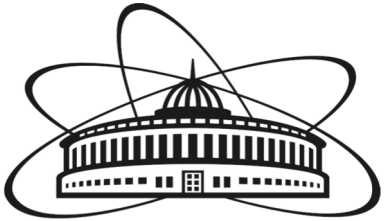


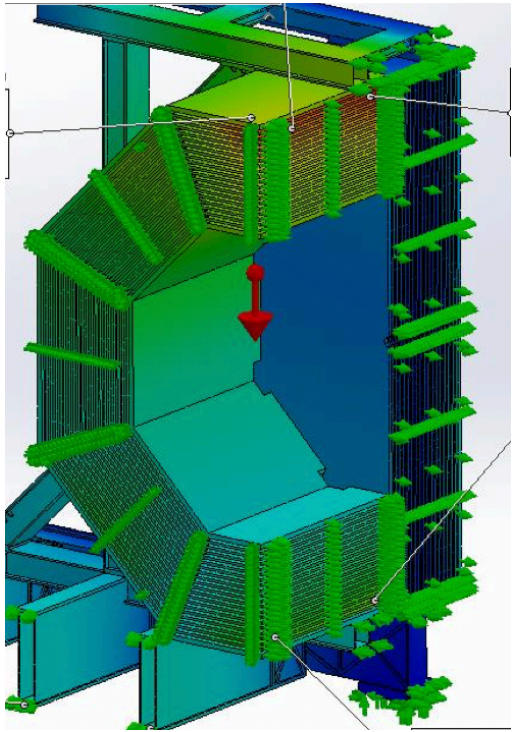
Status of the Description of the Muon System in SpdRoot

Alexander Verkheev on behalf of SPD Muon team

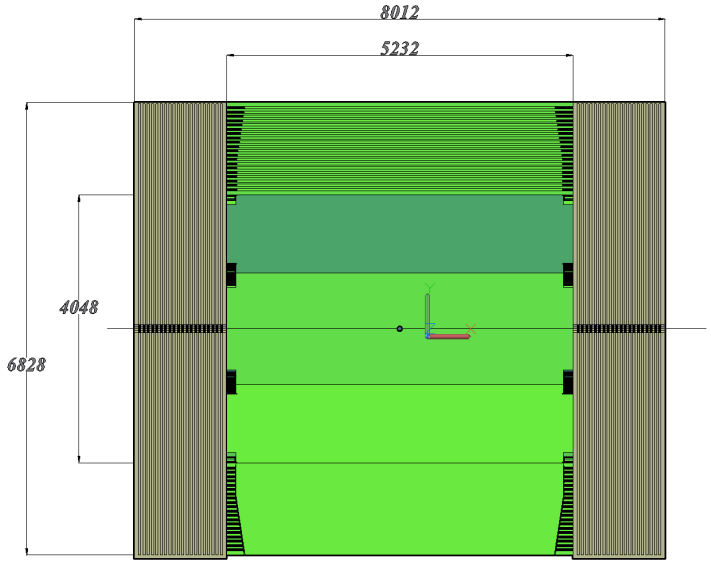
SPD Collaboration Meeting
Samara, 25 October 2023

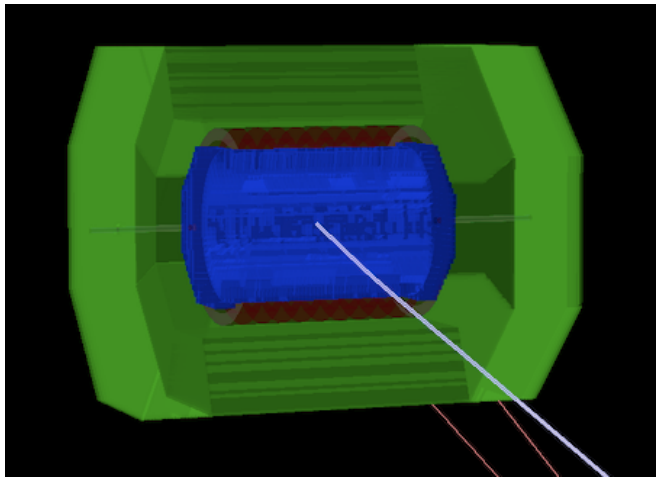
Muon System as a PID Detector

- SPD Muon System based on Range System technique is a good PID system for muon identification and muon-to-hadron separation.
- It works in full energy range of secondary particles at SPD (0.5 ÷ 10 GeV).
- Important feature of Range System is possibility to be used as coarse sampling (30-60 mm of Fe) hadron calorimeter.



