FROM MPD EVENT 3D-VISUALIZATION TO SCADA CONTROL SYSTEM

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Outline

Prototype of the browser-based Multi-Purpose Detector (MPD) Event 3D-Visualization was realized two years ago and now we should take the next step to supervisory control of the detectors. The control system architecture comprising computers, programmable logic controllers, sensors, networked data communications and graphical user interfaces for high-level sustained supervision of the detectors and their real time processes.

The architecture is based on **SCADA** control system (**S**upervisory **C**ontrol **A**nd **D**ata **A**cquisition) that was developed to be a universal means of remote-access to a variety of local control modules, which could be from different manufacturers and allowing access through standard automation protocols. The SCADA concept was realized in Tango Controls - free Open Source solution as one of the flexible, and highly scalable toolkit.

JavaScript Engines from different vendors

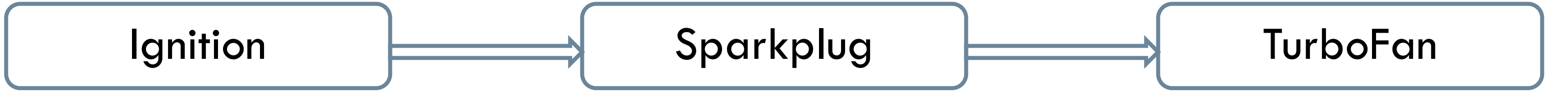
- **V8** is an open-source JavaScript engine developed by The Chromium Project for **Google Chrome** and Chromium web browsers. The V8 assembler is based on the Strongtalk assembler. On December 2010, a new compiling infrastructure named Crankshaft was released, with speed dramatically improvements.
- **SpiderMonkey** currently maintained by the Mozilla Foundation and it is written in C/C++ and contains an interpreter, the IonMonkey just-in-time (*JIT*) compiler, and a garbage collector. It is still used in the **Firefox** web browser.
- **JavaScriptCore** (*JSC*) is Apple's engine for its **Safari** browser based on optimizing *JIT* compiler named *FTL* (Faster Than Light) was announced on May 2014. As of February 2016, the backend of *FTL JIT* is replaced by “Bare Bones Backend” (or ***B3*** for short).

Modern Back-end Frameworks

- **Node.JS –** is the world’s most popular and widely used server-side, open-source, cross-platform JS runtime environment built on ***Google’s V8 JS engine***. It's been dominating the web development world since 2009. Node.js is lightweight and ideal for scalable, data-intensive, real-time web applications that can run on distributed devices thanks to its asynchronous I/O and event-driven architecture.
- **Deno –** is introduced in 2018 by the same author ***Ryan Dahl*** as Node.JS. It's dubbed as its successor. Deno is a JavaScript, TypeScript, and WebAssembly runtime with secure defaults and no file, network, or environment access unless explicitly enabled. It’s built on the same ***Google’s V8 JS engine, Rust, and Tokio***. Security was one of the main reasons Ryan Dahl created Deno.
- **Bun** - is a new all-in-one JS runtime and toolkit based on ***JSC engine from Safari***. It is a complete **NPM**-compatible (**N**ode **P**ackage **M**anager) highly-optimized APIs for building JS apps including a package manager, test runner, and bundler. Bun is four times faster then Node.JS and designed as a drop-in for Node.JS. Its 1st release was published just two months ago!

How Google's V8 JavaScript Engine Works?

- V8- open source project, developed by Google and written in C++.
- V8 translates JavaScript code into a more efficient machine code instead of using an interpreter.
- The originally V8 design consisted of two compilers that compile source code directly into machine code.
  - Full-codegen - it is a fast compiler that produces unoptimized code
  - Crankshaft - a slower compiler that produces fast and optimized code
- The new V8 compiler pipeline since May 2021 instead of Crankshaft
  - Ignition – interpreter translate fragment of JavaScript lines to intermediate byte code
  - Sparkplug – none-optimizing compiler from byte code to native machine code
  - TurboFan - highly optimizing compiler



Ignition → Sparkplug → TurboFan

Modern JavaScript front-end Frameworks

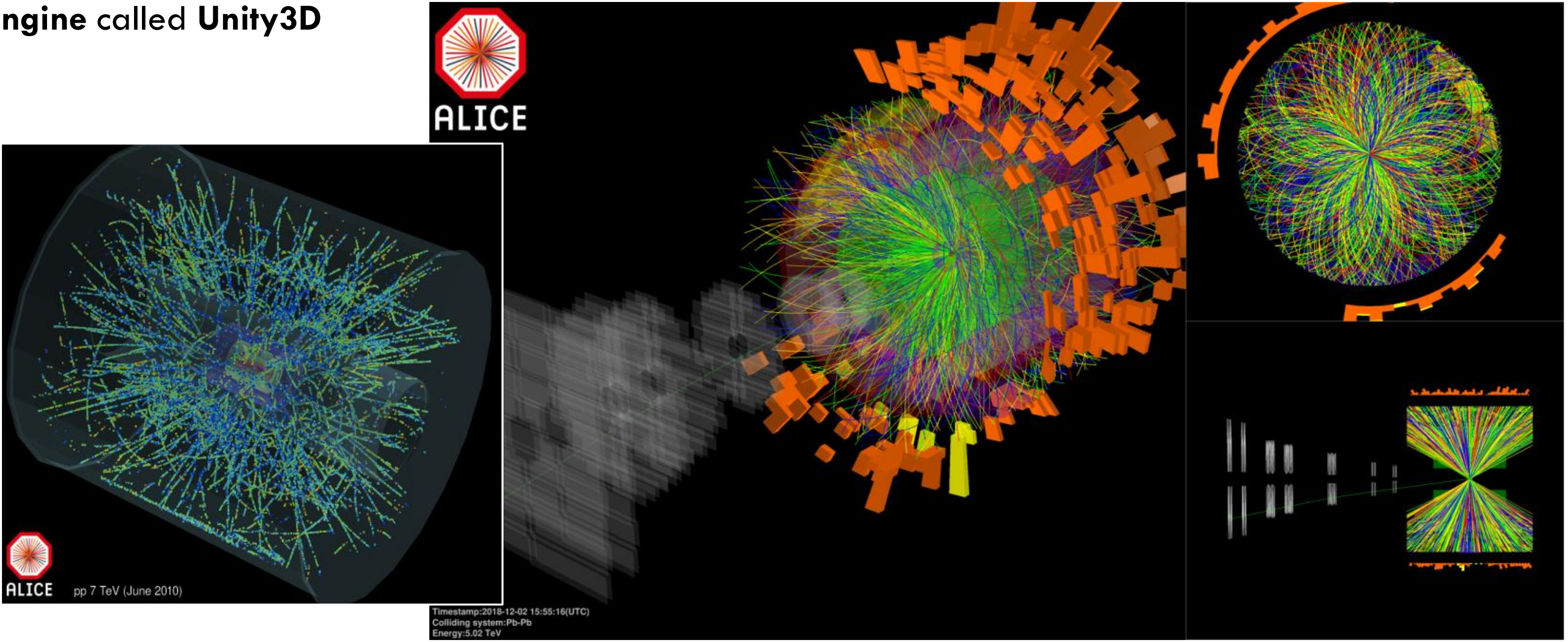
Angular, developed by Google, was first released in 2010

