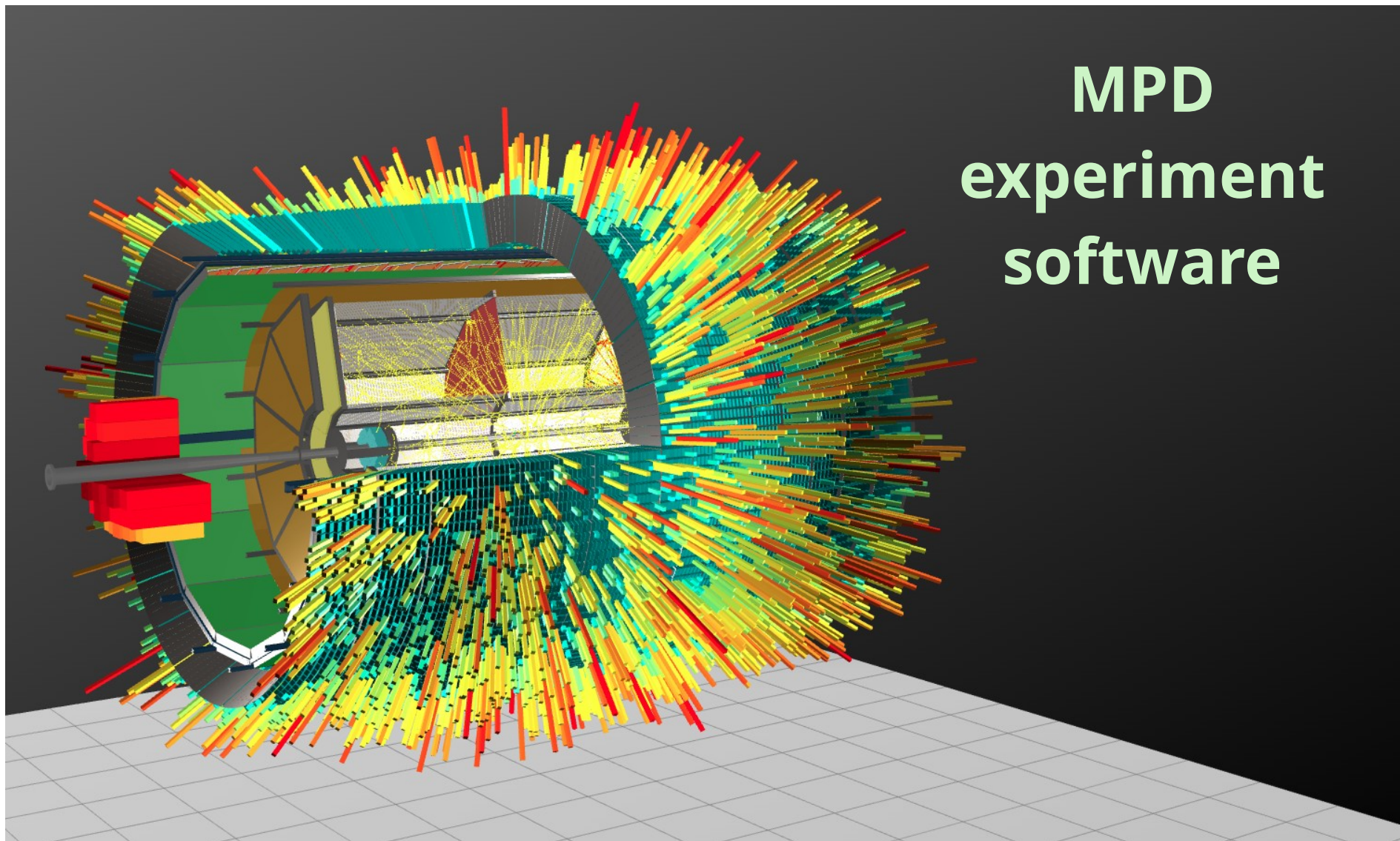


MPD experiment software



*Rogachevsky Oleg
for MPD collaboration*

IT school LIT
11.10.2024
Dubna

JINR 1957



Рождение $\tilde{\Sigma}^-$ -гиперона отрицательными π -мезонами с импульсом 8,3 Бэв/с

Группа физиков Лаборатории высоких энергий Объединенного института ядерных исследований в составе В. И. Векслера, Н. М. Вирясова, Е. Н. Кладницкой, А. А. Кузнецова, А. В. Никитина, М. И. Соловьева (СССР), Ван Ган-чана, Ван-Цу-

цзена, Дин Да-цао (Китай), Нгуен Дин Ты (Вьетнам), А. Михула (Румыния), Ким Хи Ина (Корея), Иржи Врана (Чехословакия) проводит работу с пучками отрицательных π -мезонов на 24-литровой пропановой пузырьковой камере. Пузырьковая ка-

НОВОСТИ НАУКИ И ТЕХНИКИ

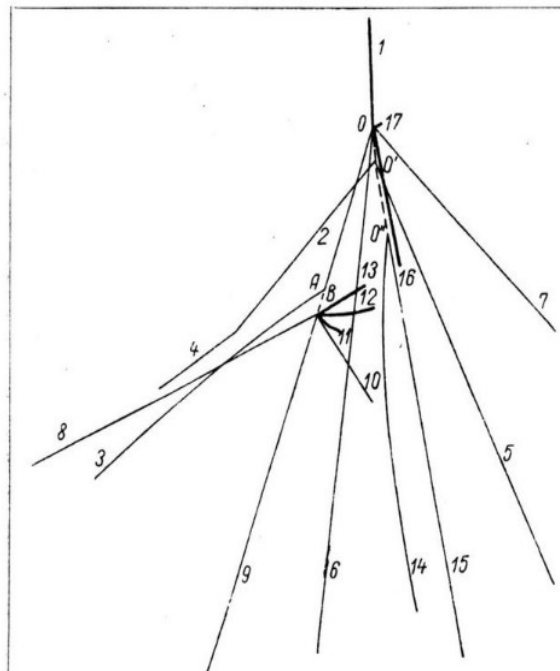
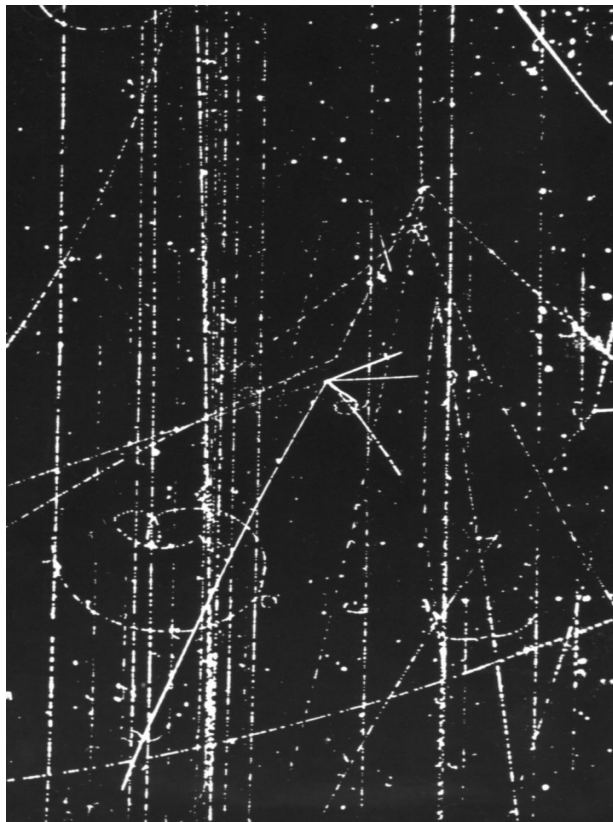
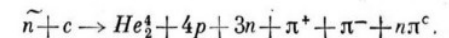


Схема основных следов, приведенных на фотографии.

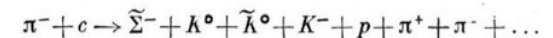
Распад частицы 2 в точке A на частицу 3 и нейтральную частицу в направлении AB очень хорошо согласуется с кинематикой распада Σ -гиперона. След 3—это след π^+ -мезона. Нейтральная частица на расстоянии 7,7 мм от точки распада образует в точке B высокоэнергичную шестилучевую звезду (следы 8—13).

Энергия, унесенная только заряженными частицами (1483 ± 60 Мэв), намного больше кинетической энергии нейтральной частицы (940 ± 100 Мэв). Поэтому нейтральная частица определена как антинейтрон. В предположении, что часть энергии унесена нейтронами и π^0 -мезонами, энергия в звезде после учета энергии связи нуклонов в ядре определена более чем в 2300 Мэв. Эта энергия близка к энергии аннигиляции антинейтрона.

Наиболее вероятной реакцией в точке B будет:



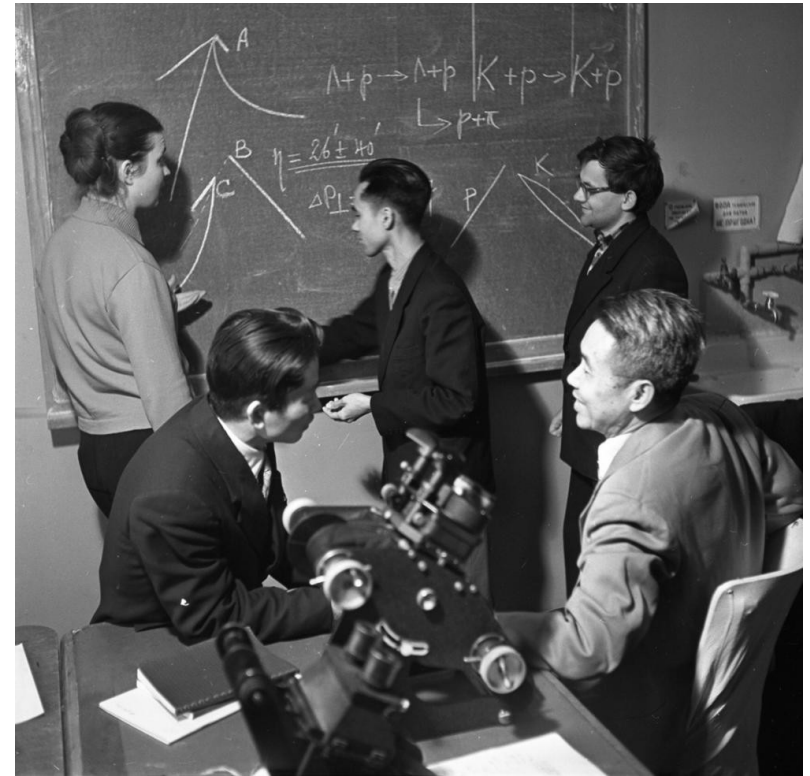
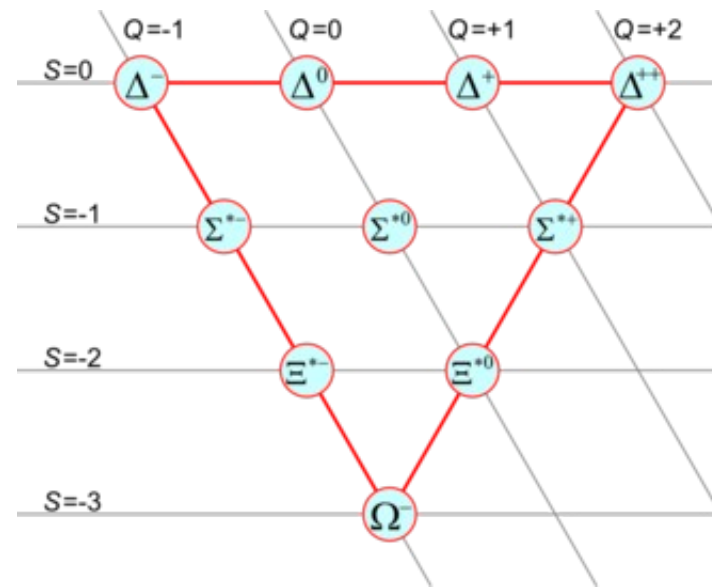
Отсюда следует, что в точке O первичный π^- -мезон образовал до сих пор не наблюдавшуюся частицу антисигма минус гиперон, распадающуюся в точке A по схеме $\tilde{\Sigma}^- \rightarrow \pi^+ + \bar{n}$. Присутствие двух нейтральных K-мезонов позволяет записать реакцию рождения $\tilde{\Sigma}^-$ -гиперона следующим образом:



Отрицательная частица (след 6) определена как K^- (по соображениям сохранения странности).

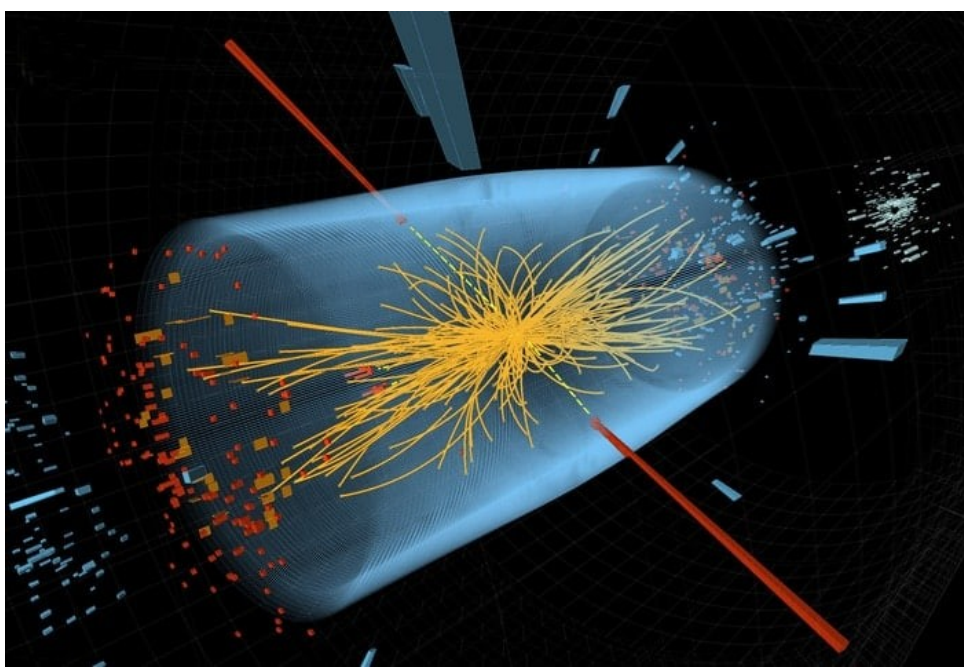
Для времени жизни этого $\tilde{\Sigma}^-$ -гиперона полу-