SPD Setup (Sketch and Model)





SpdIsotropicGenerator (1 mu, E = 5 GeV)

https://git.jinr.ru/alver/spdroot/-/blob/master/macro/DisplayEvent.C

How to Get Information from RS

RS geometry and Geant4 hits processing are defined in
rst/barrel/SpdRsTB2.cxx and rst/ecps/SpdRsTEC2.cxx

```
SpdRsTB2* rs_barrel = new SpdRsTB2();     // RS (BARREL)
SpdRsTEC2* rs_ecps = new SpdRsTEC2();  // RS (ENDCAPS)

run->AddModule(rs_barrel);
run->AddModule(rs_ecps);

SpdIsotropicGenerator* isogen1 =
                                    new SpdIsotropicGenerator("isogen1");
SpdPythia8Generator* P8gen = new SpdPythia8Generator();
```

Output:
spdsim->SpdRsTB2Point
spdsim->SpdRsTEC2Point

https://git.jinr.ru/alver/spdroot/-/blob/master/macro/SimuRs.C

How to Get Information from RS

Clusters are reconstructed based on the MC-truth information for each particle that enters RS from inside. Particle object allow one to trace the origin of the particles.

RS hits and clusters processing are defined in
reco/rs/SpdRsMCHitProducer.cxx and reco/rs/SpdRsMCClusterMaker.cxx

```
// [MUON-HADRON RANGE SYSTEM (BARREL+EC) HIT PRODUCER]
// Input: mc-events, mc-particles, rs-barrel/ec-points;  Output: mc-rs-hits
SpdRsMCHitProducer* rs_hits_producer = new SpdRsMCHitProducer();
Run->AddTask(rs_hits_producer);

// [MC-CLUSTERING AND MC-RECONSTRUCTION FOR RANGE SYSTEM]
// Input: mc-event, mc-particles, mc-rs-hits; Output: mc-rs-clusters, mc-rs-particles
SpdRsMCClusterMaker* rs_clust_producer = new SpdRsMCClusterMaker();
Run->AddTask(rs_ clust_producer);
```

Output:
spdsim->RsMCHits
spdsim->MCRsClusters
spdsim->SpdRsParticles

https://git.jinr.ru/alver/spdroot/-/blob/master/macro/RecoRs.C

How to Get Information from RS

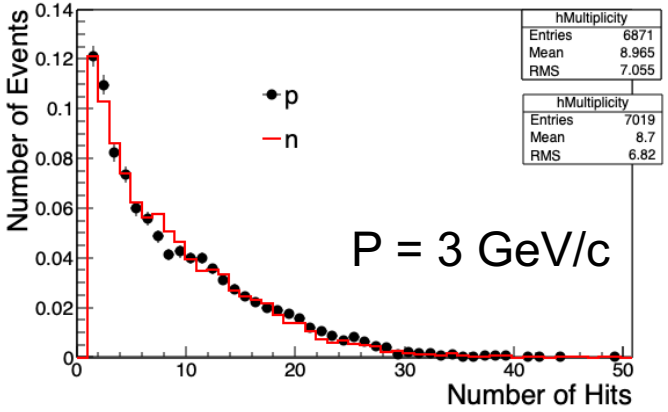
MC particle ←→ MC cluster ←→ MC hits

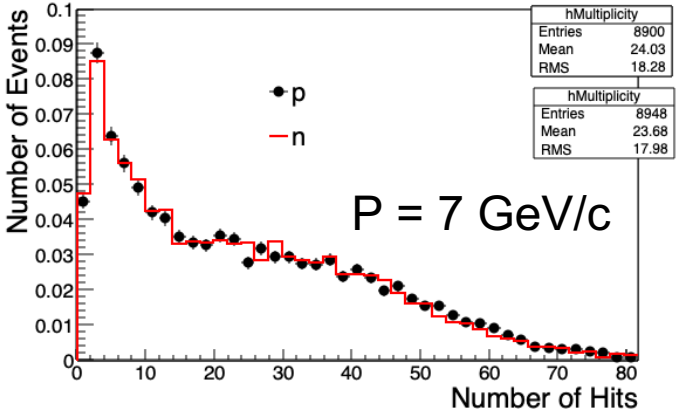
```
SpdMCDataIterator* IT = new SpdMCDataIterator();
…
IT->Init();

RsHits = IT->GetRsHits();
RsClustersMC = IT->GetRsClustersMC();
RsParticlesMC = IT->GetRsParticlesMC();
```

