

PANDA实验 EMC软件进展

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(代表Panda中国软件组)

第十三届全国粒子物理学术会议

2021.8.17



Outline

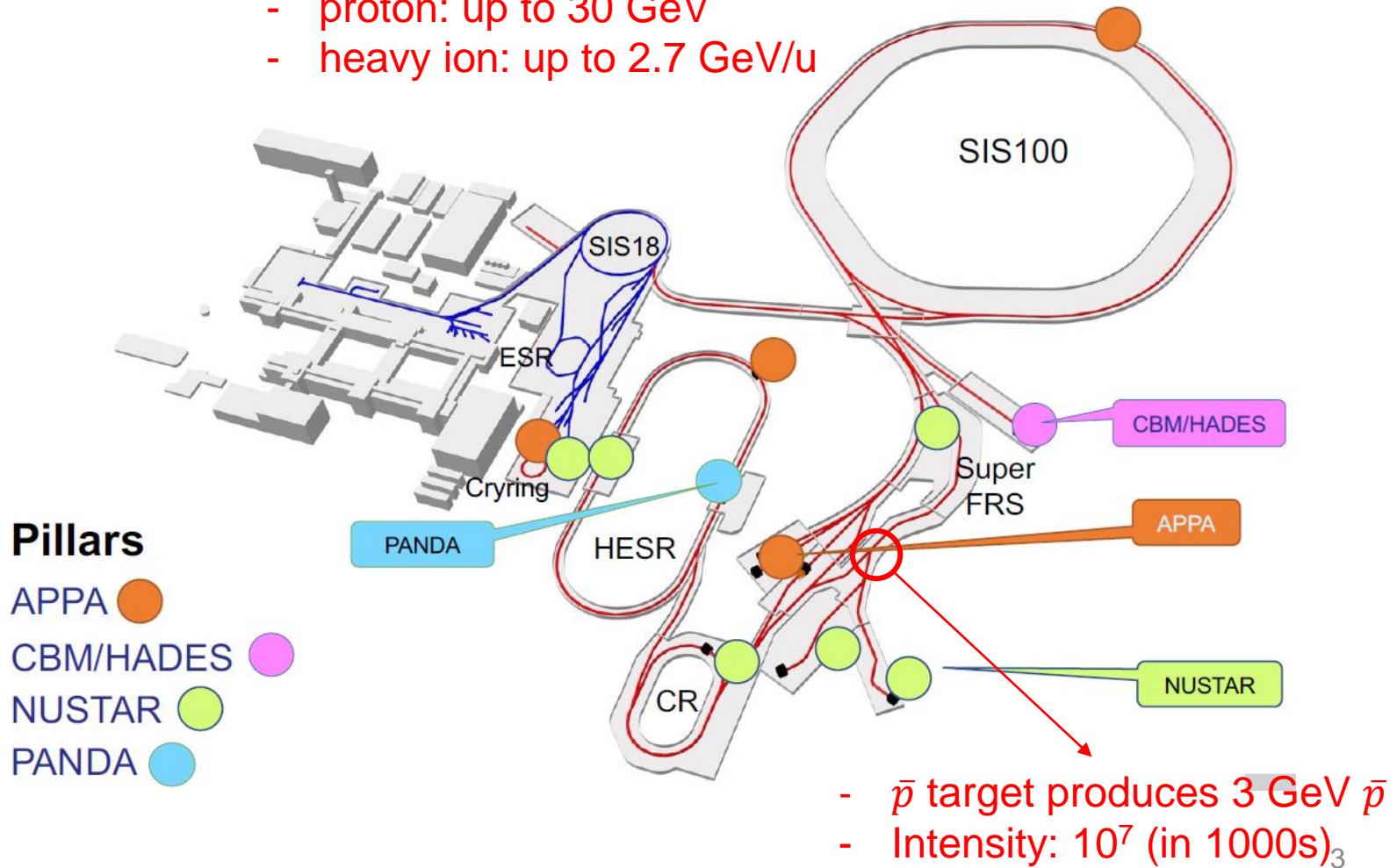
- **Introduction**
 - Fair
 - Panda Detectors
- **EMC Software Work**
 - Geometry construction
 - Digitization
 - Reconstruction
 - Calibration
- **Summary and Outlook**



Facility for Antiproton and Ion Research (FAIR) @ GSI, near Darmstadt

SIS100 can accelerate:

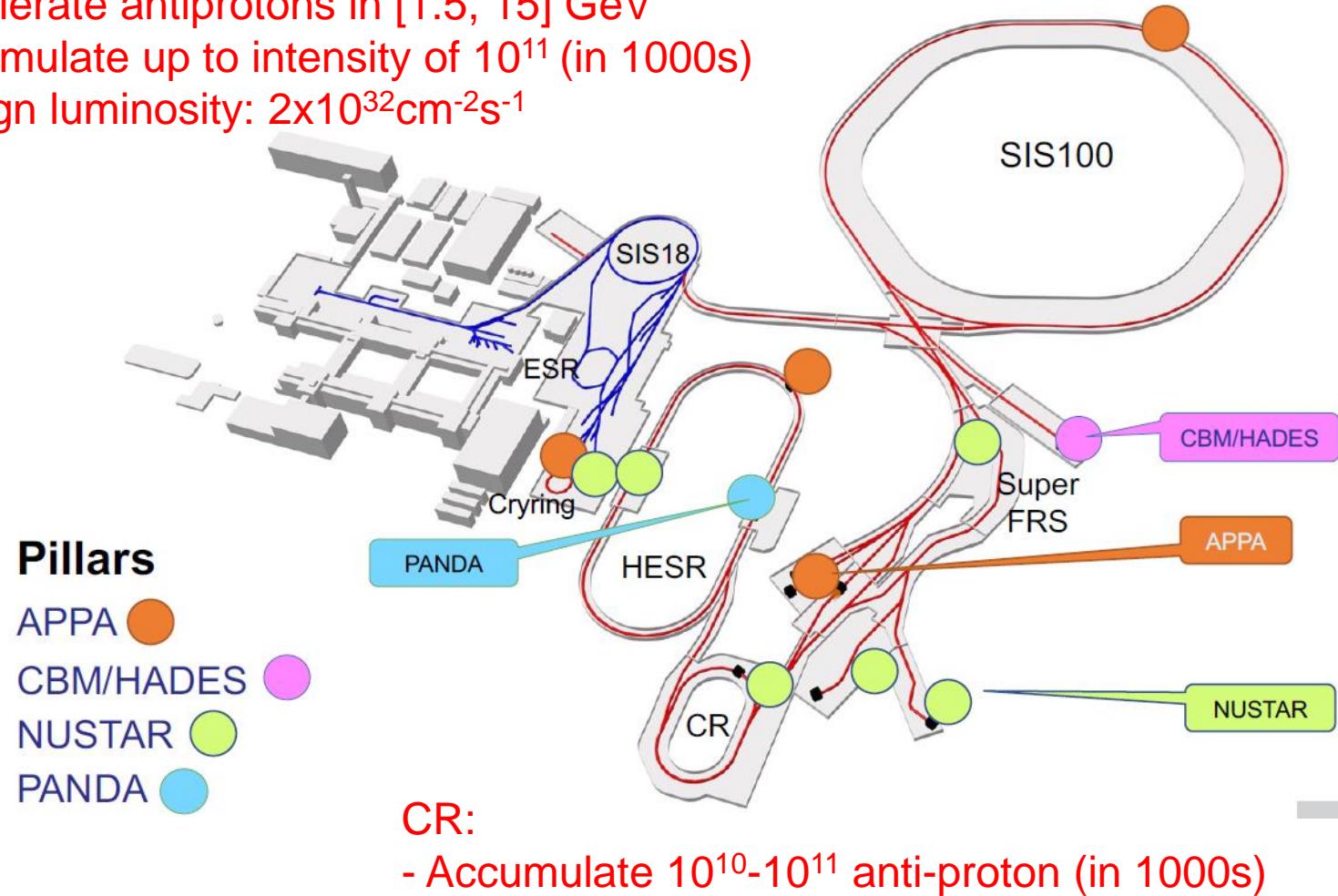
- proton: up to 30 GeV
- heavy ion: up to 2.7 GeV/u



Facility for Antiproton and Ion Research (FAIR) @ GSI, near Darmstadt

HESR:

- Accelerate antiprotons in [1.5, 15] GeV
- Accumulate up to intensity of 10^{11} (in 1000s)
- Design luminosity: $2 \times 10^{32} \text{ cm}^{-2} \text{s}^{-1}$