React, developed by Facebook, was initially released in 2013

Vue, also known as Vue.js, is the youngest member of the group. It was developed by ex-Google employee ***Evan You*** in 2014

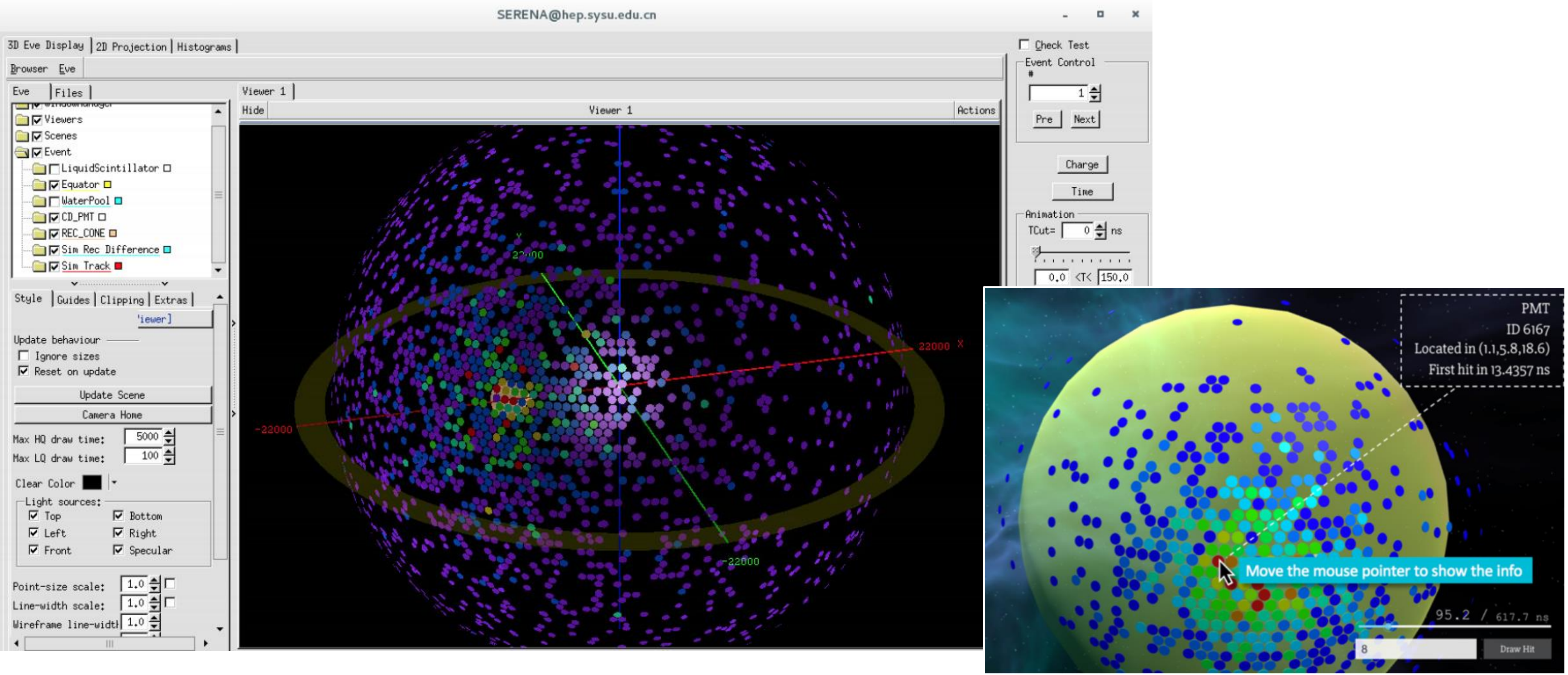
Alice Event Visualization Environment at LHC

- AliEve is a visualization tool based on the ROOT’s TEveManager. It provides a 3D and 2D visualization of the detector’s geometry read from ROOT files.
- The Total Event Display (TEV) is a project of the CERN Media Lab and it has been developed using the **game engine** called **Unity3D**



JUNO - Jiangmen Underground Neutrino Observatory Experiment at China

- JUNO Event Display is based on the ROOT EVE package and later **Unity3D** game engine



SERENA@hep.sysu.edu.cn

☑ Viewers
☑ Scenes
☑ Event
□ LiquidScintillator
☑ Equator
□ WaterPool
☑ CD_PMT
☑ REC_CONE
☑ Sim Rec Difference
☑ Sim Track

