep on three.js)
 - **Event Display** app is being rewritten with JQ Mobile UI library
 - better support of newest mobile devices, better UI
- Validation & Stress-testing: TBD, not expected at alpha stage
- Implementation of GDML support creates solid ground for a generic Event Display: cross-experiment usage is now possible!

<http://www.star.bnl.gov/~dmitry/eventdisplay2/>

Event Display v2: why GDML?

At the moment, GDML is a commonly supported geometry export format of all involved parties. V2 may use any other format if suggested to..



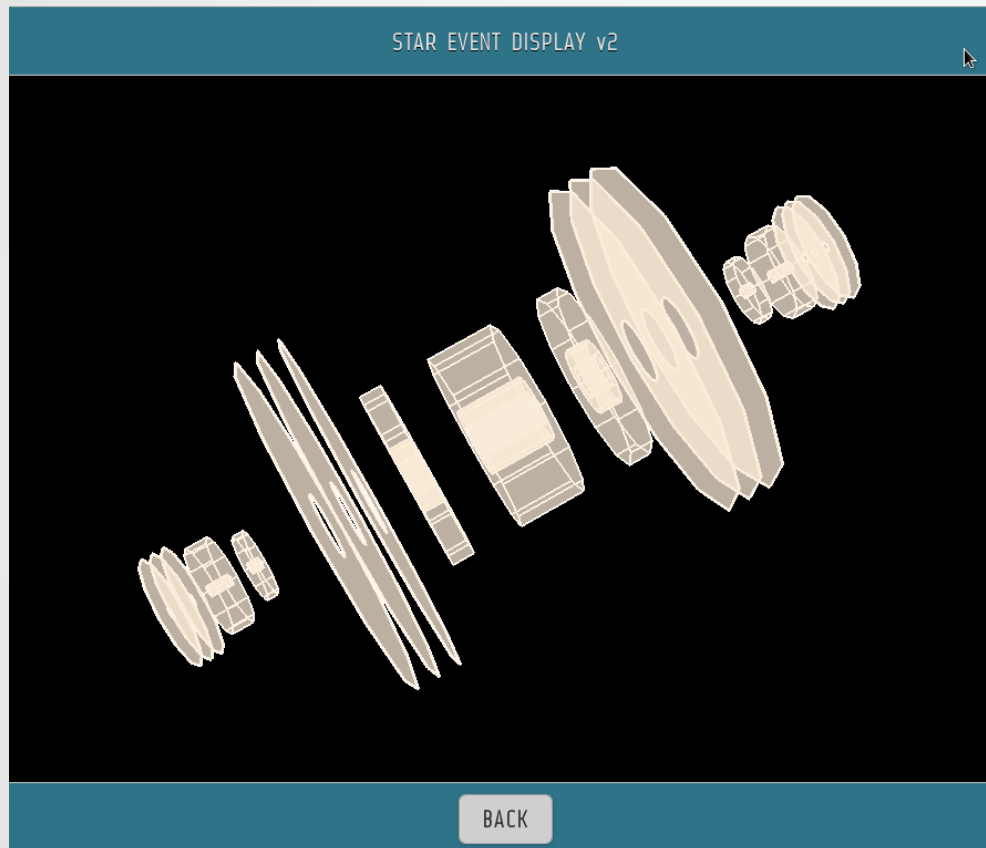
v2: GDML import implementation

- Definitions:
 - constants, expressions, variables, positions, rotations, scales, units
 - quantities, matrices, G4 constants
- Materials:
 - Density => volume transparency
 - G4 materials
- Solids:
 - all solids implemented including boolean solids, ellipsoids, elliptical cones, twisted shapes, tessellated solids, scaled solids
- Boolean solids:
 - union, subtraction, intersection
 - multiUnion
- Structure:
 - volumes and physvolume, hierarchy, placement, assemblies, loops over physvols
 - loops over materials and volume definitions, replicated volumes, parametrized volumes, volume divisions
- Setup:
 - worldref, multiple worldref
- Extensions:
 - auxillary tags: visibility, color
 - multiple file support

V2 fully understands ROOT's GDML output, and goes beyond that subset...