Output:
hit layer, hit coordinates,
number of cluster,
particle' PID
detector

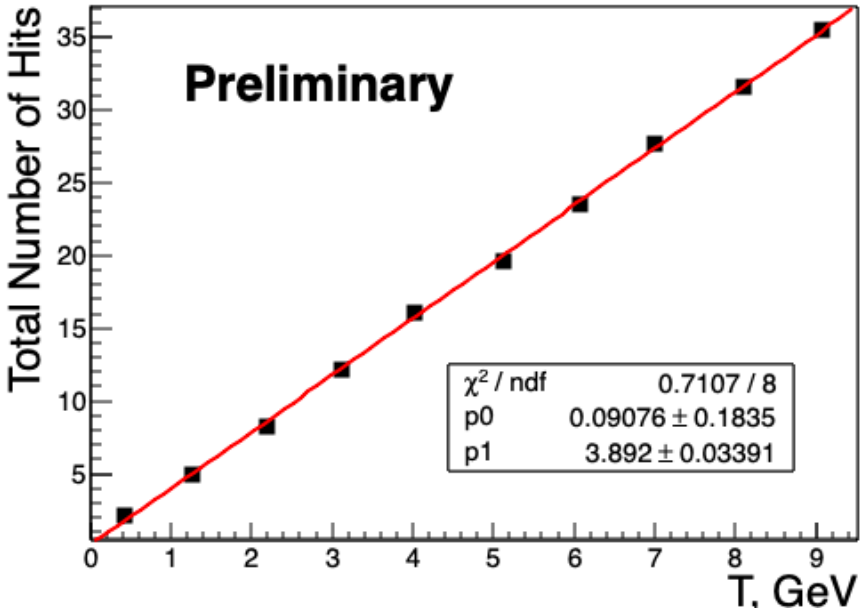
https://git.jinr.ru/alver/spdroot/-/blob/master/macro/AnalyseRs.C