Update behaviour
□ Ignore sizes
☑ Reset on update

Max HQ draw time: 5000
Max LQ draw time: 100

Light sources:
☑ Top ☑ Bottom
☑ Left ☑ Right
☑ Front ☑ Specular

Point-size scale: 1.0
Line-width scale: 1.0
Wireframe line-width 1.0

□ Check Test
Event Control
1

Animation
TCut= 0 ns
0.0 <T< 150.0

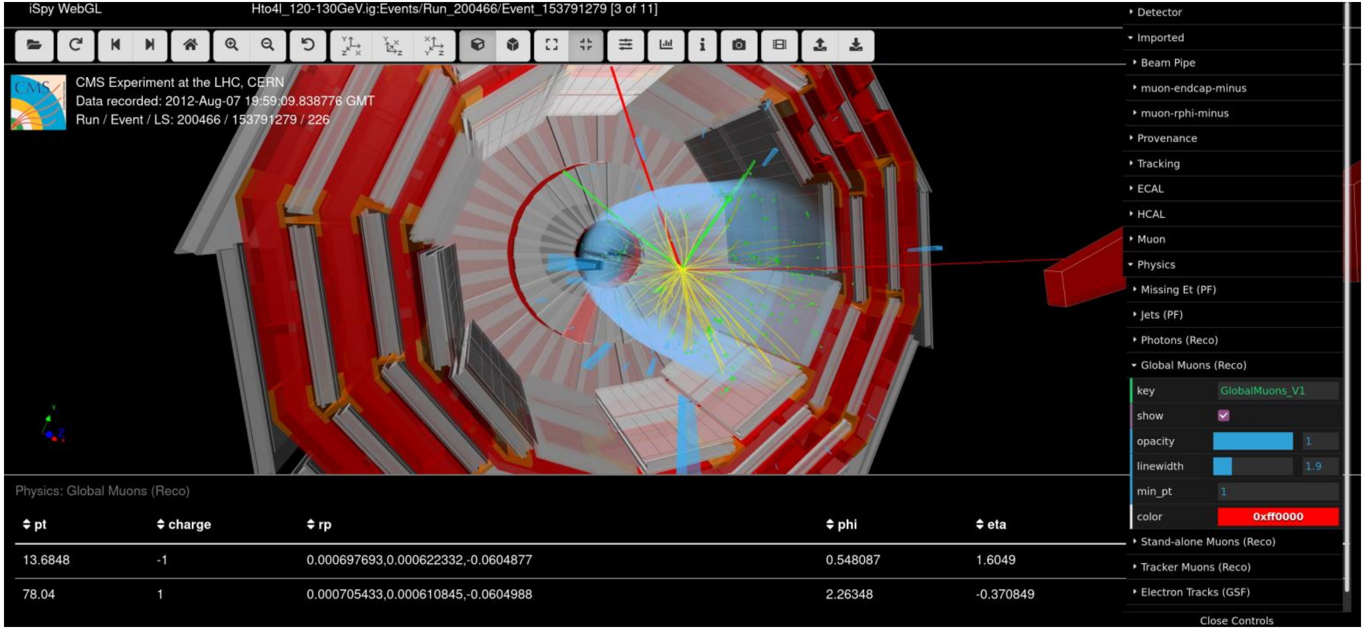
PMT
ID 6167
Located in (1.1,5.8,18.6)
First hit in 13.4357 ns

Move the mouse pointer to show the info

95.2 / 617.7 ns

iSpy Analyzer – CMS Event Display at LHC

- Original client was developed on C++ and QtGUI
- 2014 move to a new browser-based project **iSpy WebGL** by Tom McCauley



iSpy WebGL

Hto4l_120-130GeV.ig:Events/Run_200466/Event_153791279 [3 of 11]

CMS Experiment at the LHC, CERN
Data recorded: 2012-Aug-07 19:59:09.838776 GMT
Run / Event / LS: 200466 / 153791279 / 226

Physics: Global Muons (Reco)

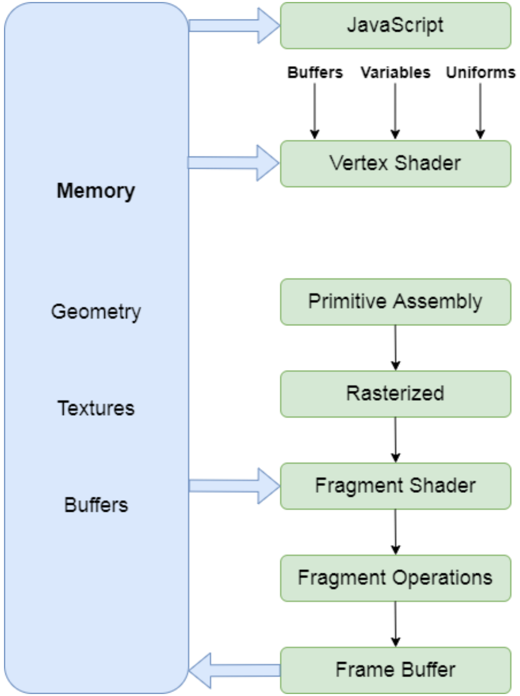
pt	charge	rp	phi	eta
13.6848	-1	0.000697693,0.000622332,-0.0604877	0.548087	1.6049
78.04	1	0.000705433,0.000610845,-0.0604988	2.26348	-0.370849

key	GlobalMuons_V1
show	☑
opacity	1
linewidth	1.9
min_pt	1
color	0xff0000

https://ispy-webgl.web.cern.ch/

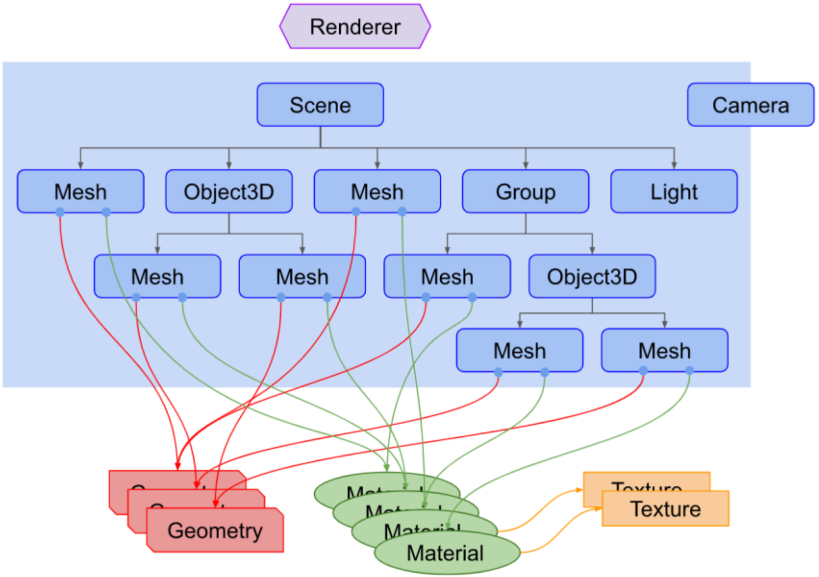
Web-based Graphics Library (WebGL)

- The original author is Mozilla Foundation.
- The current developer is Khronos Working Group
- WebGL is a cross-platform, royalty-free web standard for a low-level 3D graphics API based on OpenGL ES (*GLES*), exposed to ECMAScript via the HTML5 Canvas element.
- WebGL is a shader-based API using OpenGL Shading Language (*GLSL*), with constructs that are semantically similar to those of the underlying GLES API.
- WebGL 2.0 exposes the OpenGL ES 3.0 API.
- Perform **massively parallel GPGPU** computations using *GPU*