v2: Early Development Tests

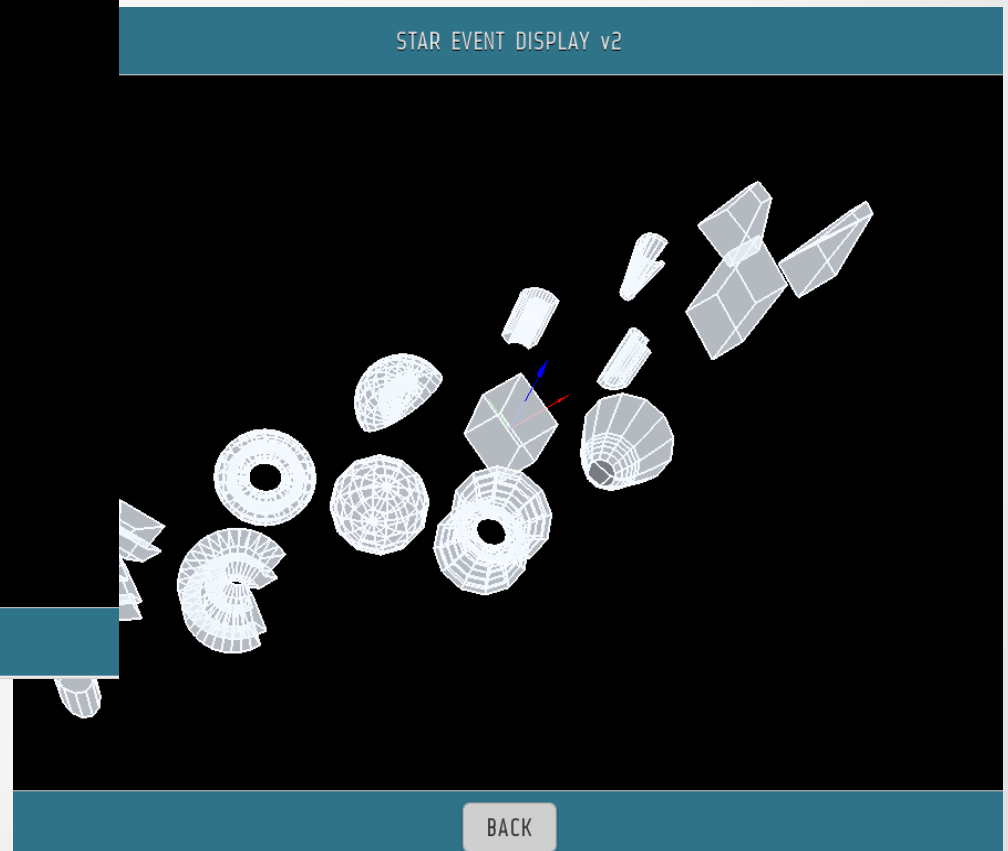
<http://www.star.bnl.gov/~dmitry/eventdisplay2/>