JINR 1960

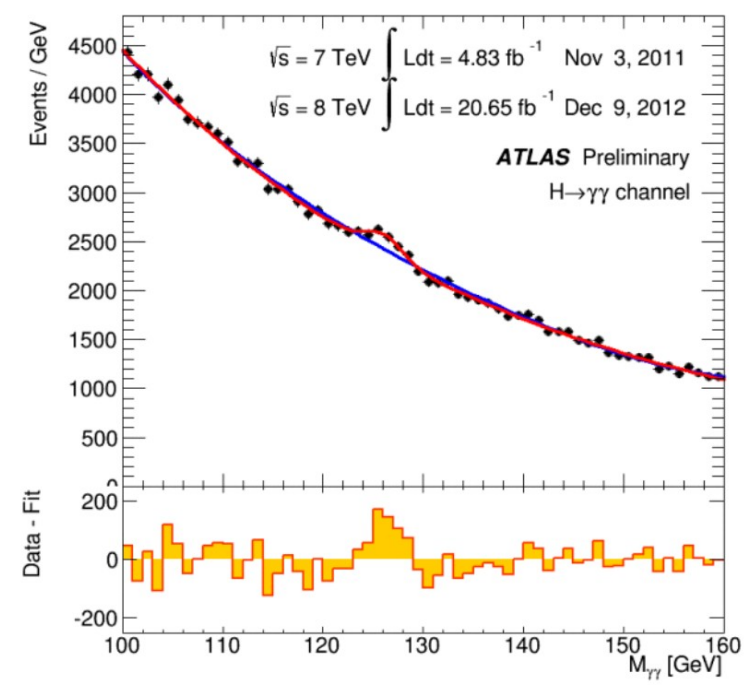
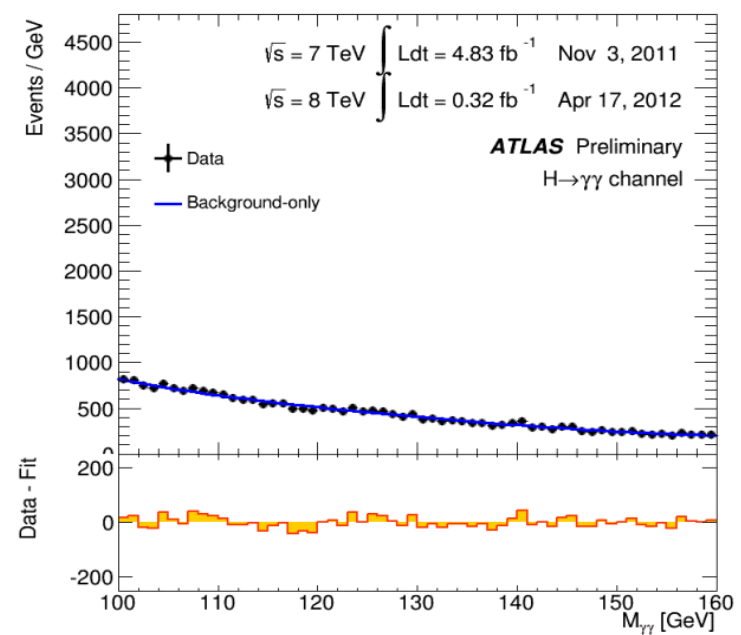


Big data for Higgs discovery

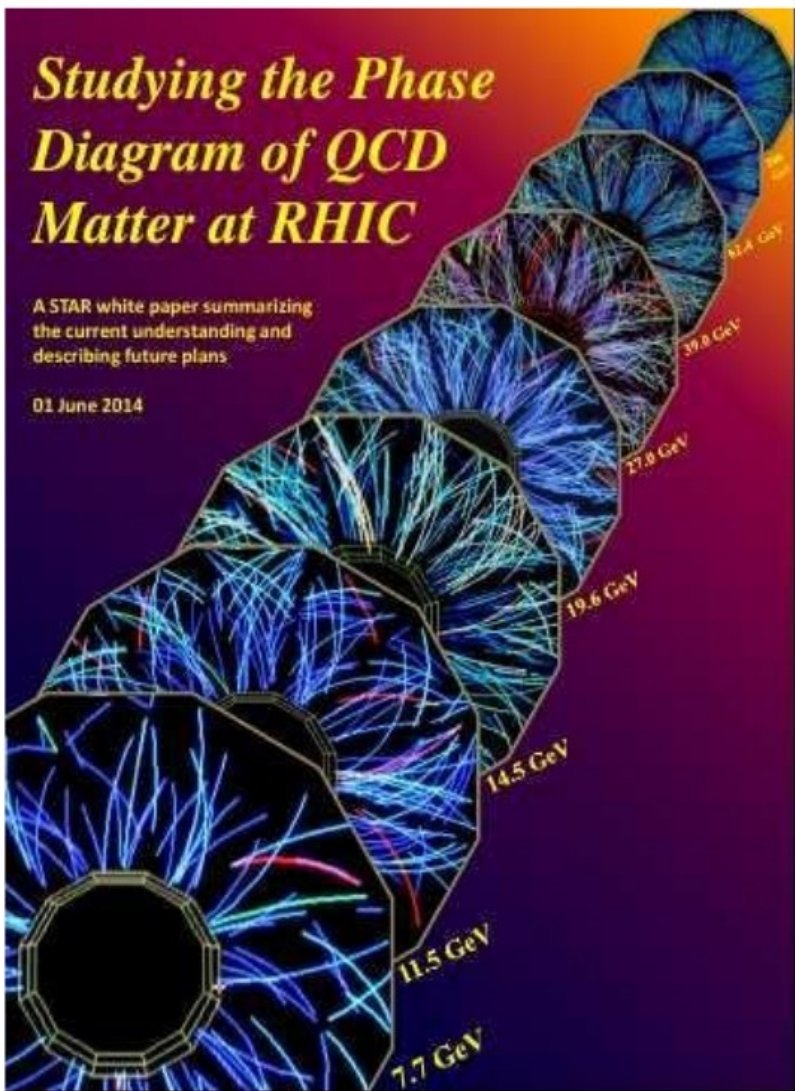
$$H \rightarrow \gamma\gamma$$



One inverse femtobarn (fb^{-1}) corresponds to approximately 100 trillion (10^{12}) proton-proton collisions.



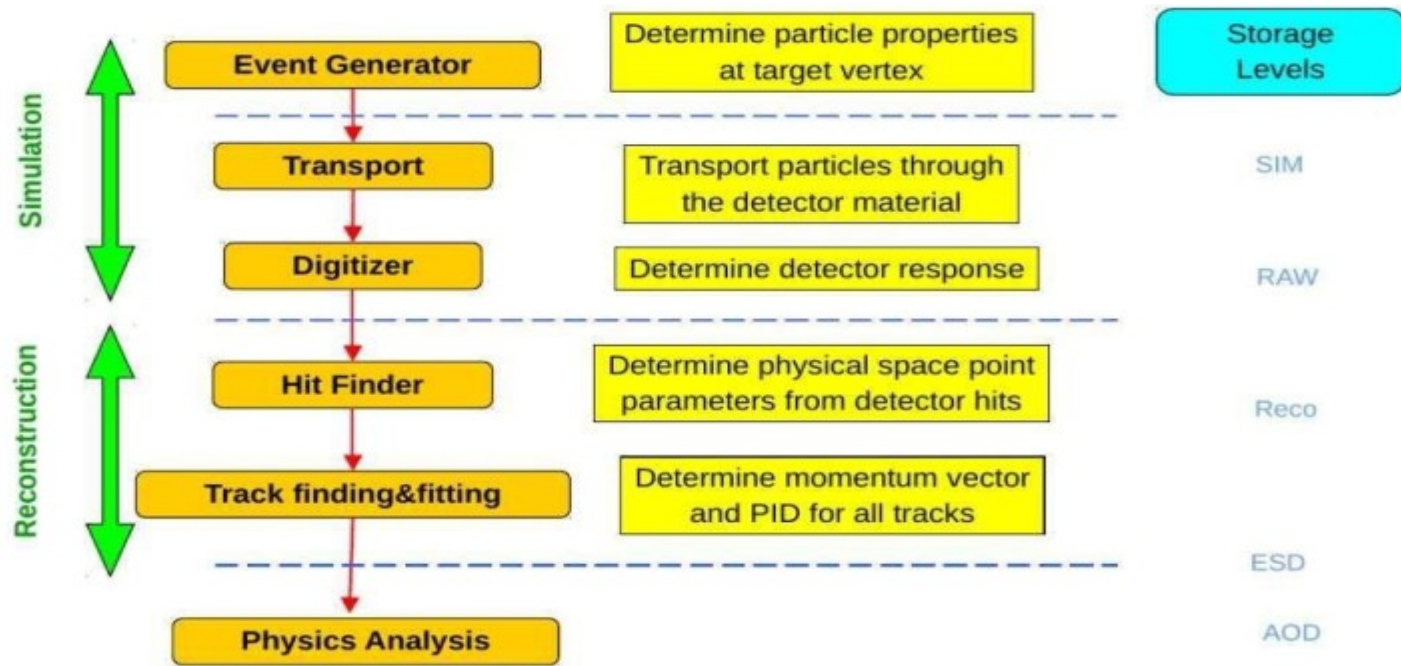
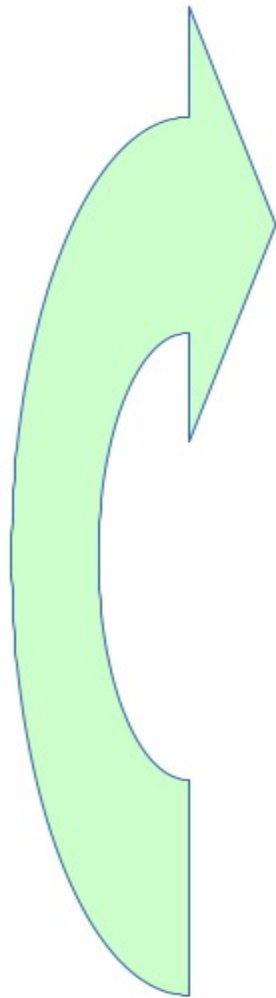
Big data for QCD phase transition



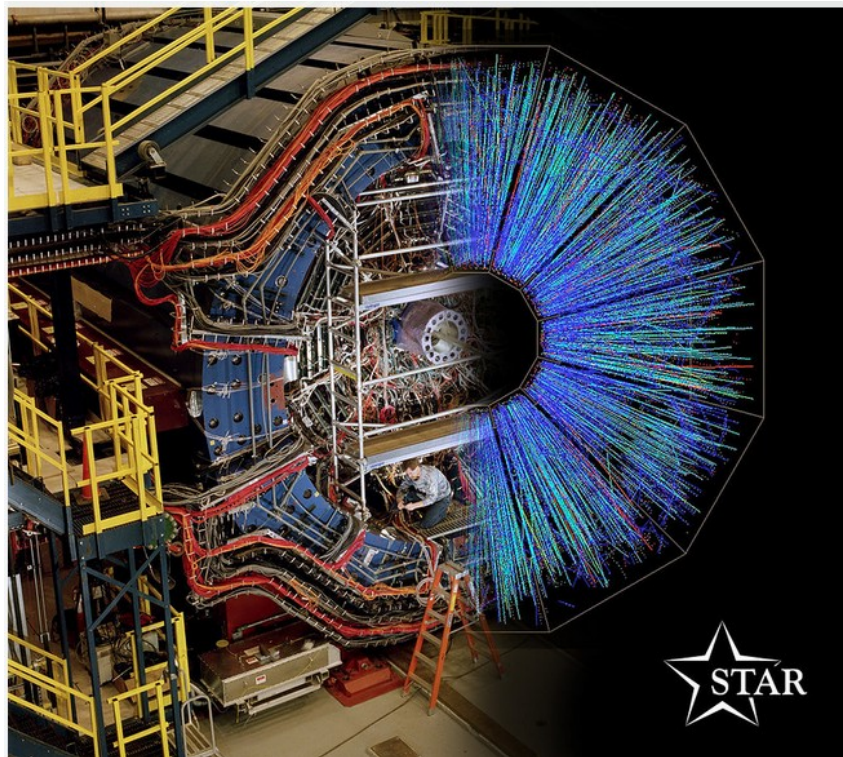
| $\sqrt{s_{NN}}$ (GeV) | Beam Energy (GeV/nucleon) | Collider or Fixed Target | $y_{center\ of\ mass}$ | μ^B (MeV) | Run Time (days) | No. Events Collected (Request) | Date Collected |
|-----------------------|---------------------------|--------------------------|------------------------|---------------|----------------------|--------------------------------|----------------|
| 200 | 100 | C | 0 | 25 | 2.0 | 138 M (140 M) | Run-19 |
| 27 | 13.5 | C | 0 | 156 | 24 | 555 M (700 M) | Run-18 |
| 19.6 | 9.8 | C | 0 | 206 | 36 | 582 M (400 M) | Run-19 |
| 17.3 | 8.65 | C | 0 | 230 | 14 | 256 M (250 M) | Run-21 |
| 14.6 | 7.3 | C | 0 | 262 | 60 | 324 M (310 M) | Run-19 |
| 13.7 | 100 | FXT | 2.69 | 276 | 0.5 | 52 M (50 M) | Run-21 |
| 11.5 | 5.75 | C | 0 | 316 | 54 | 235 M (230 M) | Run-20 |
| 11.5 | 70 | FXT | 2.51 | 316 | 0.5 | 50 M (50 M) | Run-21 |
| 9.2 | 4.59 | C | 0 | 372 | 102 | 162 M (160 M) | Run-20+20b |
| 9.2 | 44.5 | FXT | 2.28 | 372 | 0.5 | 50 M (50 M) | Run-21 |
| 7.7 | 3.85 | C | 0 | 420 | 90 | 100 M (100 M) | Run-21 |
| 7.7 | 31.2 | FXT | 2.10 | 420 | 0.5+1.0+ scattered | 50 M + 112 M + 100 M (100 M) | Run-19+20+21 |
| 7.2 | 26.5 | FXT | 2.02 | 443 | 2+Parasitic with CEC | 155 M + 317 M | Run-18+20 |
| 6.2 | 19.5 | FXT | 1.87 | 487 | 1.4 | 118 M (100 M) | Run-20 |
| 5.2 | 13.5 | FXT | 1.68 | 541 | 1.0 | 103 M (100 M) | Run-20 |
| 4.5 | 9.8 | FXT | 1.52 | 589 | 0.9 | 108 M (100 M) | Run-20 |
| 3.9 | 7.3 | FXT | 1.37 | 633 | 1.1 | 117 M (100 M) | Run-20 |
| 3.5 | 5.75 | FXT | 1.25 | 666 | 0.9 | 116 M (100 M) | Run-20 |
| 3.2 | 4.59 | FXT | 1.13 | 699 | 2.0 | 200 M (200 M) | Run-19 |
| 3.0 | 3.85 | FXT | 1.05 | 721 | 4.6 | 259 M -> 2B(100 M -> 2B) | Run-18+21 |

Experiment simulations

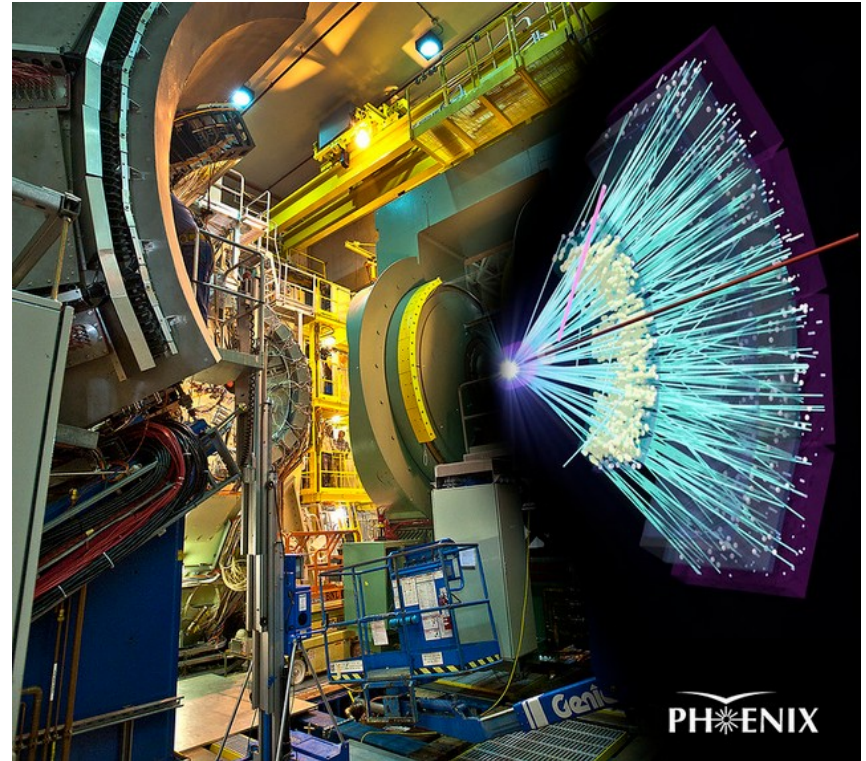
Simulation, the third way to scientific knowledge after theory and experiment.