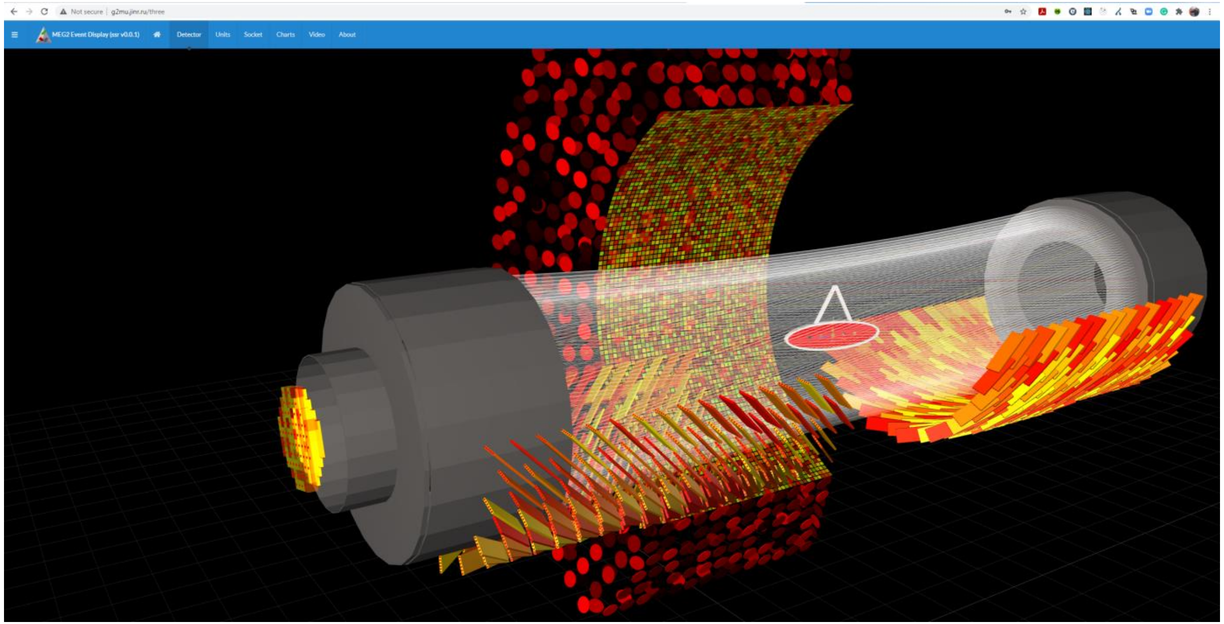
ThreeJS API basic concept

- **WebGL** is a very low-level system that only draws points, lines, and triangles.
- **Three.JS** is a cross-browser JavaScript library and Application Programming Interface (*API*) used to create and display animated 3D computer graphics in a web browser using WebGL.
- **ThreeJS** handles stuff like scenes, lights, shadows, materials, textures, 3D math and so on…



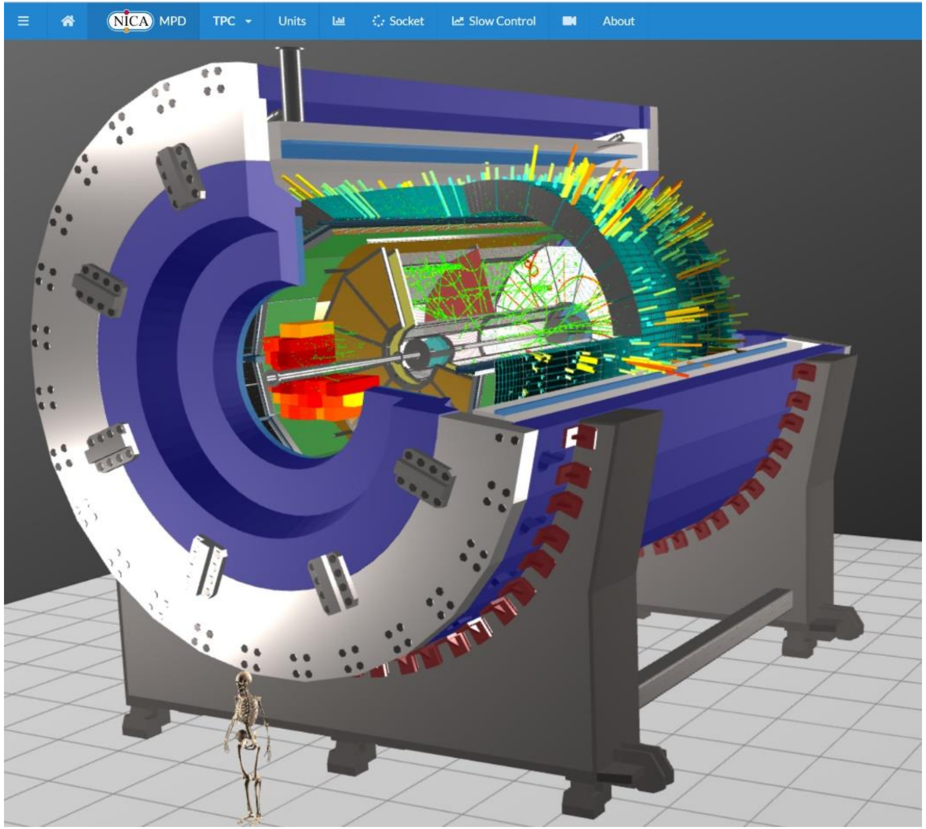
MEGII experiment at PSI, Switzerland

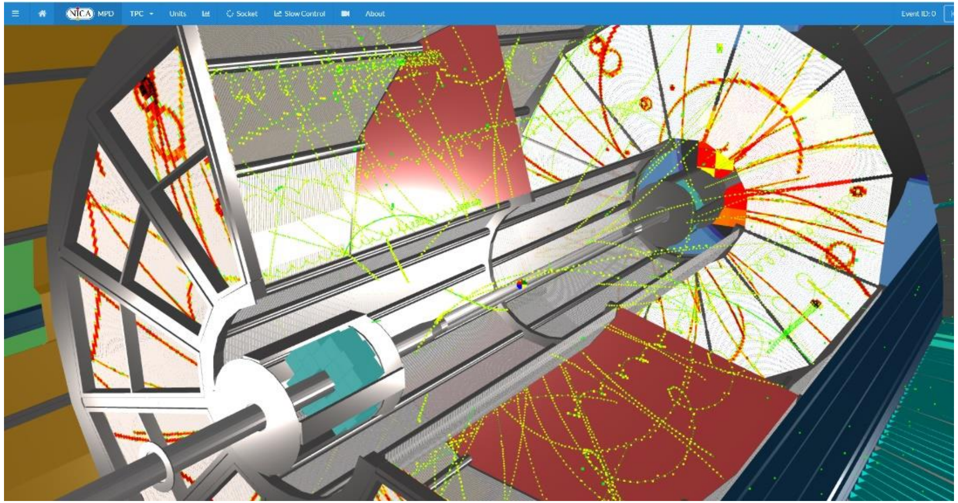
- In April 2019 Stefan Ritt (technical Coordinator of the MEG experiment in Switzerland) suggested me try to use the **WebGL** library to create a new Event Display page with 3D visualization for MEGII collaboration in frame of **MIDAS** (**M**aximum **I**ntegration **D**ata **A**cquisition **S**ystem) distributed package.