FAIR — Facility for Antiproton and Ion
Research in Europe

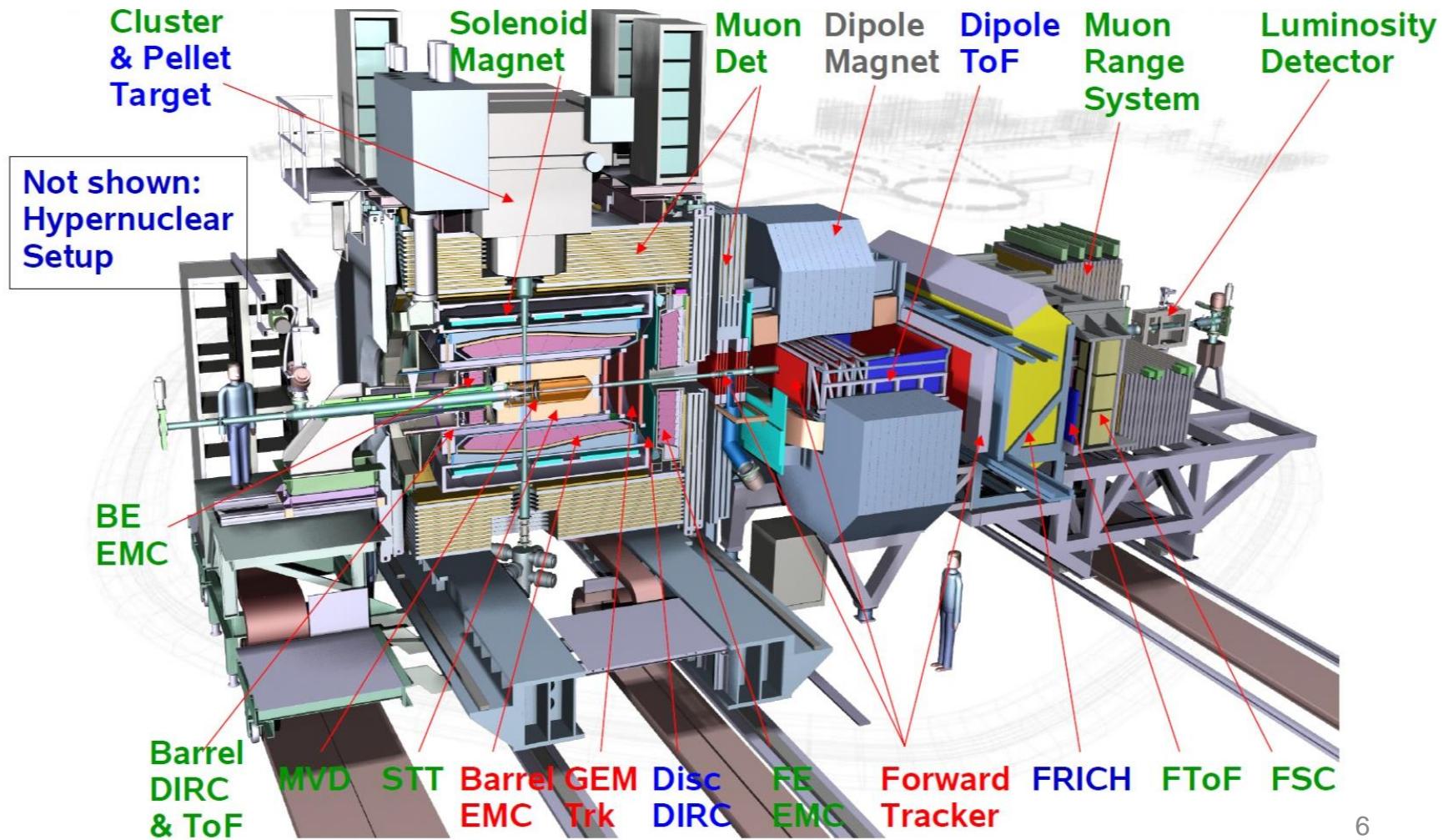
FAIR — Facility for Antiproton and Ion Research in Europe FAIR Site in April 2021

5

"Report from the Technical Coordinator" Lars Schmitt, PANDA Collab Meeting 21/2

PANDA Day-1/Phase 1/Phase 2

PANDA = antiProton ANihilation at DArmstadt



PANDA Schedule

Current Status

- Construction of many Phase 1 systems has started
- Integration and infrastructure planning progressing
- Delays in several parts due to delayed funding or contracting
- Covid-19 needs to be accounted still

Installation periods according to present plans

- Installation period 1: solenoid, dipole, supports etc. in parallel with installation of technical building infrastructure
- Installation period 2: all other systems after building completed.