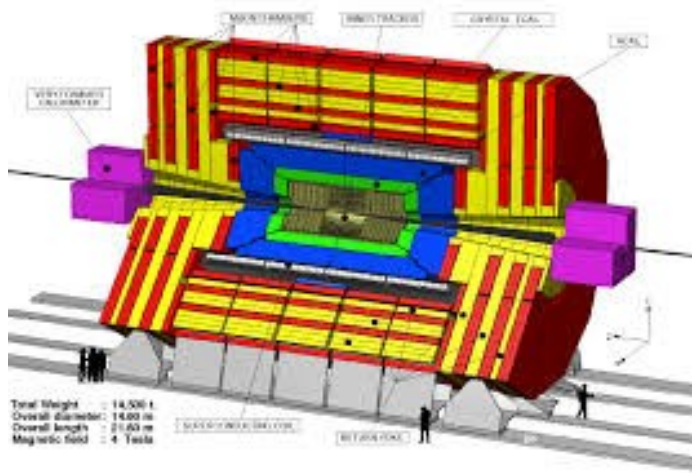
RHIC experiments 2000



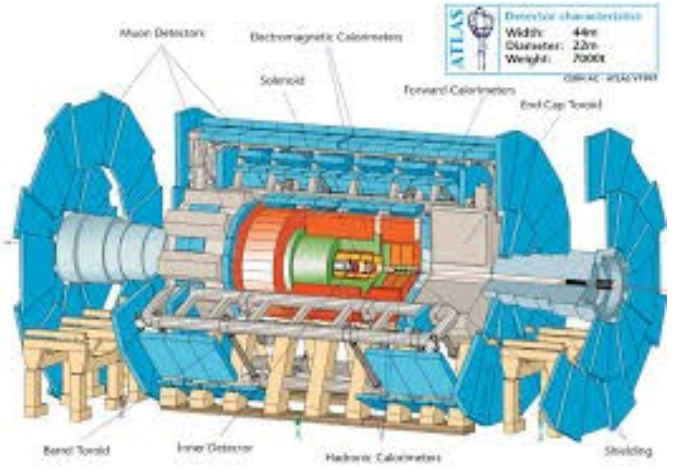
root4star



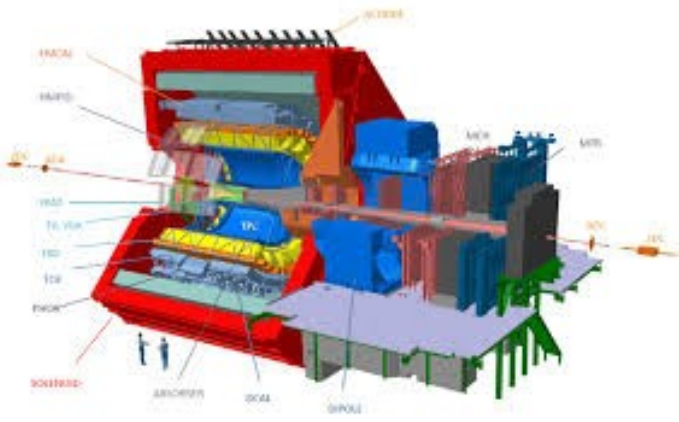
LHC experiments



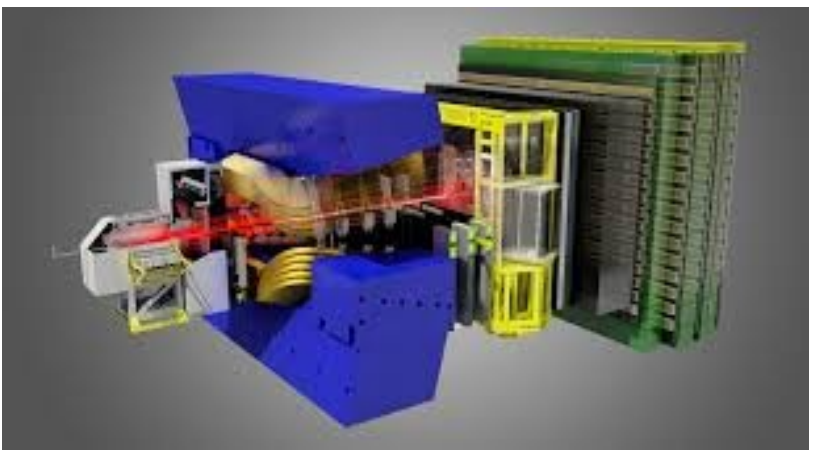
CMS - CMSsw



ATLAS - Athena

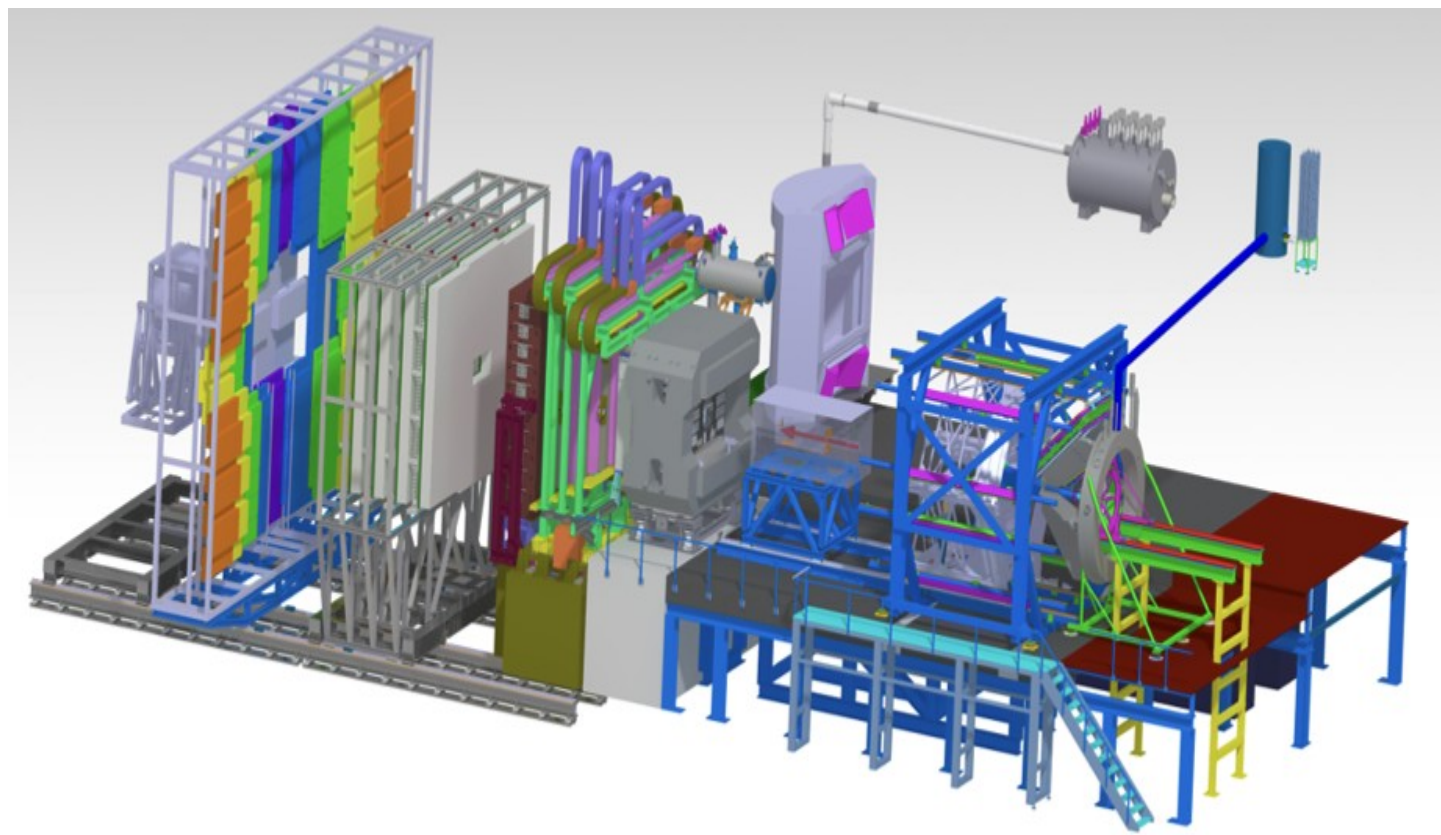


ALICE - Aliroot



LHCb - Gaudi

CBM experiment in GSI (2004)