Not secure | g2mu.jinr.ru/three
MEG2 Event Display (ssr v0.0.1)
Detector
Units
Socket
Charts
Video
About

http://g2mu.jinr.ru/

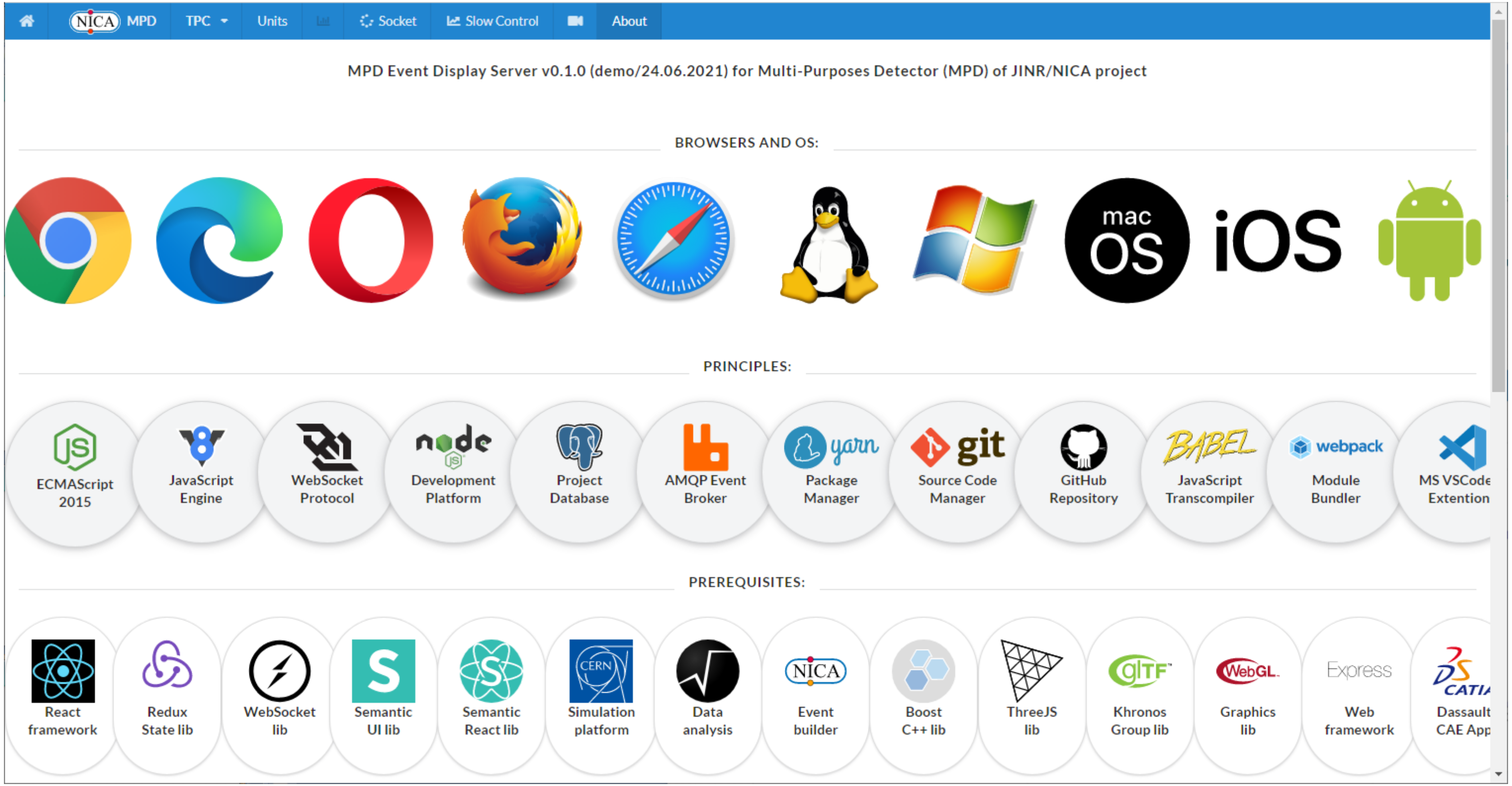
MPD Event Display Main page





https://mpd-edsrv.jinr.ru/

MPD Event Display About page



MPD Event Display Server v0.1.0 (demo/24.06.2021) for Multi-Purposes Detector (MPD) of JINR/NICA project

BROWSERS AND OS:

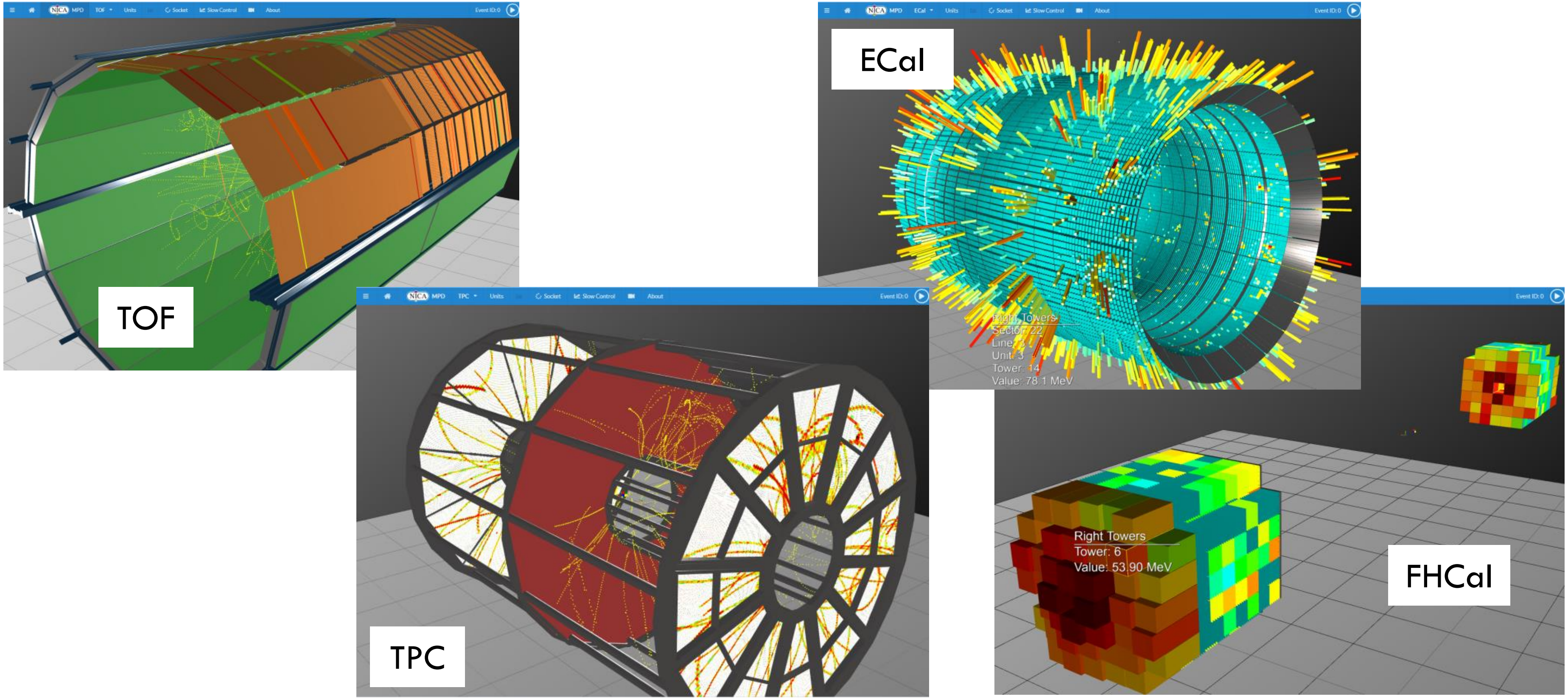
PRINCIPLES:

- ECMAScript 2015
- JavaScript Engine
- WebSocket Protocol
- Development Platform
- Project Database
- AMQP Event Broker
- Package Manager
- Source Code Manager
- GitHub Repository
- JavaScript Transcompiler
- Module Bundler
- MS VSCode Extention

PREREQUISITES:

- React framework
- Redux State lib
- WebSocket lib
- Semantic UI lib
- Semantic React lib
- Simulation platform
- Data analysis
- Event builder
- Boost C++ lib
- ThreeJS lib
- Khronos Group lib
- Graphics lib
- Web framework
- Dassault CAE App

MPD Event Display detectors



Right Towers
Sector: 22
Line: 3
Unit: 3
Tower: 14
Value: 78.1 MeV

Right Towers
Tower: 6
Value: 53.90 MeV

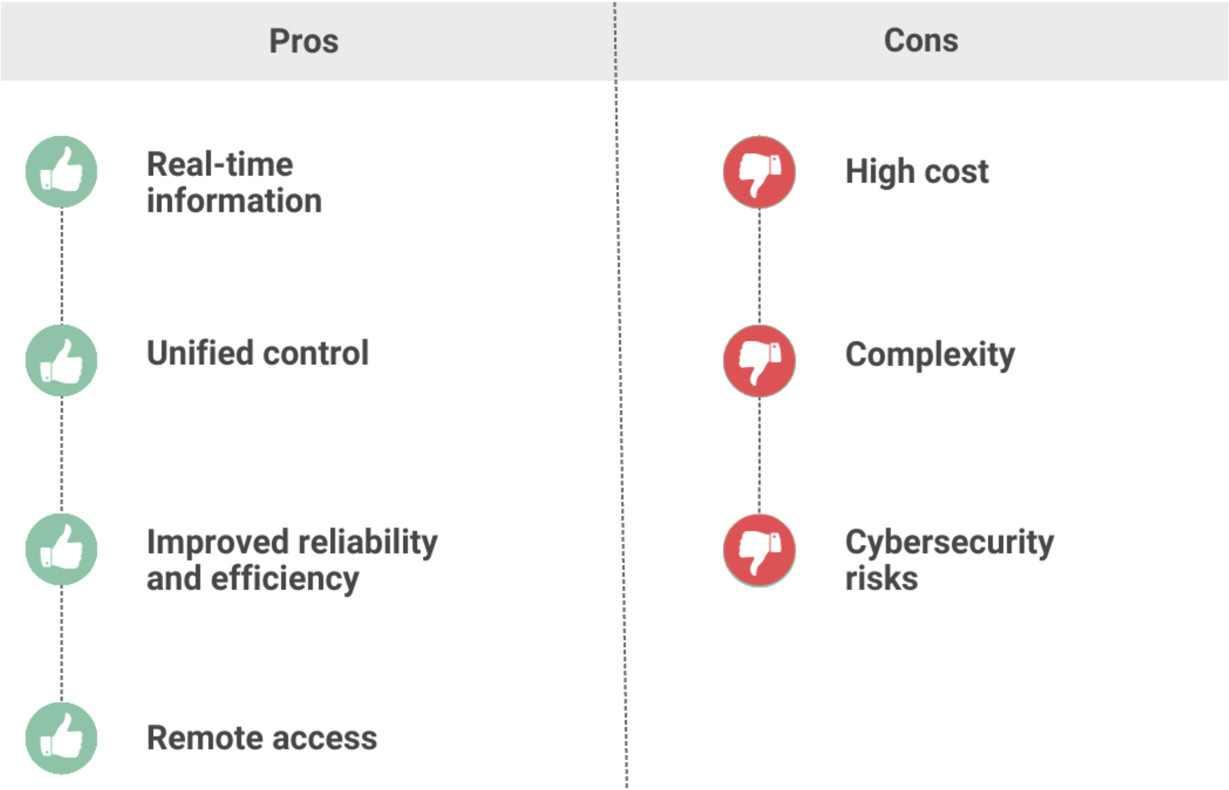
SCADA Control System

- Modern SCADA (**S**upervisory **C**ontrol **A**nd **D**ata **A**cquisition) is a category of software for real-time monitoring and control of distributed equipment.
- SCADA systems utilize Distribution Control Systems (DCS), Process Control Systems (PCS), Programmable Logic Controller (PLC) and Remote Terminal Units (RTU) that perform the majority of local and remote process alarming, monitoring and control.