Calorimetry for Hadrons



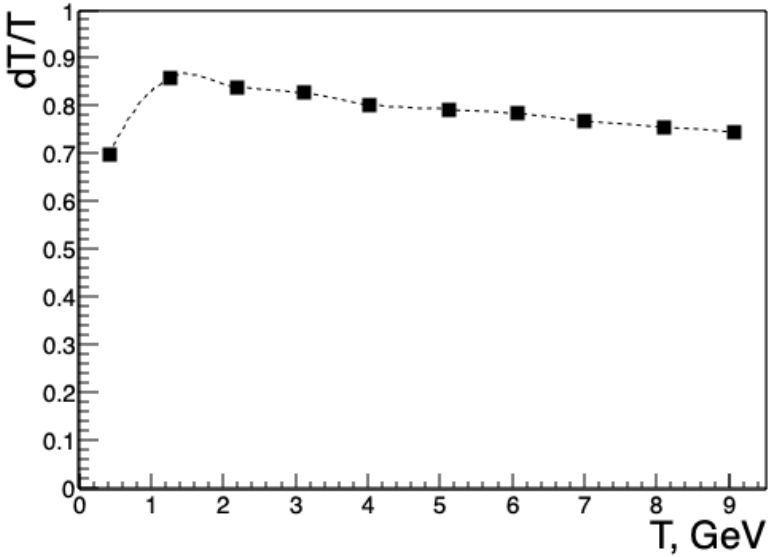


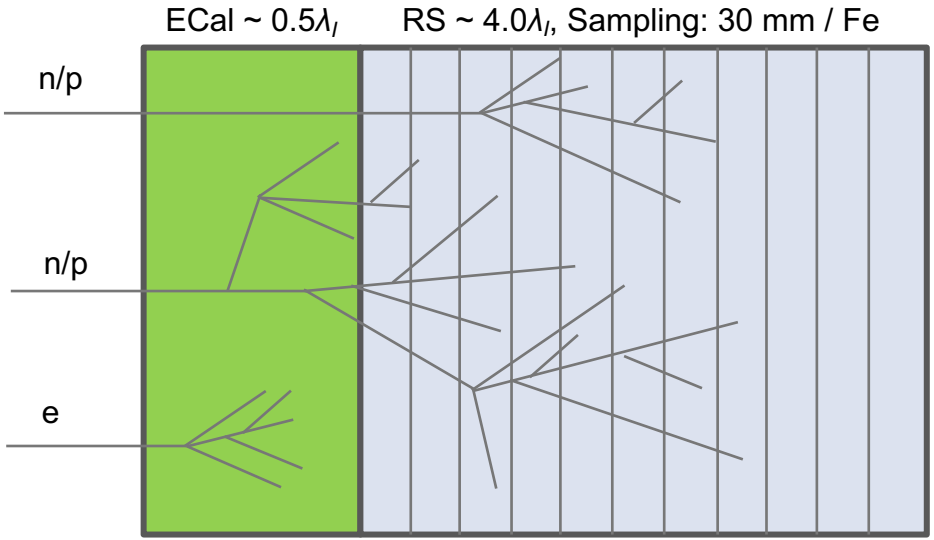
SpdIsotropicGenerator, (p, n) P = 1..10 GeV/c, 10k, Theta [80, 100 deg]



Every 1 GeV gives 4 additional hits in RS

Calorimetry for Neutrons





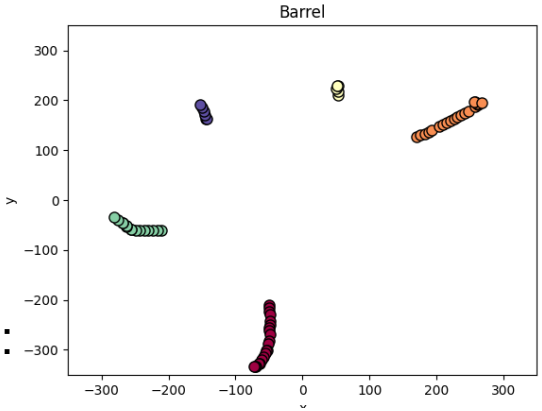
There is a ”leak” of shower in RS due to a hadron shower can start in ECal.

Particle Reconstruction in RS

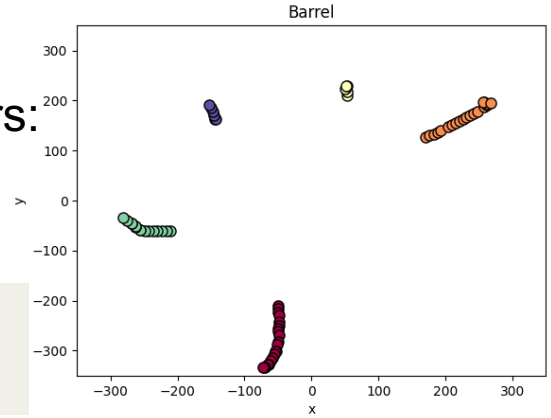
Input: 50k $J/\psi \to \mu\mu$ sqrt(s) = 27 GeV:
- hits in Barrel: (x, y) of wires at layers and z of strips
- hits in EndCaps: (y, z) of wires and x of strips

Clustering (forms group of hits) is unsupervised machine learning technique that groups data points into clusters based on their similarities.

Real MC clusters:



DBSCAN clusters:



DBSCAN algorithm performance: purity of 0.97.

$$\text{Purity} = \frac{\sum_i N_{i,\text{hits}}^{\text{correct}}}{N_{\text{hits}}^{\text{total}}}$$