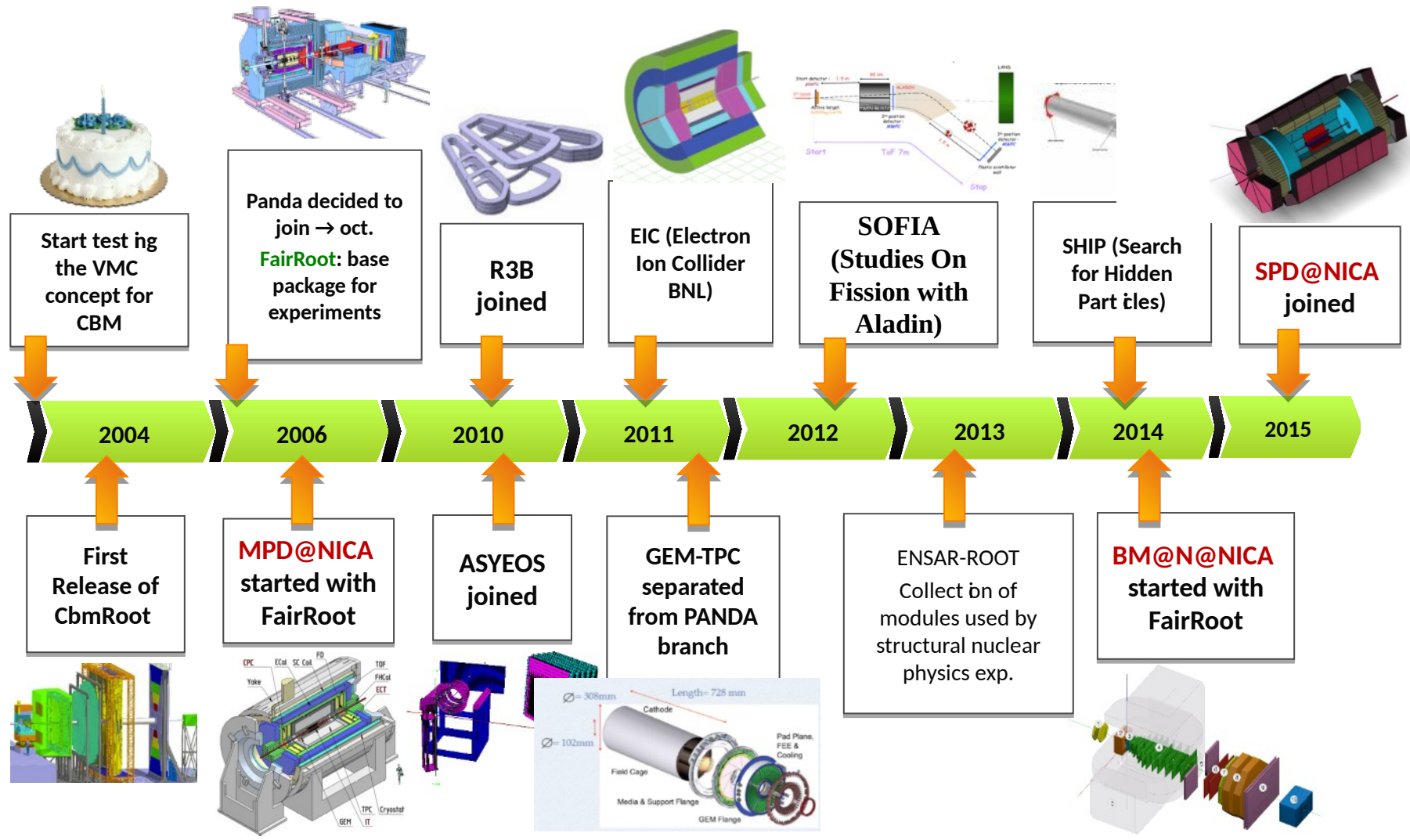


CBM - cbmroot

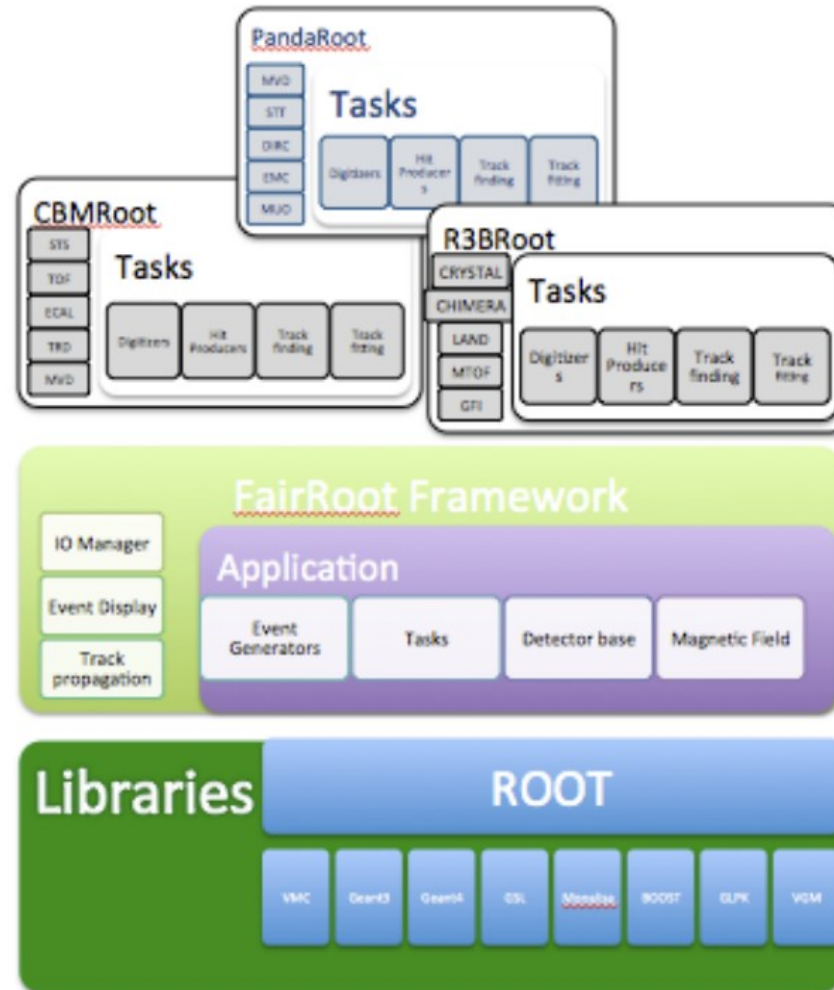
NICA @ Mpd 2007



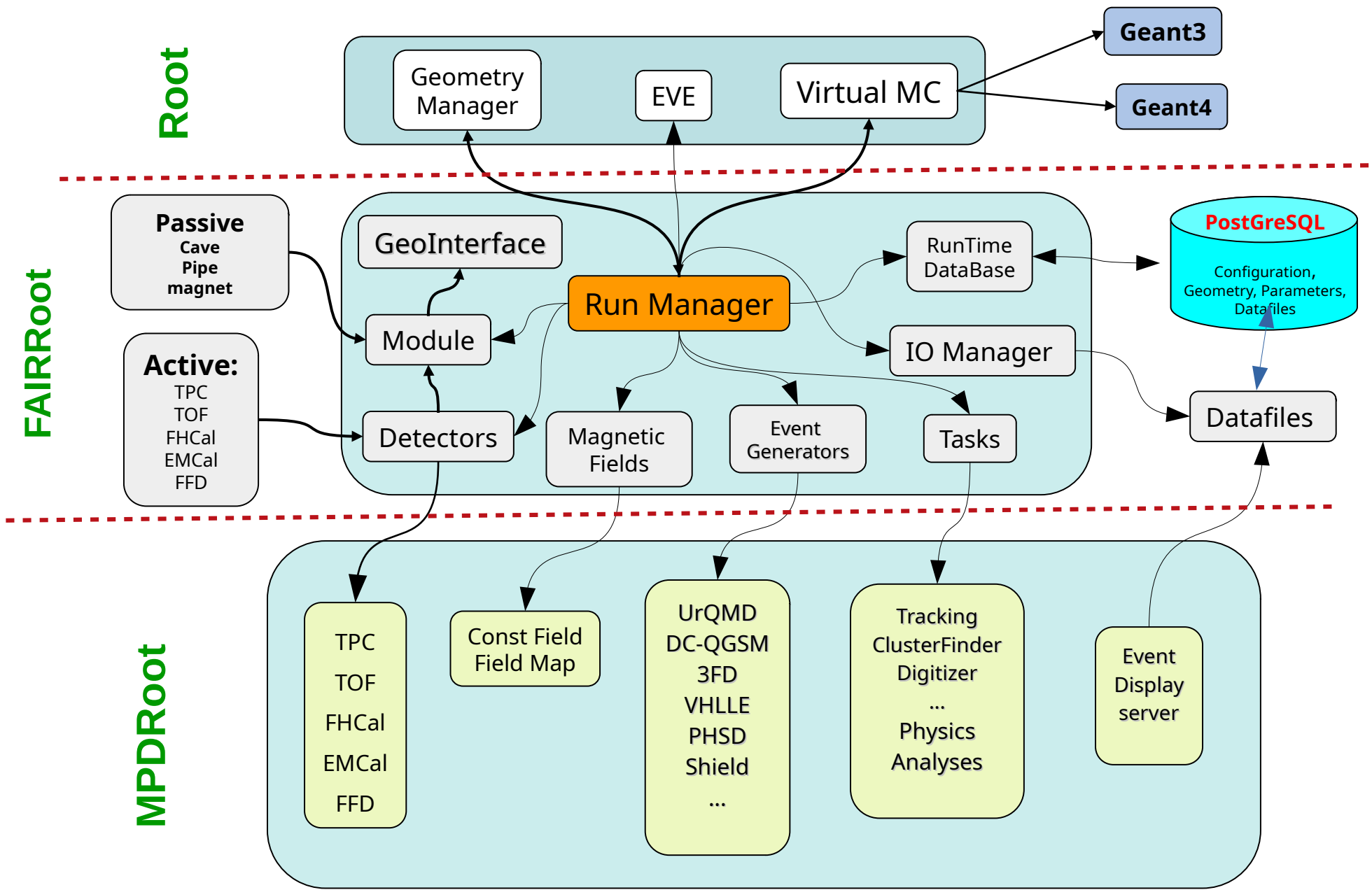
MpdRoot history



FAIR experiments framework



MpdRoot structure



Centralized build of mpdroot

Requirements:

we want to deliver latest version of MPDroot to the users,
all dependencies have to be satisfied and no version clashes,
results need to be repeatable

Solution:

- CVMFS – robust distribution of software not only between clusters/supercomputers
- aliBuild – set of tools for building software together with its dependencies
- toolbox – rootless wrapper for podman (docker). Supported on most linux-based systems. On MacOS and Windows one can use docker
- EnvironmentModules – environment enabling loading multiple versions of the same software with its dependencies

MPDroot installation

INSTALL CVMFS AND TOOLBOX (Users and Developers)

Supported OS: Fedora, CentOS, AlmaLinux, Ubuntu 22.04, 20.04, Debian 11, Manjaro 21
NOTE: If your OS is based on any of those, then pass it to nica-init script, for example
`./nica-init.sh -d Ubuntu -v 20.04`

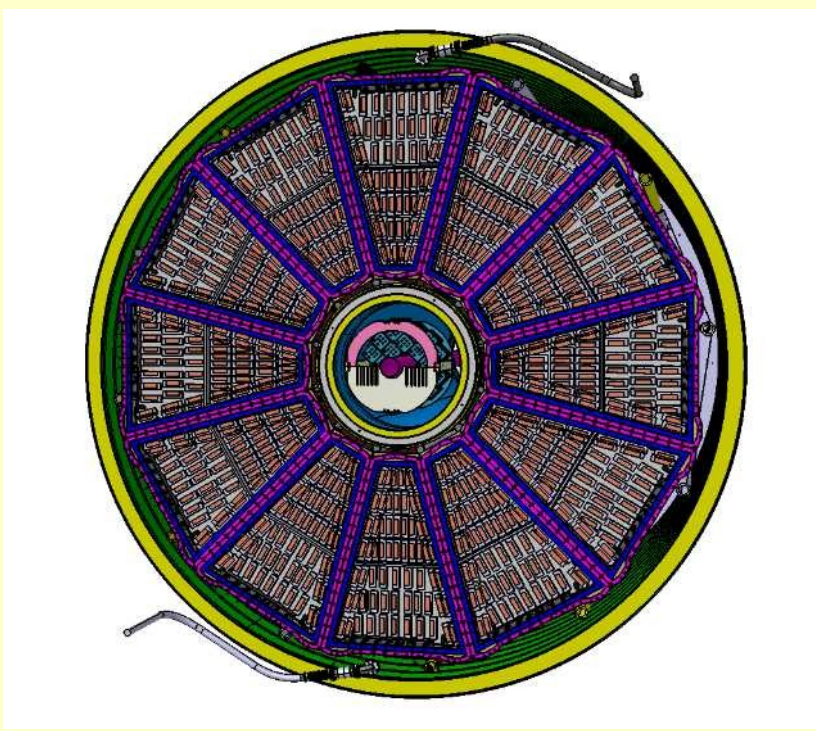
```
[user@fedora ~]$ wget https://git.jinr.ru/nica/nicadist/-/raw/master/scripts/nica-init.sh --no-check-certificate
--2021-12-02 00:00:00-- https://git.jinr.ru/nica/nicadist/-/raw/master/scripts/nica-init.sh
.....
2021-12-02 00:00:02 (87.9 MB/s) - 'nica-init.sh' saved [10794/10794]

[user@fedora ~]$ chmod +x nica-init.sh && ./nica-init.sh
Installing toolbox on Fedora 38
[sudo] password for user:
.....
.....
Creating container c7-nica-dev ...
.....
.....
Installing cvmfs service as container ...
.....
.....
=====
INSTALLATION SUCCESSFUL
How to use:
1. Enter toolbox container by:
   toolbox enter c7-nica-dev
2. Load MPDroot environment as a user by:
   [user@toolbox]$ module add mpdroot
   or MPDroot environment as a developer by:
   [user@toolbox]$ module add mpddev
=====
[user@fedora ~]$
```