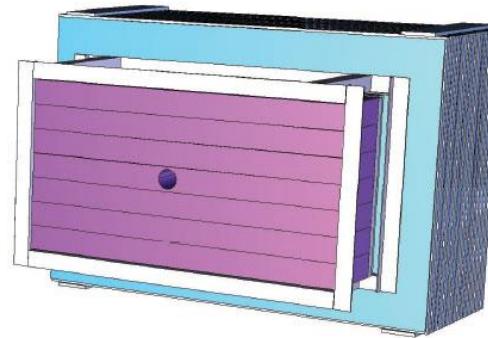
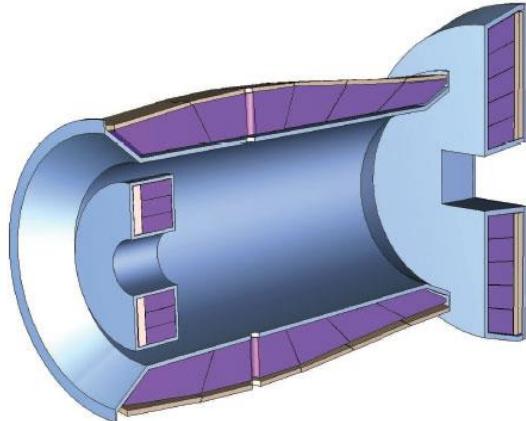
Boundary conditions for plan revision

- Completion of PANDA hall 2 years later than initially planned
- Start of installation period 1 on **June 6 2024**
- Mitigation: testing and pre-assembly of parts at other sites, storage

Ready for beam end 2026

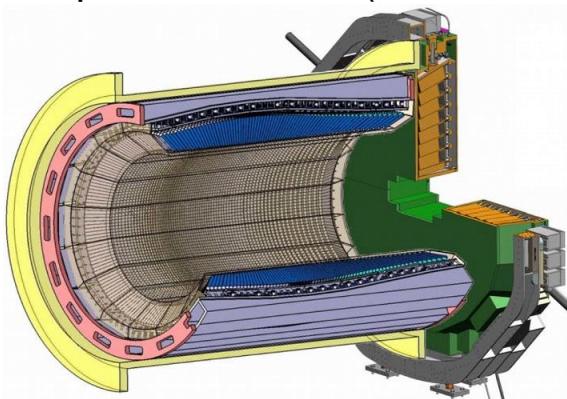
Electromagnetic Calorimetry

- PANDA physics: Complete reconstruction of multi-photon and lepton-pair channels of importance
- Good energy and spatial resolution for photons up to 15 GeV
- High yield and background rejection
- Target spectrometer: Homogenous barrel part plus two endcaps
- Forward spectrometer: Sample calorimeter

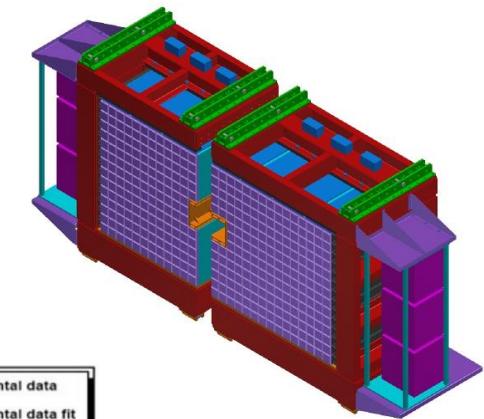
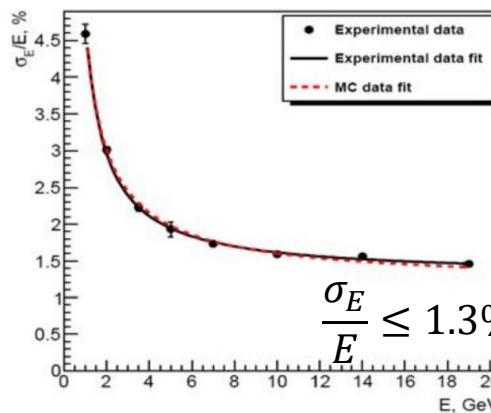


Electromagnetic Calorimetry

- 2nd generation PbWO₄ (PWO-II), improved light yield, radiation hardness, 15744 crystals
- Operating at -25°C ($\times 4$ light yield)
- Read out: Large area APDs (2 per crystal), vacuum photo tetrodes (inner forward endcap)
- Shashlik type sampling calorimeter:
- Lead absorbers, plastic scintillators, light collection by wavelength shifting fibers, PMT readout