GDML-imported geometry

No dependencies on G3 / G4 / ROOT
or any other HEP/NP framework

Uses latest version of Three.js library
Supports boolean solids via ThreeCSG



Geo Shape Test

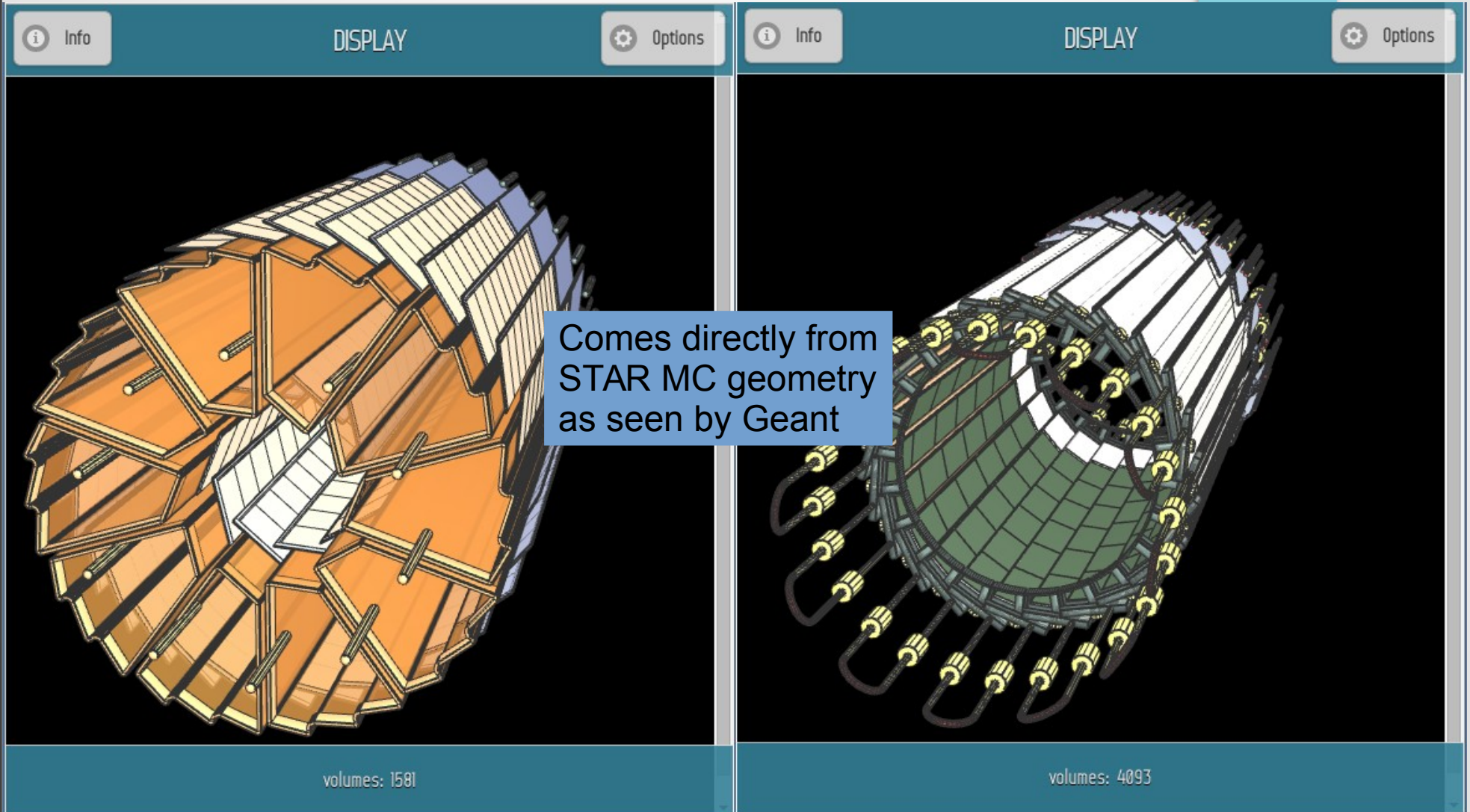
v2: complete geometry imported from GDML

<http://www.star.bnl.gov/~dmitry/eventdisplay2/>

The screenshot displays the STAR Event Display v2 interface. At the top left, there is an 'Info' button. The main display area shows a 3D model of the STAR Hall, with a blue box indicating 'Rotate, Zoom, Clip' controls. A blue box on the right side of the model indicates 'Geometry Import' and 'Events Import'. A blue box at the bottom left of the model indicates 'Clipped STAR Hall overview: detector, beam optics, calorimeters'. At the bottom center of the model area, it says 'volumes: 4683'. On the right side, there is a control panel with several buttons: 'GEOMETRY SELECTION', 'EVENT SELECTION', 'VOLUME SETUP', 'CLIP SETUP', 'CAMERA SETUP', and 'VISIBILITY'. A blue box at the bottom of the control panel indicates 'Basic Controls More to be added!'.