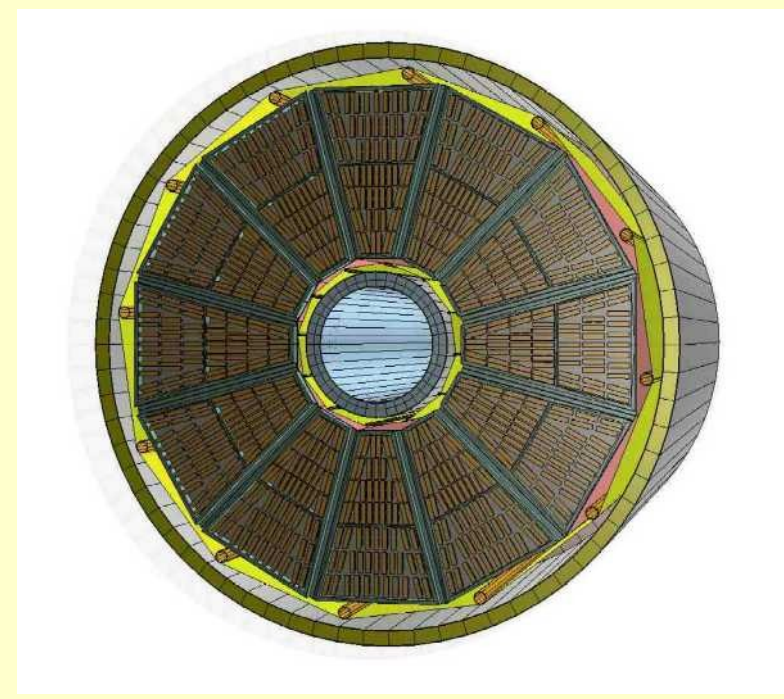


Geant TPC geometry

- Drawing



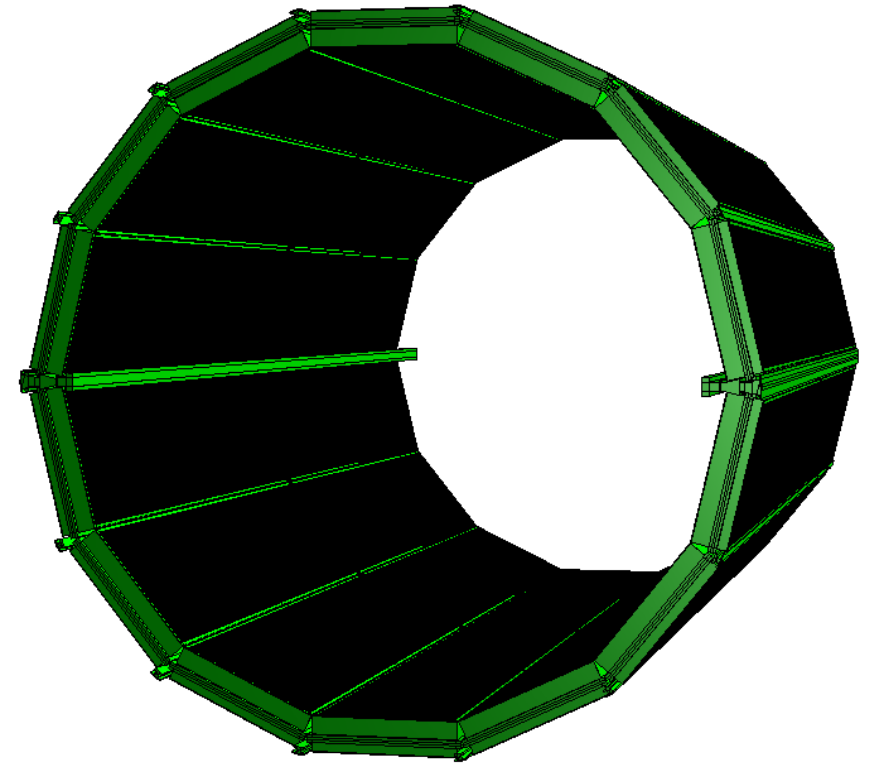
- Geant geometry



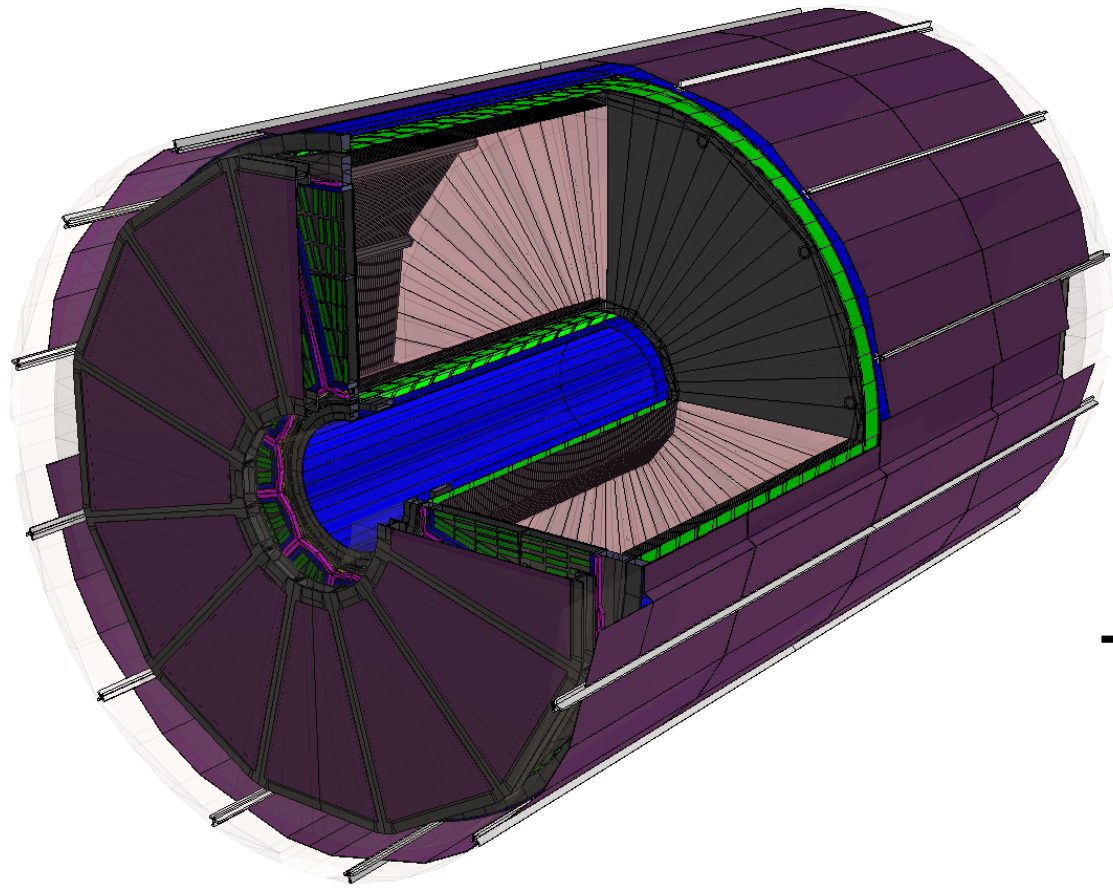
35 000 nodes

MPD geometry

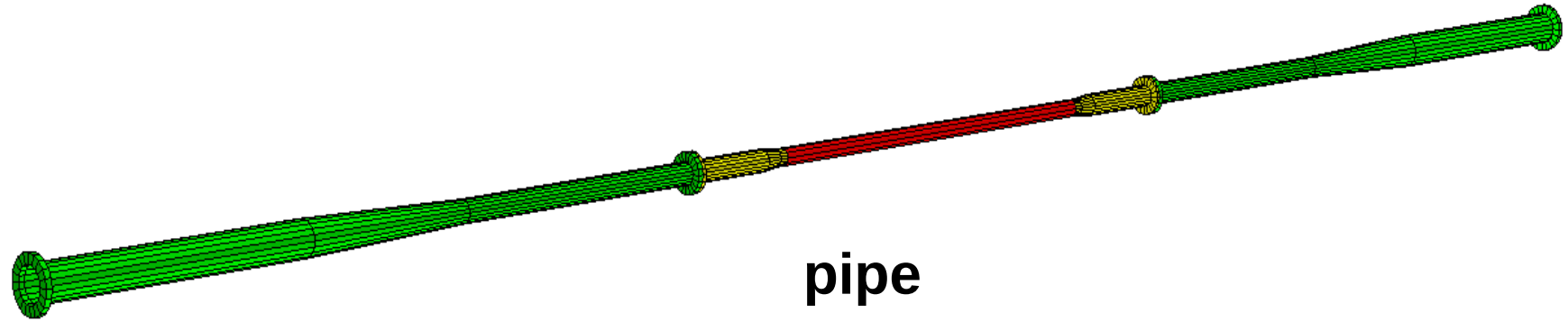
TOF



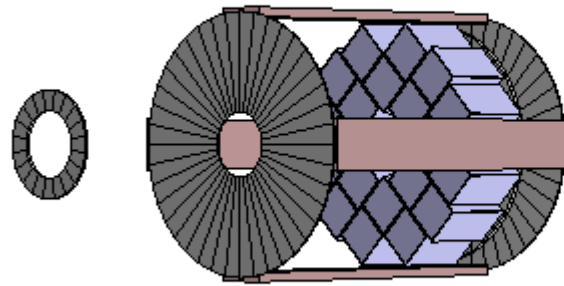
TPC



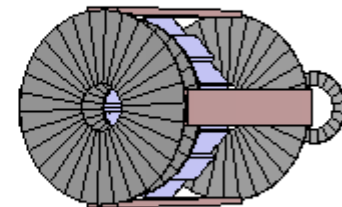
MPD geometry



pipe



FFD



Geant TPC Electronics Simulation

Each board:

 2+1 mm Copper

 3,5 mm Textolite

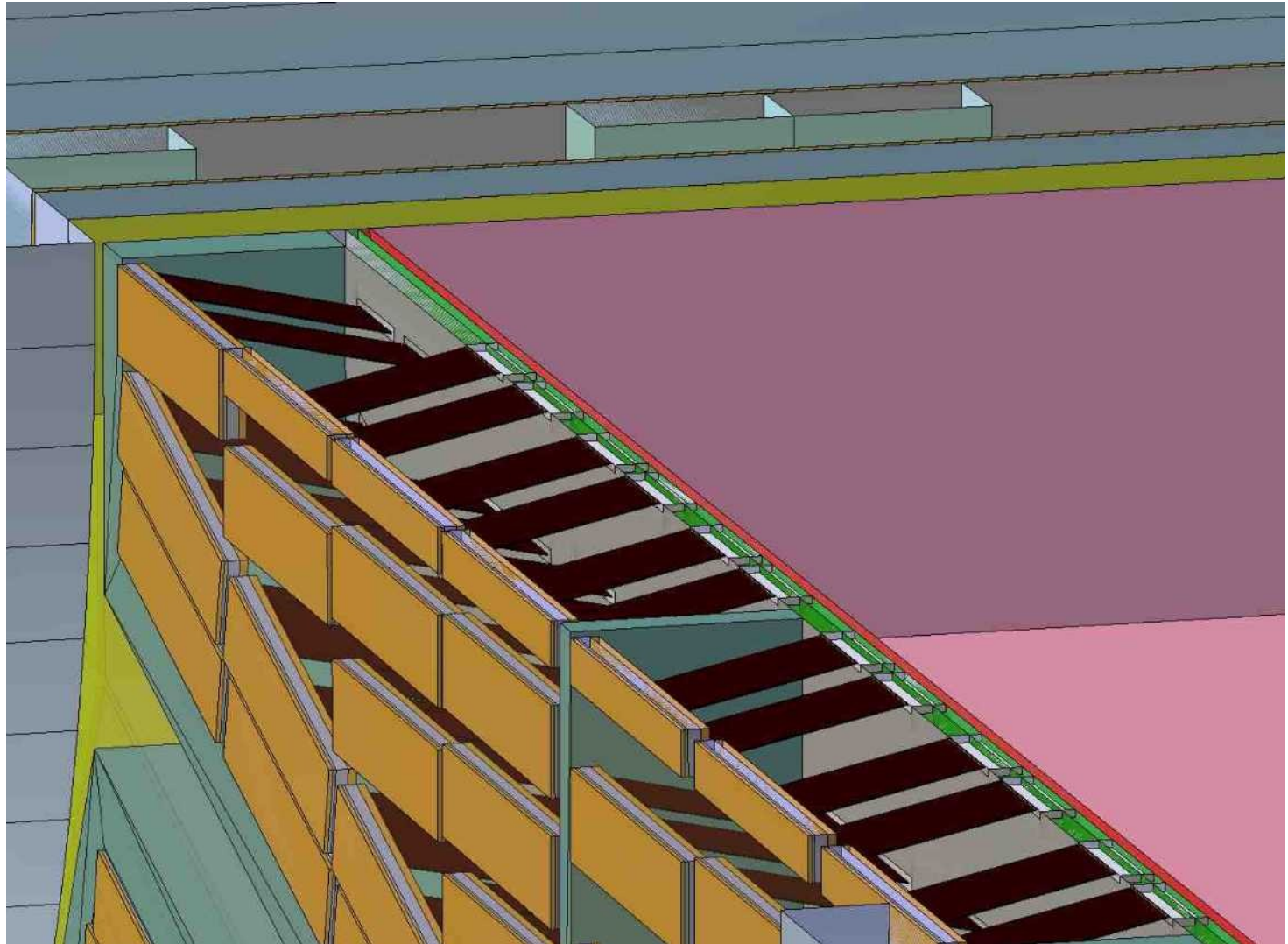
Flat cable:

 0,1+0,1 mm
 Polypropylene
 Insulation

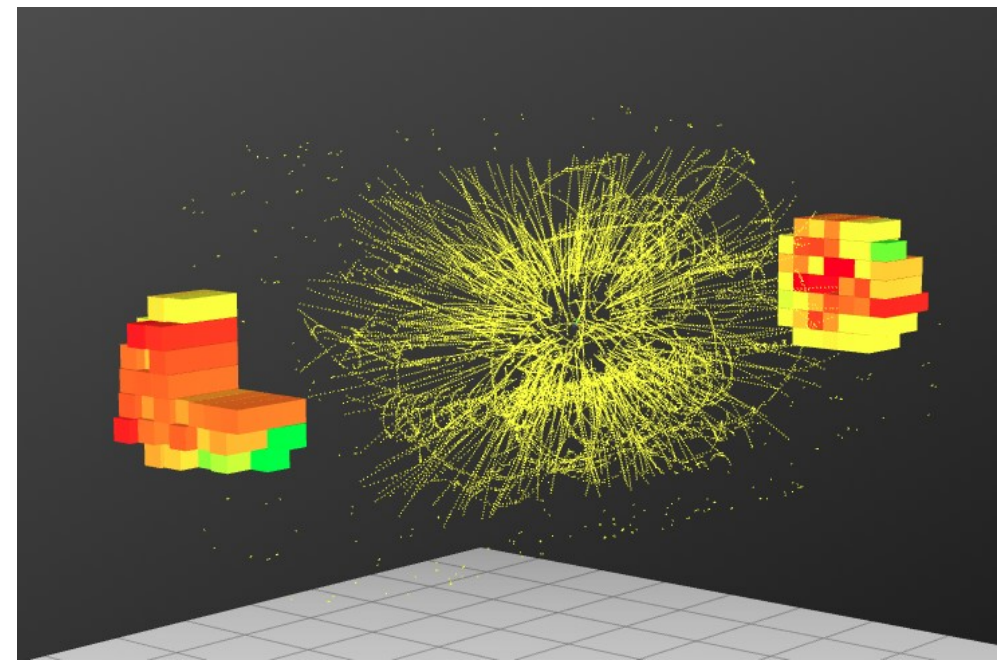
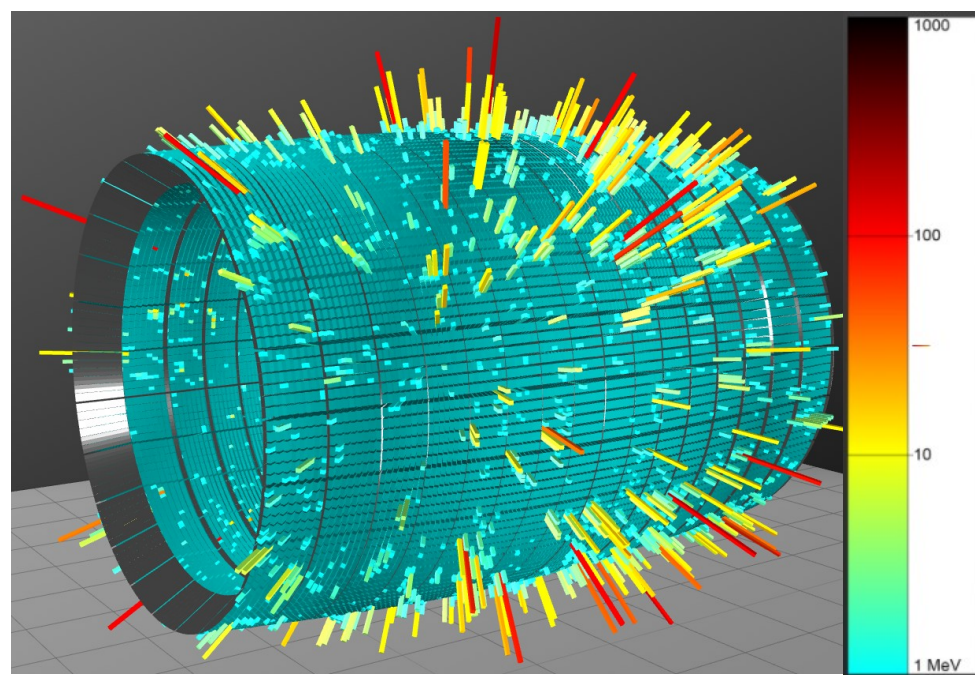
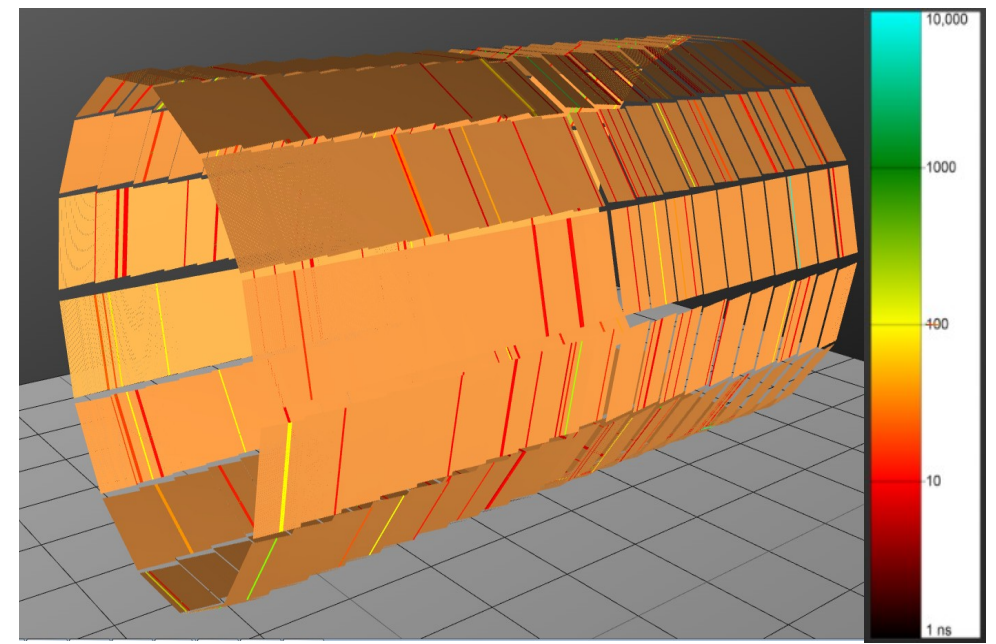
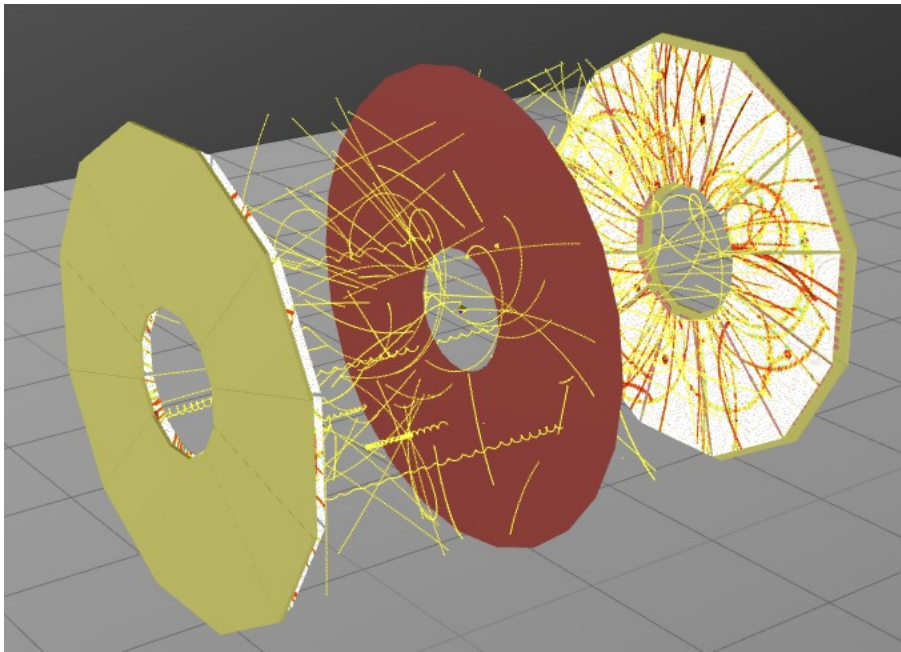
 0,15 mm
 Copper wire