Components of SCADA

- Supervisory controller also called the Master Terminal Unit (MTU)
- Remote Terminal Units (RTU)
- Programmable Logic Controllers (PLC)
- Human-machine interface (HMI) and alarm system
- Network Management Server (NMS)
- Communication components

Pro et Contra of SCADA System



Pros	Cons
Real-time information	High cost
Unified control	Complexity
Improved reliability and efficiency	Cybersecurity risks
Remote access	

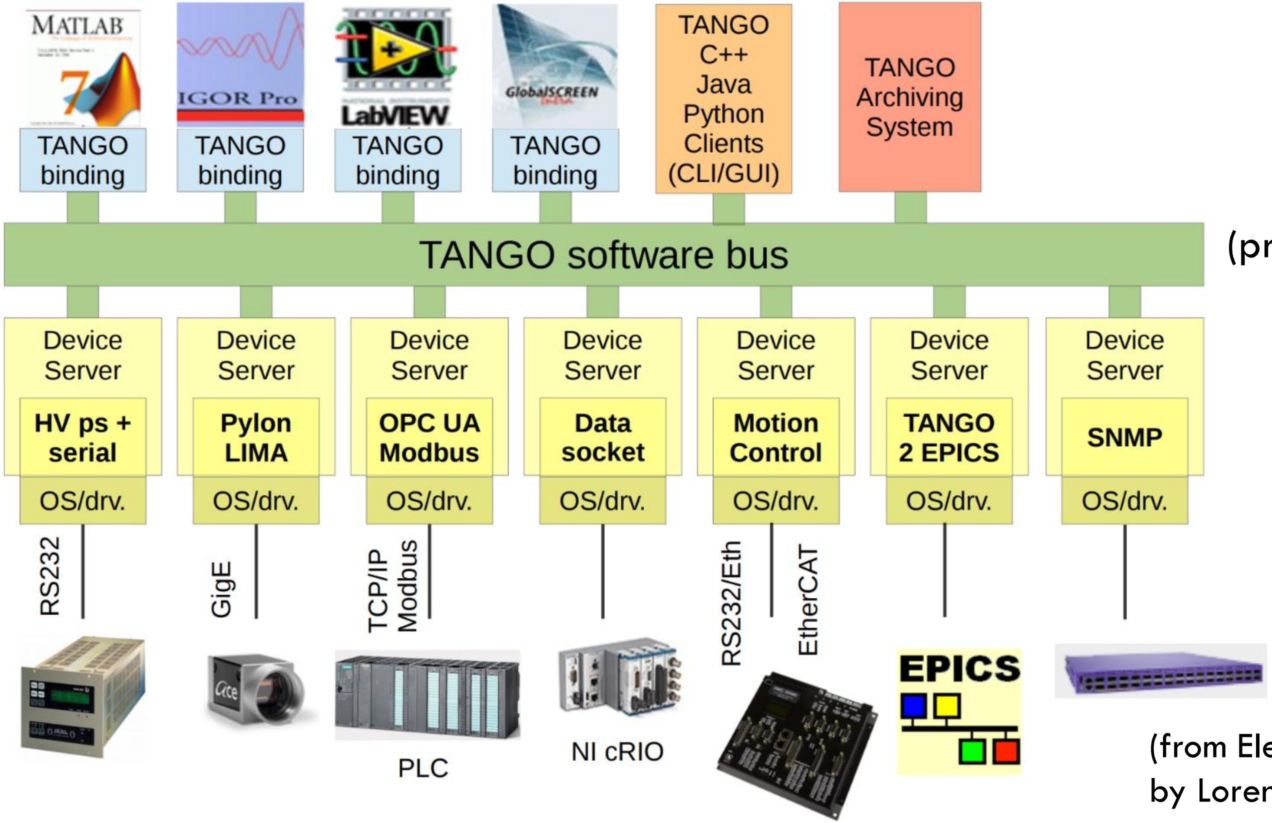
SCADA Frameworks for Science

- **EPICS: E**xperimental **P**hysics and **I**ndustrial **C**ontrol **S**ystem is a set of software tools and applications used to develop and implement distributed control systems to operate devices such as particle accelerators and other large scientific facilities. EPICS was initially developed as the Ground Test Accelerator Controls System (**GTACS**) at Los Alamos National Laboratory (**USA**) in 1988. Starting from February 2004, EPICS became freely distributable after its release under the EPICS Open License.
- **Tango Controls:** is an object oriented, distributed framework which defines a communication protocol, an API and provides a set of tools and libraries to generate and build software for **SCADA** control systems and initially developed for scientists using experimental science facilities in Grenoble, **France** about 20 years ago.

Tango Controls

- Tango Controls are based on modern technologies:
  - **CORBA** and **ZMQ** to communicate between device server and clients
  - **C/C++**, **Python** and **Java** as reference programming languages
  - Naturally implements a microservices architecture
  - Modern object oriented design patterns
  - Offers a REST interface which support HTTPS for security
  - Modern database support (MySQL, MariaDB, TangoDB)
  - **CurveZMQ** is an authentication and encryption protocol for ZeroMQ
- Tango is an open source solution under free LGPL and GPL licenses.