v2: STAR detector MC geometry is highly detailed

<http://www.star.bnl.gov/~dmitry/eventdisplay2/>



STAR Pixel Tracker

STAR Inner Silicon Tracker

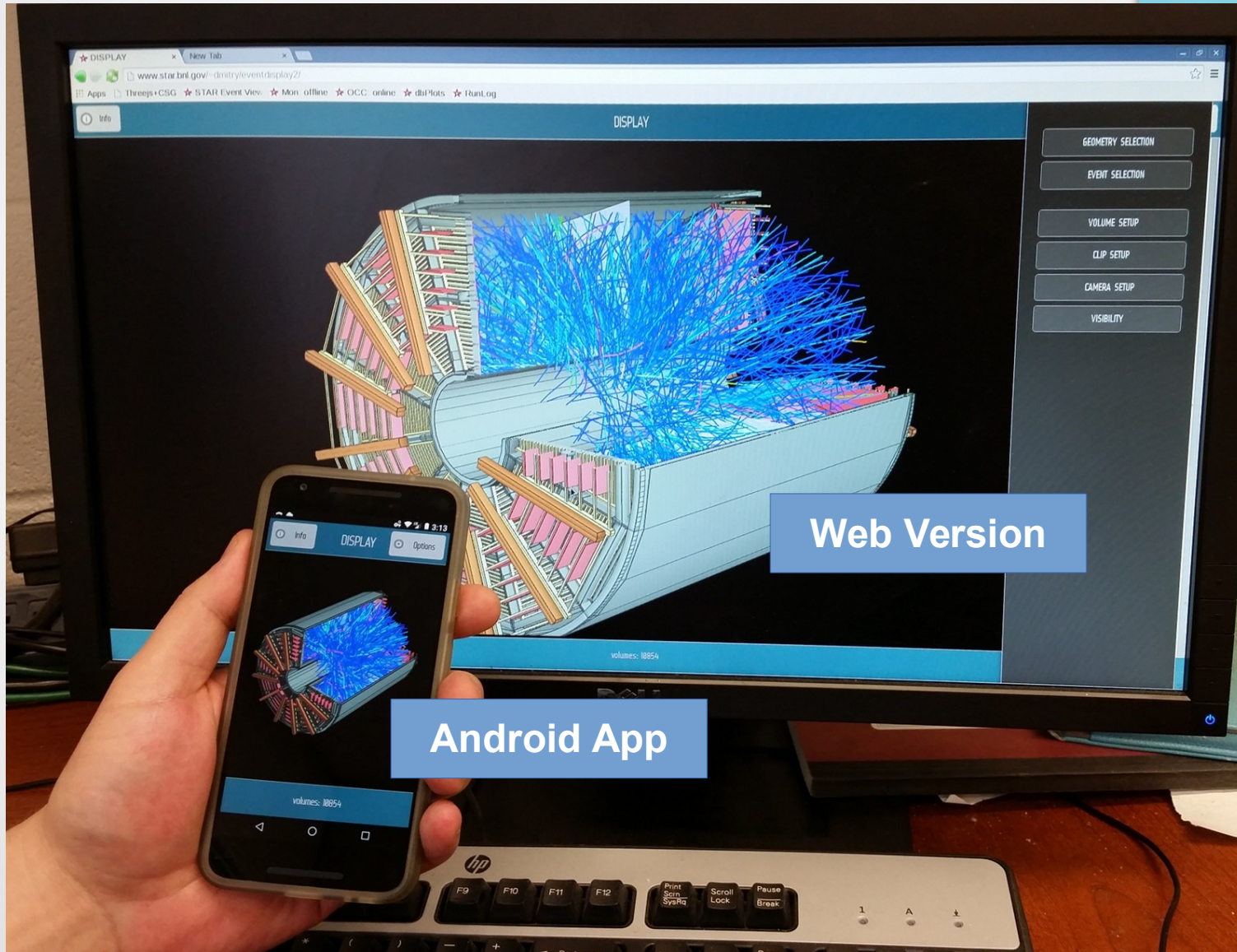
v2: Event Support: tracks and hits

Events loaded separately from geometry description

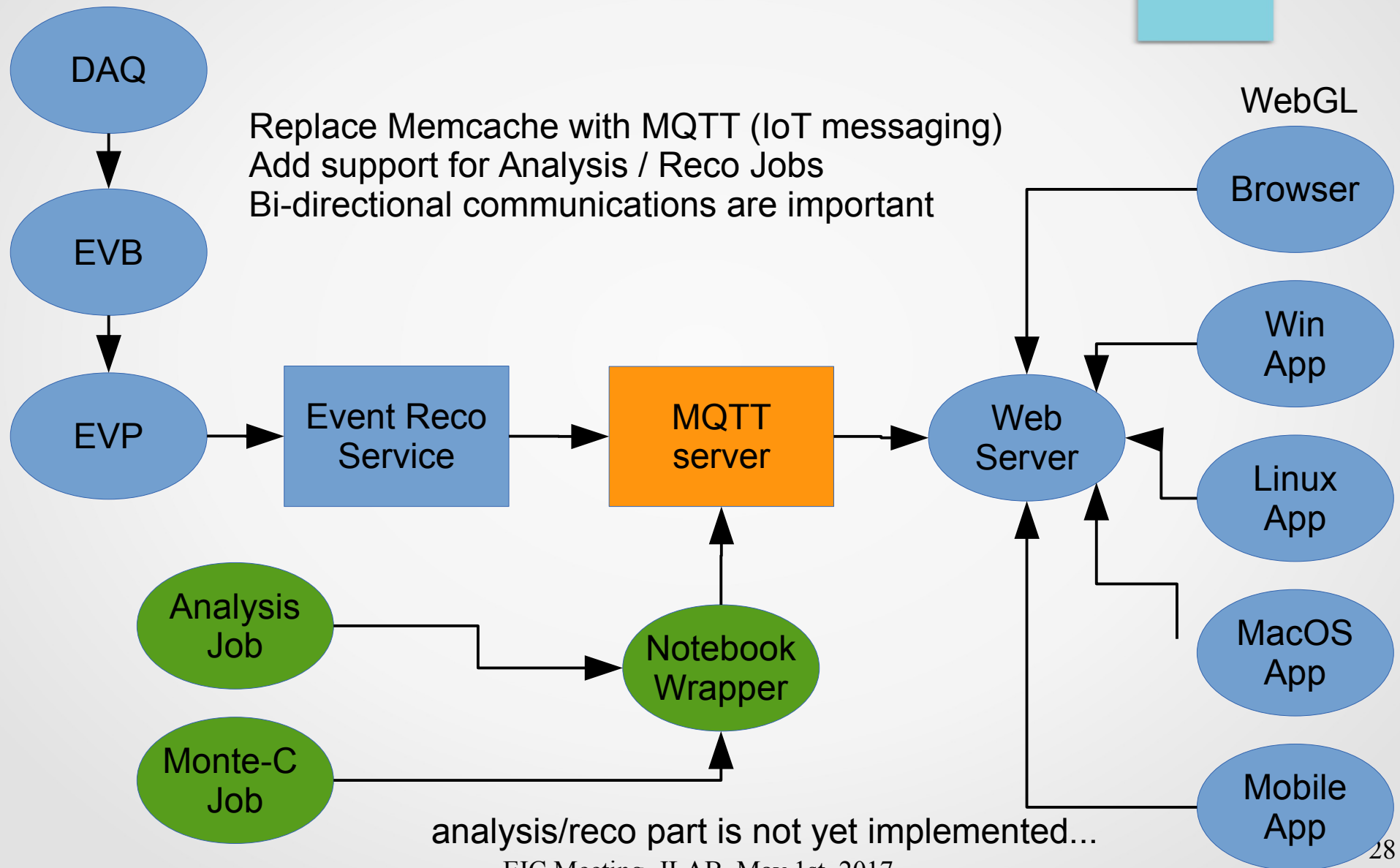
The screenshot displays a 3D visualization of a detector's internal structure, specifically the TPC (Time Projection Chamber) volume. The detector is shown in a cutaway view, revealing its cylindrical geometry and internal components. A dense network of blue lines represents particle tracks originating from a central point and extending outwards. The detector's structure is rendered in shades of orange, red, and grey. The interface includes a top bar with an 'Info' button and a 'DISPLAY' label. On the right side, there is a vertical menu with buttons for 'GEOMETRY SELECTION', 'EVENT SELECTION', 'VOLUME SETUP', 'CLIP SETUP', 'CAMERA SETUP', and 'VISIBILITY'. A text box in the lower-left corner of the 3D view reads 'TPC Tracks over TPC volume'. At the bottom of the interface, a status bar indicates 'volumes: 23886'.

v2: Web, mobile, desktop app – you name it

single source code => multiple build targets, platforms, devices



Architecture: Event Display v2



v2 is at alpha stage, beta expected this summer (TBC)

- Graphics performance has to be optimized:
 - pack shapes into single WebGL calls
 - produce less vertices per geometrical shape
 - reduce number of segments for complex shapes
 - allow basic material type in addition to Lambert material
- Error handling needs to be substantially improved
 - no tests for invalid shapes
 - no warnings upon unimplemented features
- GDML standard implementation is incomplete