Connector to
 Pads plane:

 Plastic + Air gap

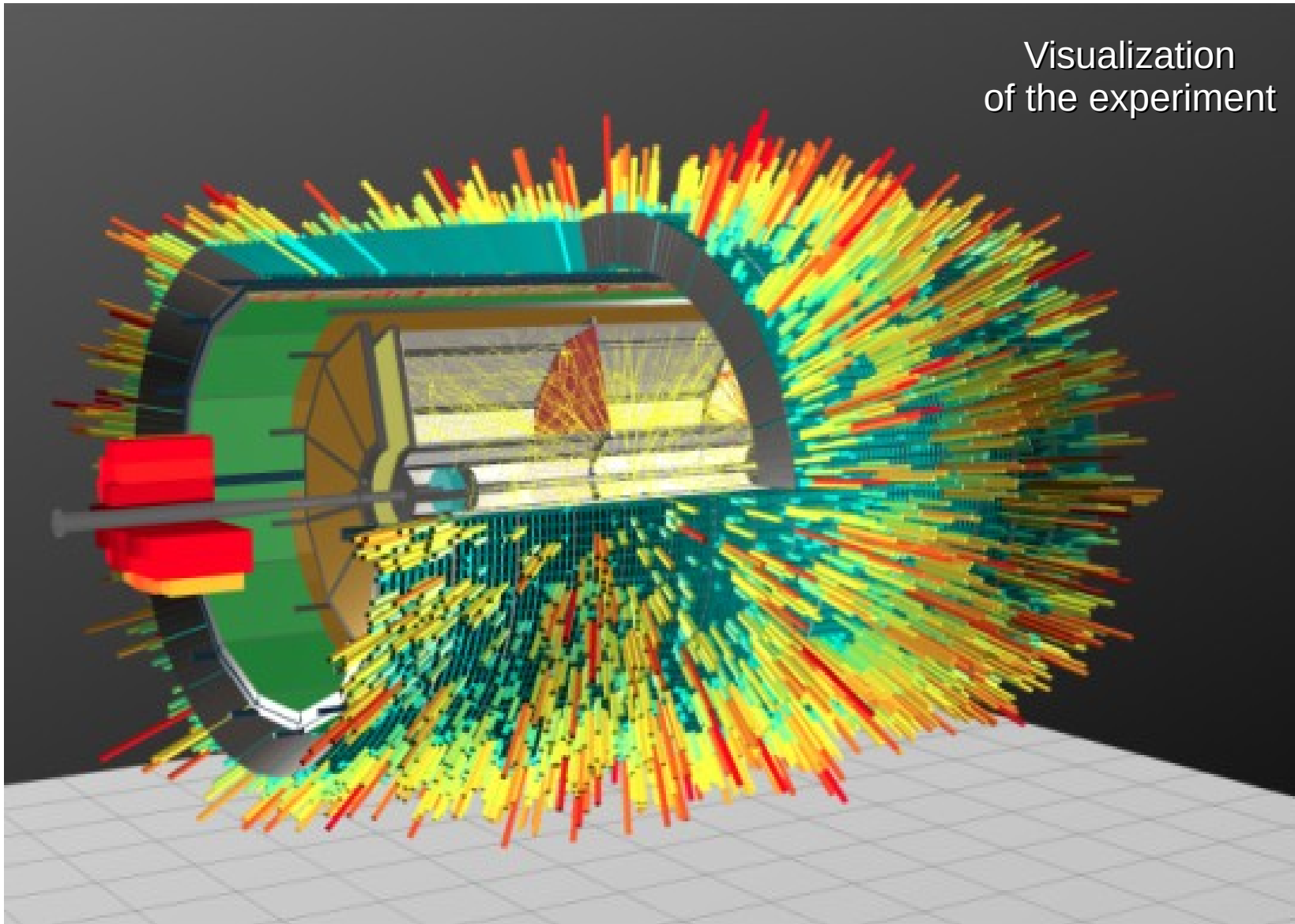


MPD EventDisplay: hits

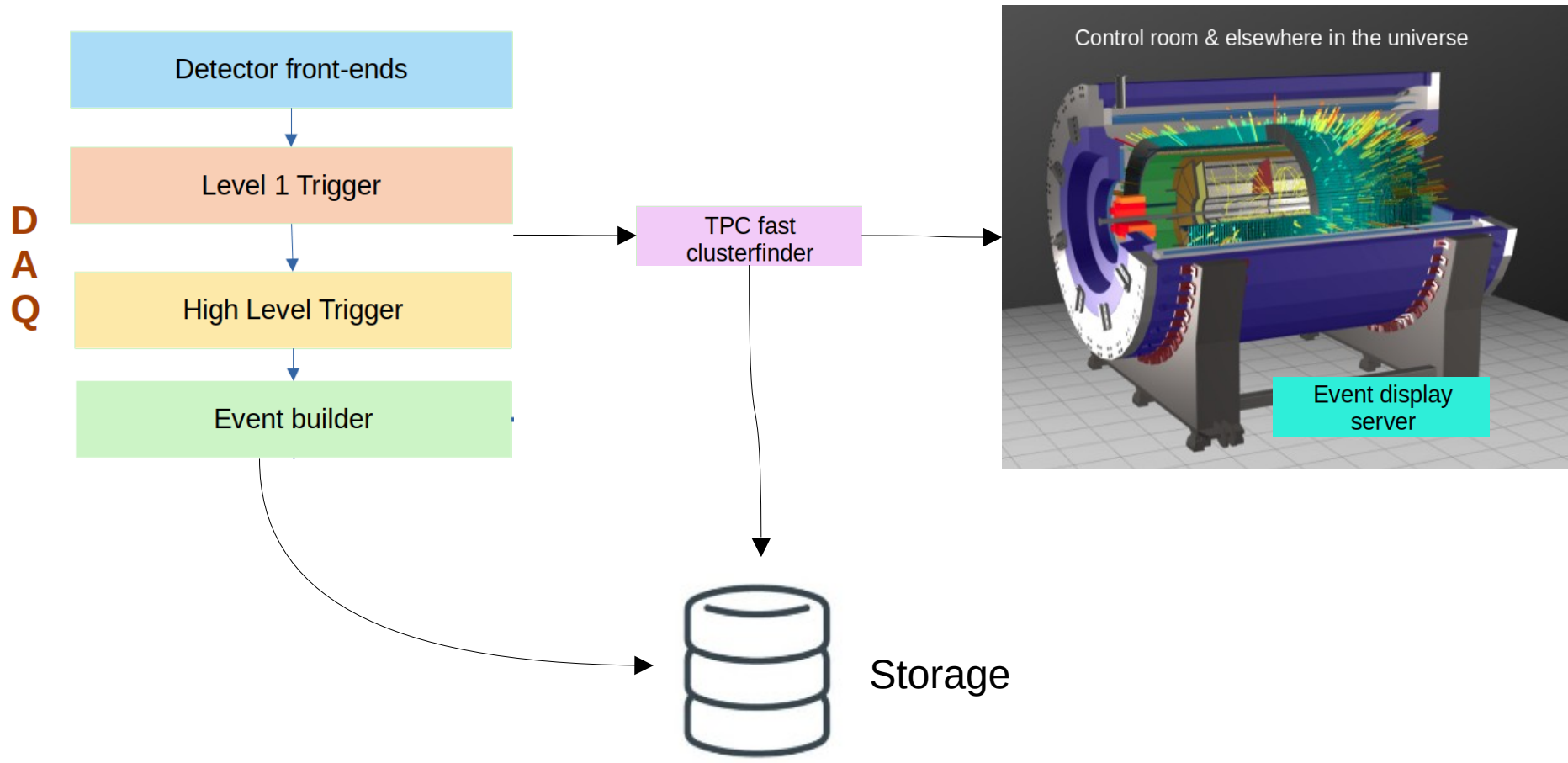


MPD EventDisplay: dst events

Visualization
of the experiment

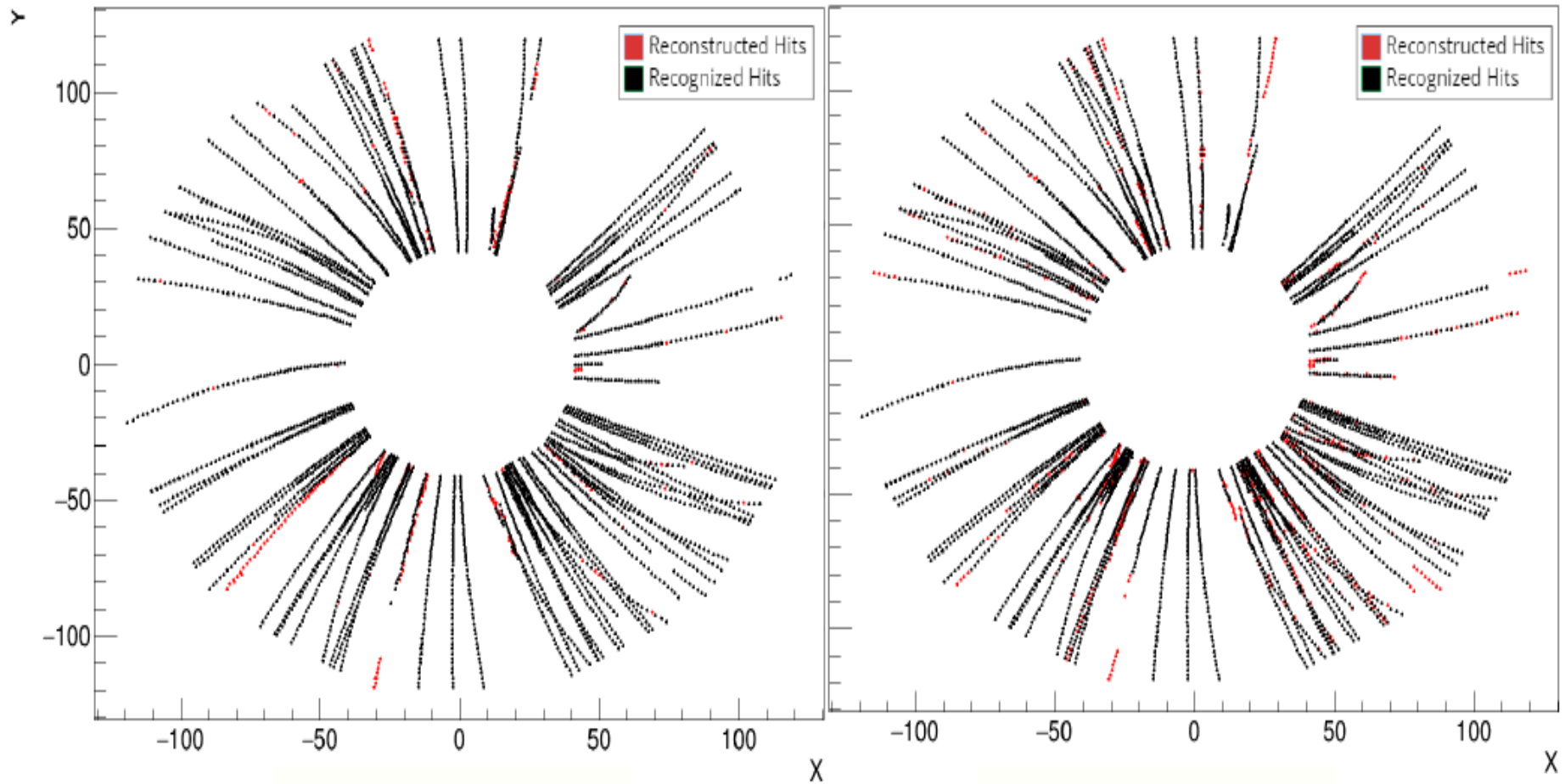


MPD TPC clusterfinder



TPC online fast clustering

Krylov V.