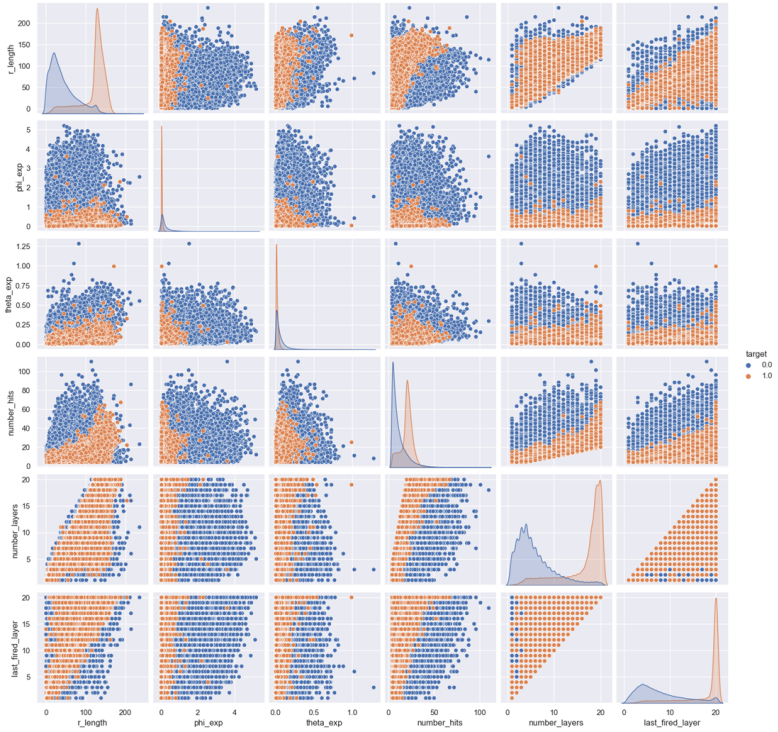
More details at https://indico.jinr.ru/event/3779/contributions/23414/attachments/17177/29250/Zel_RS.pdf

Particle Reconstruction in RS

Classification (Particle Identification) is a common task in machine learning that involved predicting the class or category of a given input data point (muons vs hadron separation)

Decision tree, Random Forest, XGBoost performance:
precision ~ 0.94-0.95, recall ~ 0.89-0.90.

CNN have shown a good result in recall metric – 0.96.



More details at https://indico.jinr.ru/event/3779/contributions/23414/attachments/17177/29250/Zel_RS.pdf

Summary and Plans

Status:
- SPD Range System geometry is integrated in SpdRoot.
- Calorimetry of hadrons is studying.
- Preliminary results of particle reconstruction is presented.

To do:
- Repeat Vika's studies for hadron and muon particle reconstruction.
- Digitization when SPD test beam data will be available.

Thanks for your attention!

Backup

Particle identification

Classification is a common task in machine learning that involved predicting the class or category of a given input data point

Performance metrics:

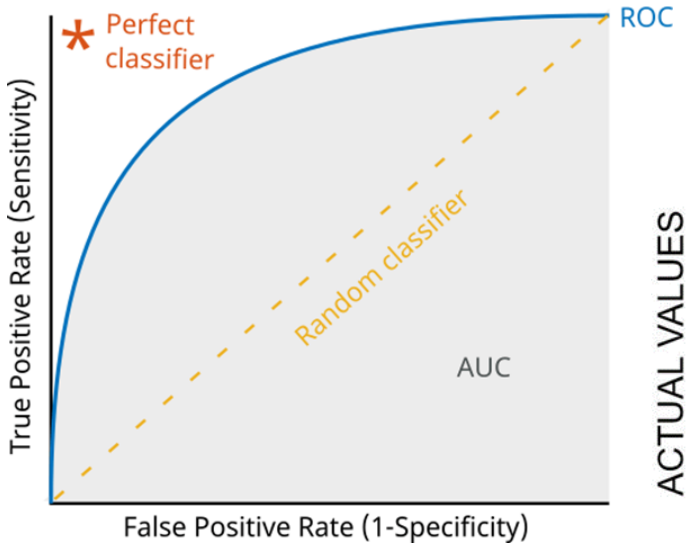
$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN}$$

$$f1 = \frac{2*precision*recall}{precision+recall}$$, where:

$$precision = \frac{TP}{TP+FP},$$

$$recall = \frac{TP}{TP+FN}$$

AUC-ROC



		PREDICTIVE VALUES	
		POSITIVE (1)	NEGATIVE (0)
ACTUAL VALUES	POSITIVE (1)	TP	FN
	NEGATIVE (0)	FP	TN

Recall demonstrates the algorithm's ability to detect a given class as a whole, while precision demonstrates its ability to distinguish that class from other classes.