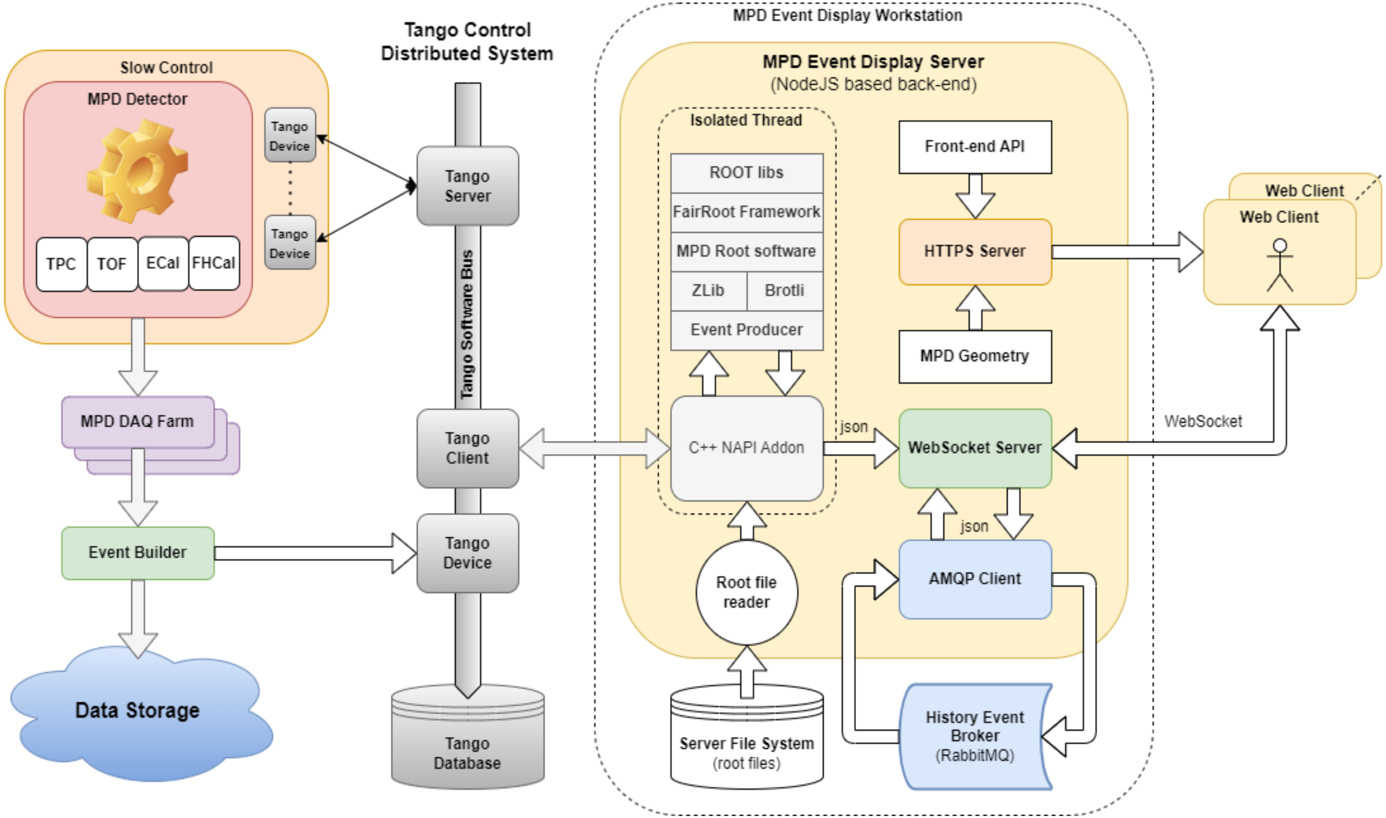
Tango Software Bus



(protocol: tango://...)

(from Eletra-Sinchrotron Trieste by Lorenzo Pivetta)

MPD Event Display Data Flow



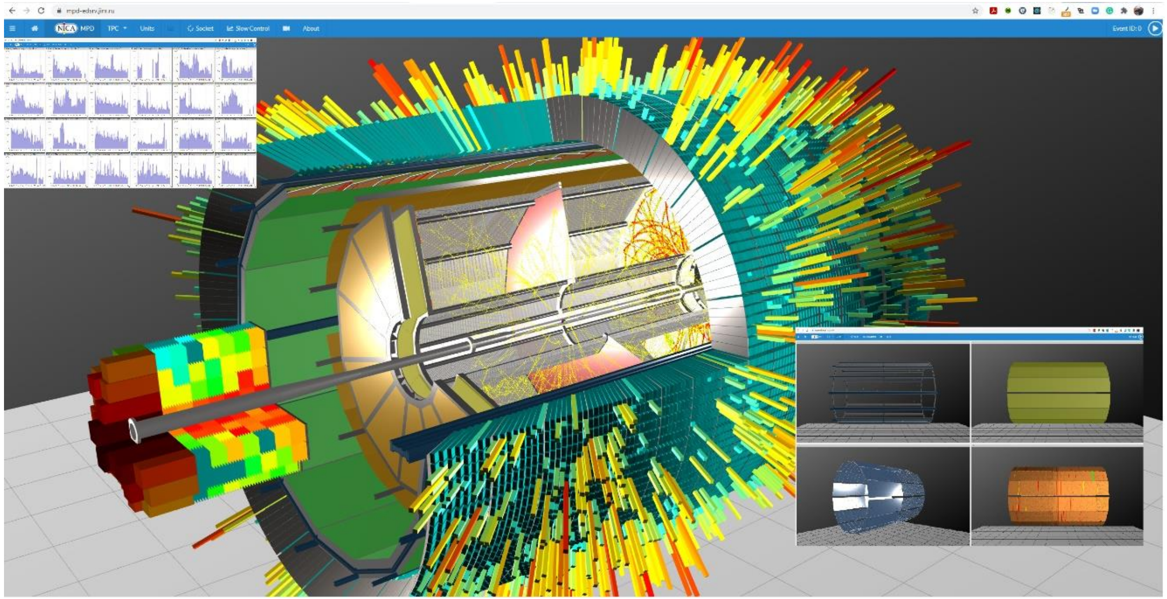
Conclusion

- The stable prototype of the Web interactive Event Display for the MPD detector is issued and it has been tested on all principal platforms and browsers including mobile devices.
- The interactive graphics part based on WebGL allows showing more than 120K active sensors and 3D objects from different detectors in one scene without excessive and annoying delays even on mobile devices.
- C++ Node API Addon makes it possible to read ROOT data files on the back-end side of the Event Display directly in native code without any cost-sensitive transformation.
- AMQP message broker based on local RabbitMQ package allows synchronizing data flow from different sources with minimal delay (no more than 25ms) even for large size events and keeps event history in the internal queues.
- In order to minimize the time for event data transfer, we use online compress/decompress in parallel working threads on the server and client-side.

What to do…

- Security and authorization parts must be done as soon as possible to prevent any interventions from strangers outside of the NICA/JINR networks and unauthorized persons.
- Need to establish business relations between software developers and engineer working groups from different detectors to approach to real life and their current tasks.
- We should start to implement SCADA concept as only we get executive decision about Tango/SCADA controls for MPD.

Thank you for your attention!


mpd-edsrv.jinr.ru
NICA MPD
TPC
Units
Socket
Slow Control
About
Event ID: 0