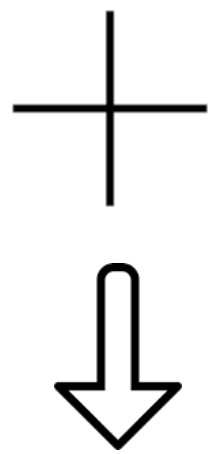
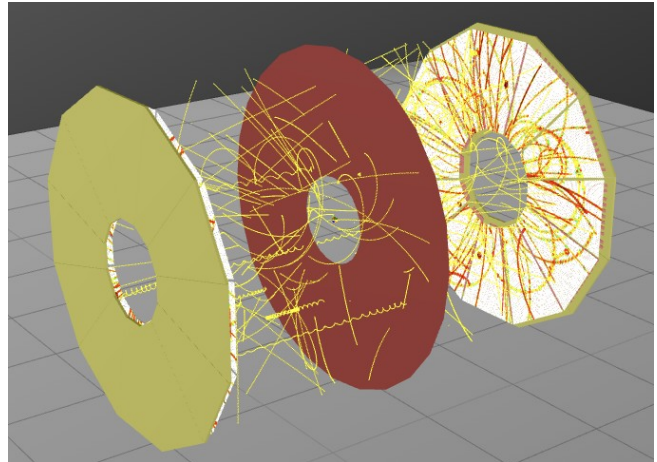


MLEM cluster finder

Fast cluster finder

TPC online dashboard

TPC eventdisplay



JavaScript
ROOT

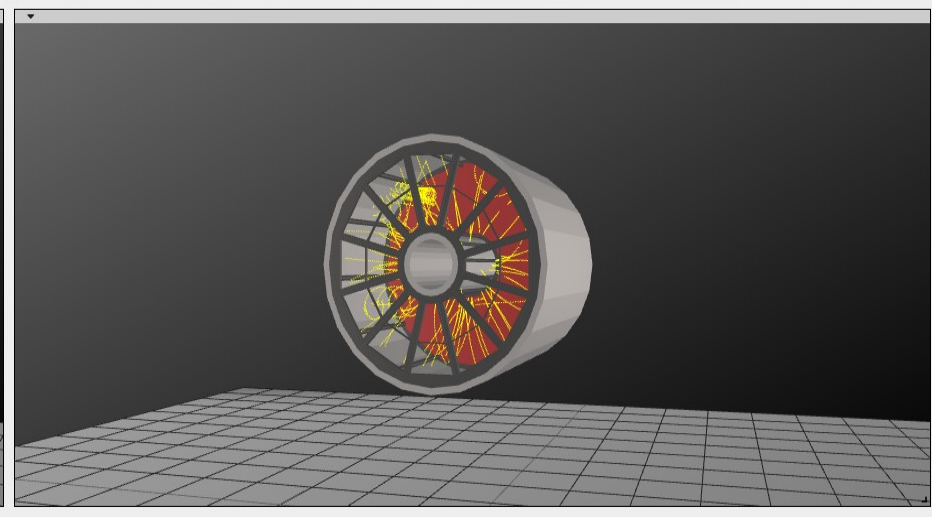
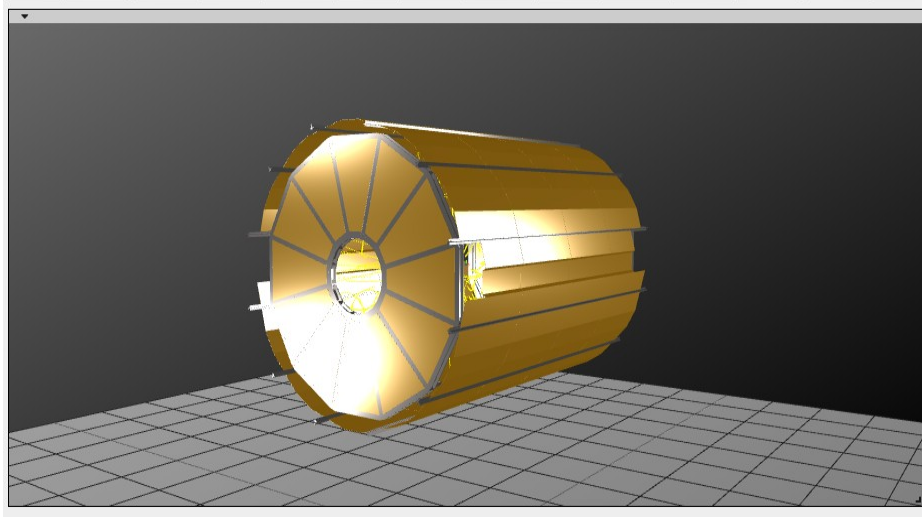
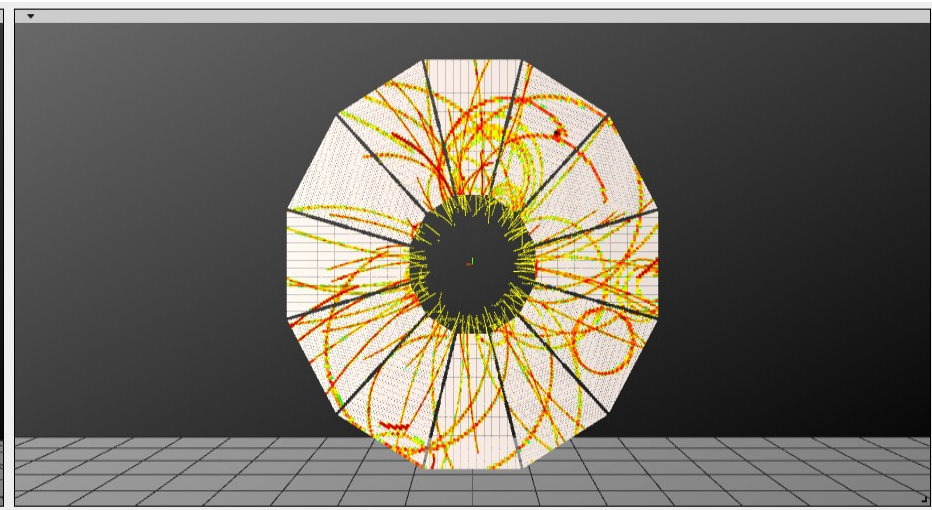
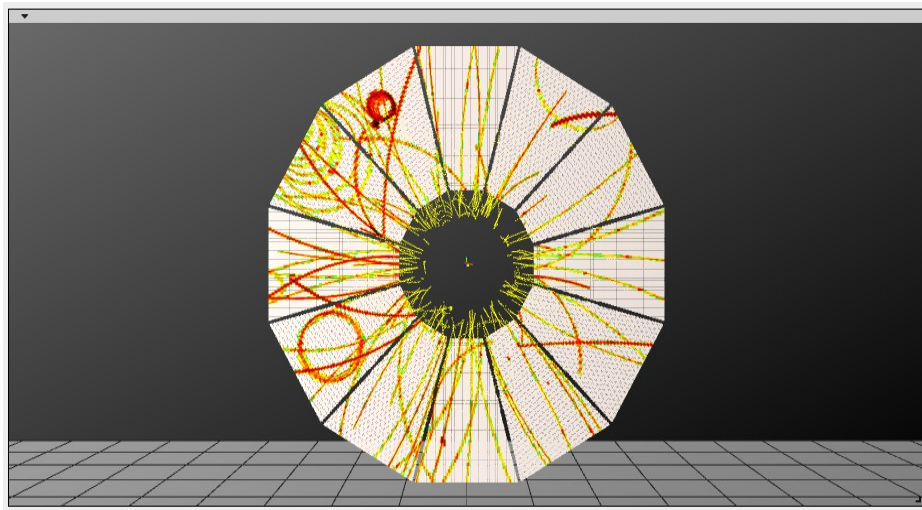
TPC detector control system (DCS)



TPC online monitoring

West

East



TPC dashboard

TPC sectors time buckets



MPD databases

- ✓ List of MPD members & authors
- ✓ MC events mass productions
- ✓ LogBook for Experiment
- ✓ TPC geometry
- ✓ TPC calibration
- ✓ TPC alignment parameters
- ✓ TOF calibration
- ✓ ECAL instrumentation
- ✓

MPD geometry alignments DB

[Home](#) [TPC alignments](#) [TOF alignments](#)