 - missing matrices, G4 defaults, loops over materials and volumes, parametrized volumes
- Web Interface is being revised
 - Many additional control knobs to be added
 - Validated on Android 5+, Web (Firefox, Chrome) only for now..

Classic paradox: remaining 20% of work will consume 80% of time

Geometry design hints to allow best visuals

- Always follow the hierarchical model:
 - do not attach mixed elements of different subsystems to the same root level or mother volume, keep them properly separated
 - use „assembly“ to group detector components (i.e. east/west parts of the calorimeter) or detector groups (all tracking detectors)
 - if thousands of elements have to be placed, use envelope containers with proper material
- Provide multiple worldrefs (entry points in GDML)
 - Complete hall + detector, detector without hall elements
 - Calorimeter groups
 - all trackers, barrel tracker, inner tracker
- Inspect your material densities carefully
 - gas-like materials are not displayed
 - liquid-like materials become semi-transparent
 - dense materials are opaque

Summary and Outlook

- Use-Cases and Requirements for a generic Event Display were presented for discussion
- Implementations of STAR Event Displays were presented, with possible extension of web-based Event Display (v2) beyond STAR to future experiments to come
 - Standalone, interoperable gdml-aware Event Display would be useful not only for EIC or STAR only, but for all HEP/NP community
- Possible future: remote access to computational resources using JS-based terminal
 - similar to Jupyter Notebook, but using MQ to disentangle web server and clients/servers
 - utilizing Event Display v2 for geometry and events visualization
 - possibly utilizing jsROOT for histograms and graphs



Thank You!
Questions? Comments?