MPD
Collaboration list

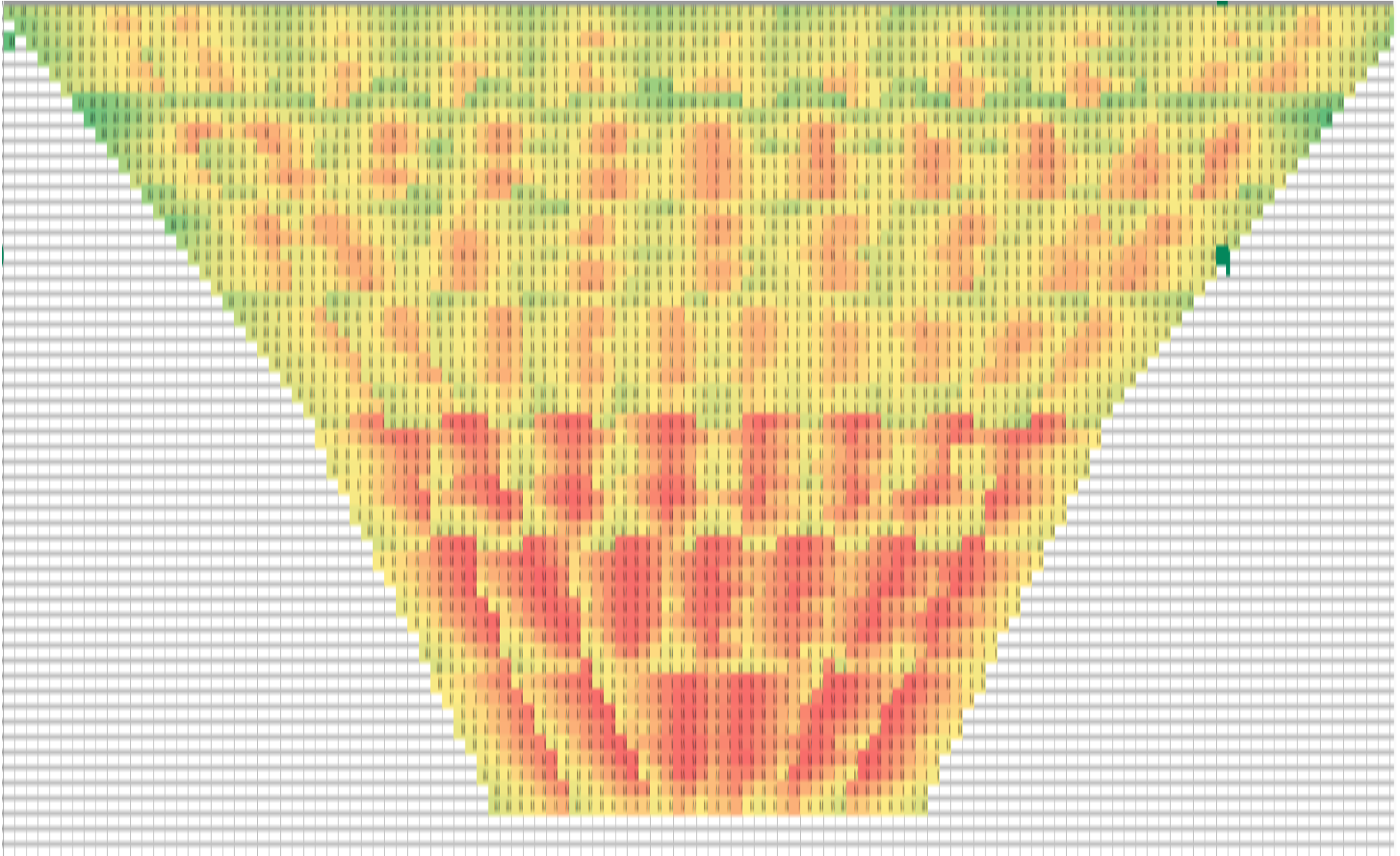
MPD Monte-Carlo DB

Login

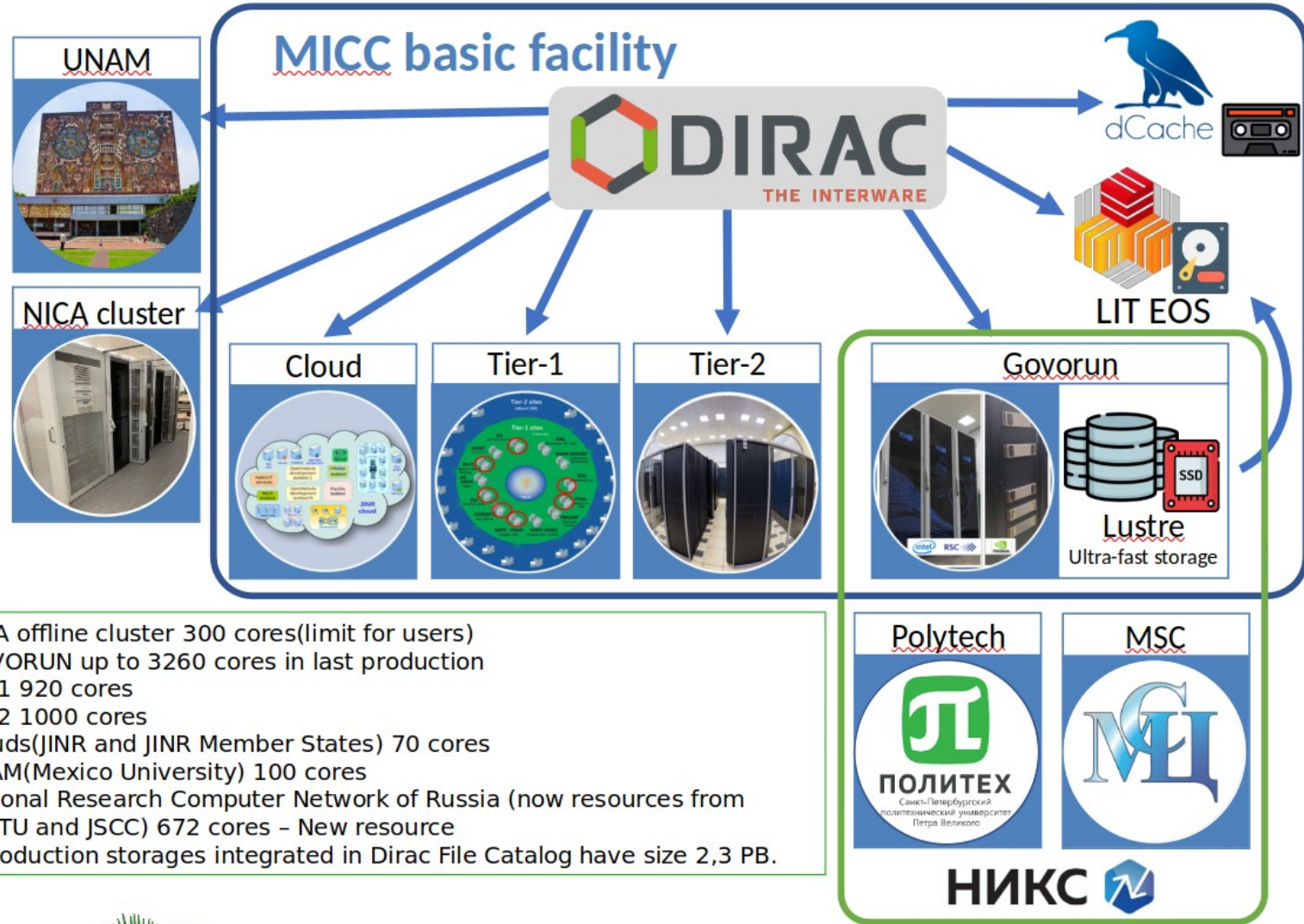
Free for the users

MPD e-Log

TPC pads capacity DB



Computing resources



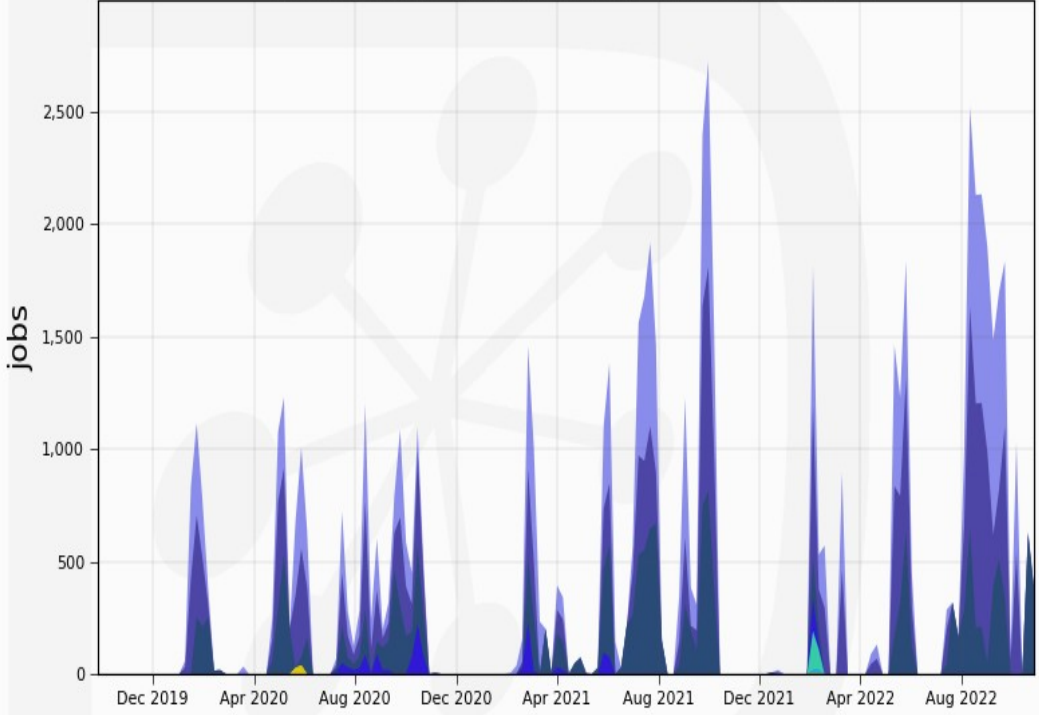
- NICA offline cluster 300 cores(limit for users)
 - GOVORUN up to 3260 cores in last production
 - Tier1 920 cores
 - Tier2 1000 cores
 - Clouds(JINR and JINR Member States) 70 cores
 - UNAM(Mexico University) 100 cores
 - National Research Computer Network of Russia (now resources from SPBTU and JSCC) 672 cores – New resource
- Mass production storages integrated in Dirac File Catalog have size 2,3 PB.



MPD mass production 2019-2023 summary

Running jobs by Site

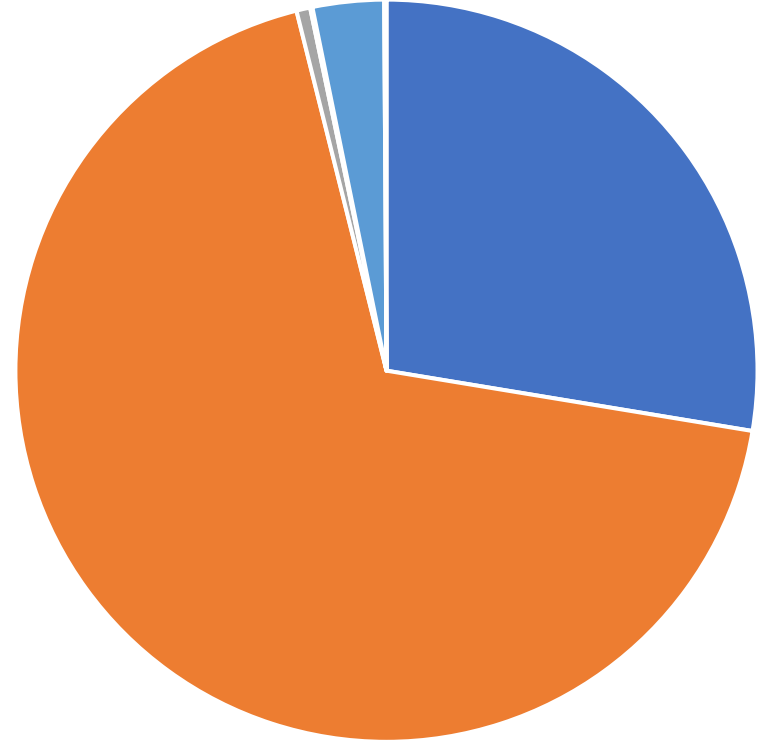
161 Weeks from Week 38 of 2019 to Week 43 of 2022



Max: 2,725, Average: 411, Current: 383

| | | | | | |
|---------------------|-------|--------------------|------|--------------|------|
| DIRAC.JINR-TIER.ru | 37.2% | DIRAC.NIKS-JSCC.ru | 0.4% | CLOUD.INP.kz | 0.0% |
| DIRAC.JINR-CREAM.ru | 33.6% | DIRAC.UNAM.mx | 0.1% | CLOUD.INP.by | 0.0% |
| DIRAC.GOVORUN.ru | 26.7% | CLOUD.JINR.ru | 0.1% | | |
| DIRAC.JINR-LHEP.ru | 2.1% | CLOUD.NOSU.ru | 0.0% | | |

Jobs



Govorun Tier1,2 NIKS Clouds NICA Mexico

MPD data mass production

| Generator | PWG | Coll. | \sqrt{s} | # of events(10^6) | Reco | |
|--------------|------|-----------------|-----------------------------|-----------------------|------|---|
| UrQMD | PWG4 | AuAu | 11 | 15 | + | |
| | | BiBi | 9 | 10 | + | |
| | | | 9.46 | 10 | + | |
| | | | | 9.2 | 95 | + |
| | | PWG2 | AuAu | 11 | 10 | + |
| | | PWG3 | AuAu | 7.7 | 10 | + |
| | | | BiBi | 7.7 | 10 | + |
| | | | | 9 | 15 | + |
| | | | pp | 9 | 10 | + |
| | | | BiBi fix target | 2.5 | 12 | + |
| | | | BiBi fix target | 3.0 | 12 | + |
| | | | BiBi fix target | 3.5 | 12 | + |
| | | | XeW fix target | 2.5 | 15 | + |
| | | XeXe fix target | 2.5 | 15 | + | |
| DCM-SMM | PWG1 | BiBi | 9.2 | 76 | + | |
| | PWG1 | BiBi | 9.2 | 1 | + | |
| PHQMD | PWG2 | BiBi | 8.8 | 15 | + | |
| | | | 9.2 | 61 | + | |
| | | | 2.4/3.0/4.5 | 10/10/2 | - | |
| vHLE-UrQMD | PWG3 | BiBi | 11.5 | 15 | + | |
| | | AuAu | 11.5 | 15 | + | |
| | | AuAu | 7.7 | 20 | + | |
| | | BiBi | 9.2 | 48 | + | |
| Smash | PWG1 | BiBi | 9.46 | 10 | + | |
| | | ArAr | 4/7/9/11 | 20/20/20/20 | - | |
| | | AuAu | 4/7/9/11 | 20/20/20/22 | - | |
| | | XeXe | 4/7/9/11 | 20/20/20/20 | - | |
| | | CC | 4/7/9/11 | 20/20/20/20 | - | |
| | | pp | 4/7/9/11 | 50/50/50/50 | - | |
| JAM | PWG3 | AuAu | 3/3.3/3.5/3.8/4.0/4.2/4.5/5 | 40/40/40/40/40/40/40 | + | |
| DCM-QGSM-SMM | PWG3 | AuAu | 4/9.2 | 5/5 | + | |
| | | AgAg | 4/9.2 | 5/5 | + | |
| | | BiBi | 4/9.2 | 5/6 | + | |
| PHSD | | BiBi | 9/9.2 | 25 | + | |
| Total | | | | 1412 | 568 | |

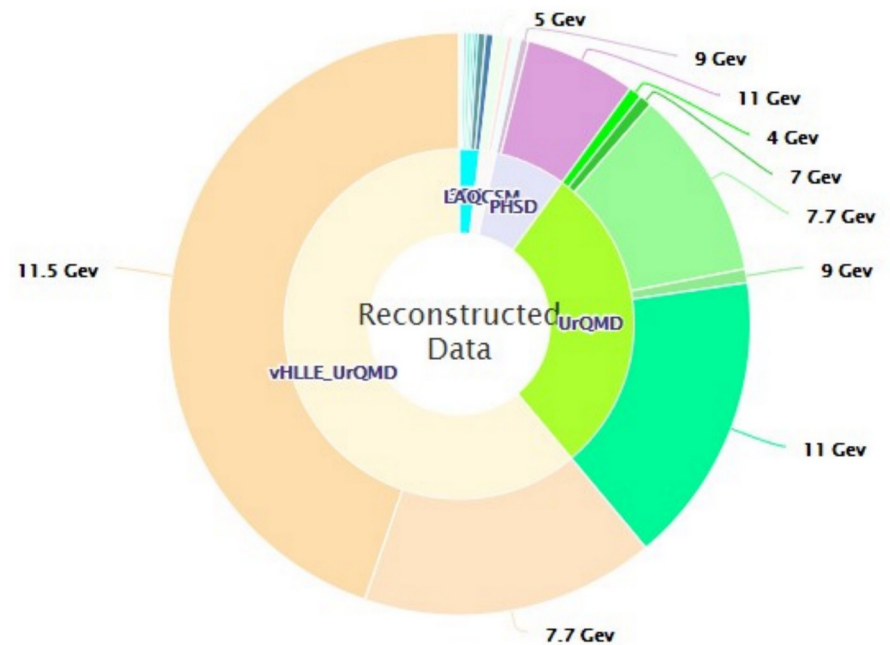
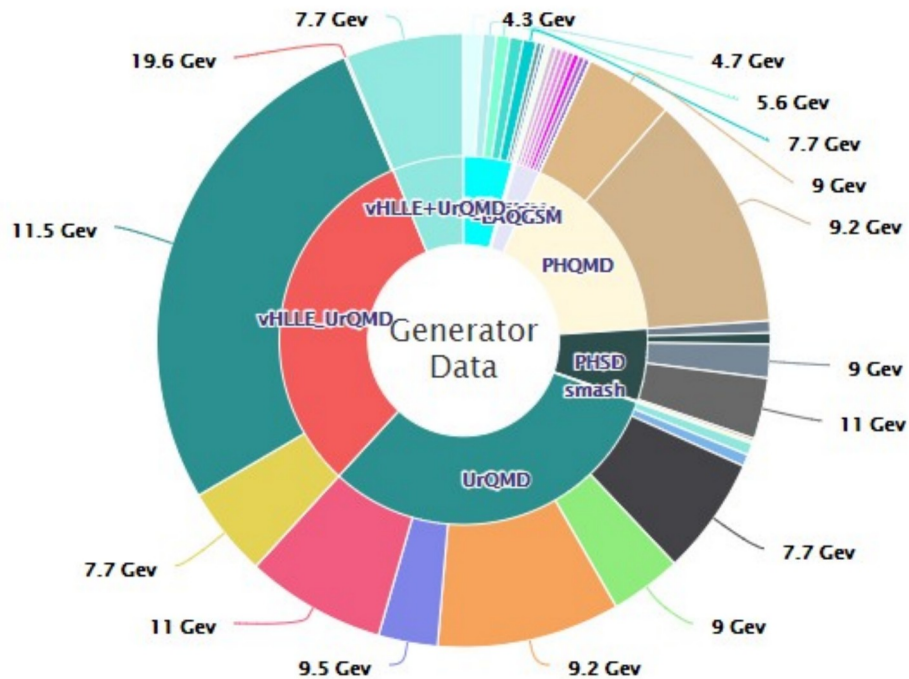
~ $1.5 \cdot 10^9$ events

MPD mass production database



<http://db-nica.jinr.ru/mpdmc/stat.php>

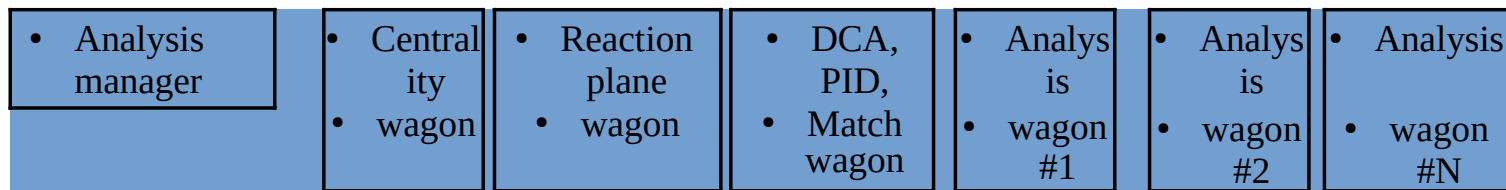
31 mass production requests were done



All production data stored in Dirac File Catalog

Physics analyses with the big data set

- ❖ Centralized Analysis Framework for access and analysis of data:
 - ✓ consistent approaches and results across collaboration, easier storage and sharing of codes and methods
 - ✓ reduced number of input/output operations for disks and databases, easier data storage on tapes
- ❖ Analysis manager reads event into memory and calls wagons one-by-one to modify and/or analyze data:



Physics analyses

Global observables

- Total event multiplicity
- Total event energy
- Centrality determination
- Total cross-section measurement
- Event plane measurement at all rapidities
- Spectators measurement

Spectra of light flavor and Hypernuclei

- Light flavor spectra
- Hyperons and hypernuclei
- Total particle yields and yield ratios
- Kinematic and chemical properties of the event
- Mapping QCD Phase Diag.

Correlations and Fluctuations

- Collective flow for hadrons
- Vorticity, Λ polarization
- E-by-E fluctuation of multiplicity, momentum and conserved quantities
- Femtoscopy
- Forward-Backward corr.
- Jet-like correlations

Electromagnetic probes

- Electromagnetic calorimeter meas.
- Photons in ECAL and central barrel
- Low mass dilepton spectra in-medium modification of resonances and intermediate mass region

Heavy flavor

- Study of open charm production
- Charmonium with ECAL and central barrel
- Charmed meson through secondary vertices in ITS and HF particles
- Explore production at charm threshold

Thanks for your attention