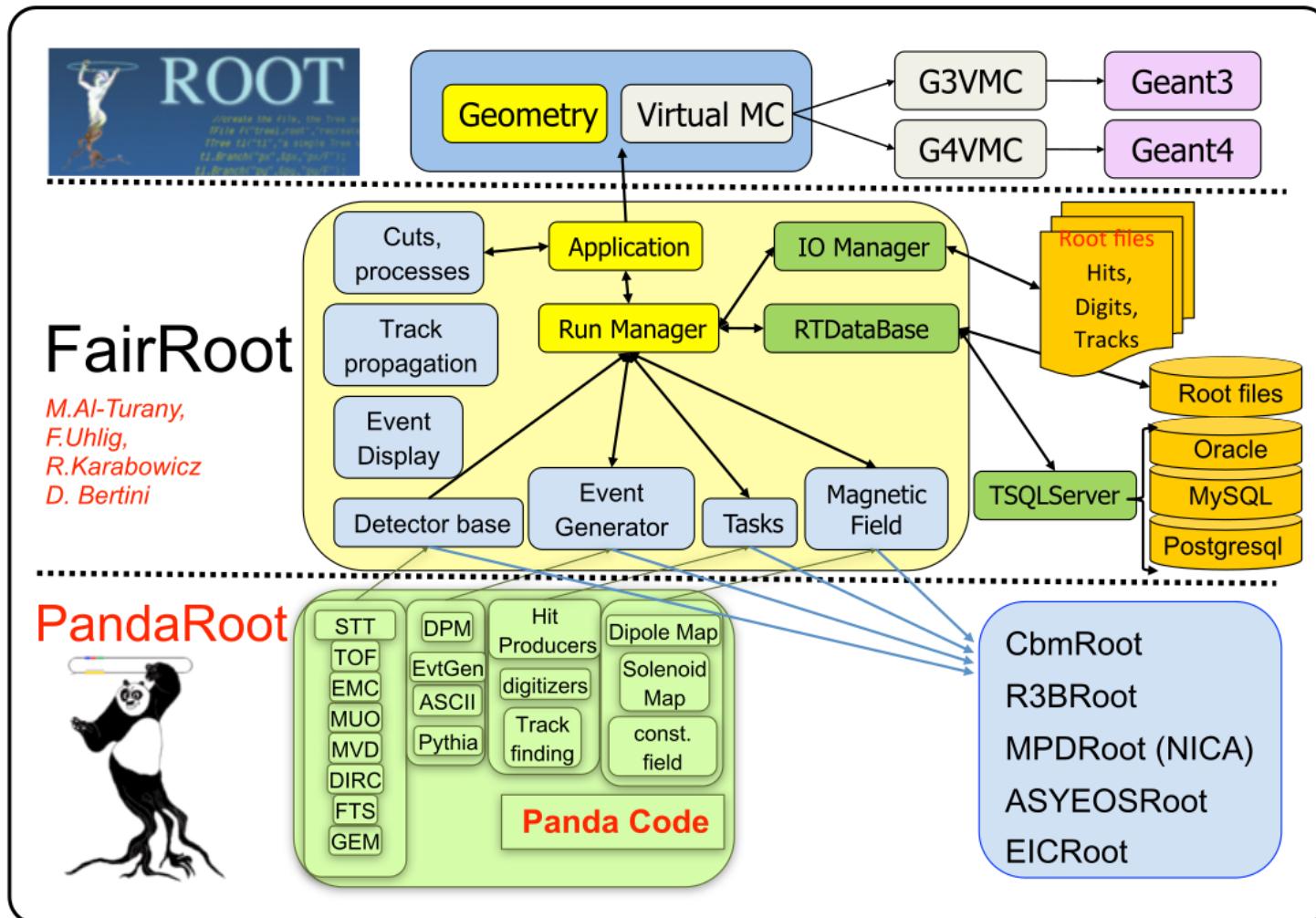


Radiation length	0.9 cm
Molière radius	2.1 cm
Crystal dimensions	$20 \times 2.5 \times 2.5 \text{ cm}^3$
Time resolution	$\leq 1 \text{ ns} (> 100 \text{ MeV})$
Energy res. $\frac{\sigma_E}{E}$	$1\% \oplus \frac{2\%}{\sqrt{E[\text{GeV}]}}$
Spacial resolution	$\leq 1.5 \text{ mm}$

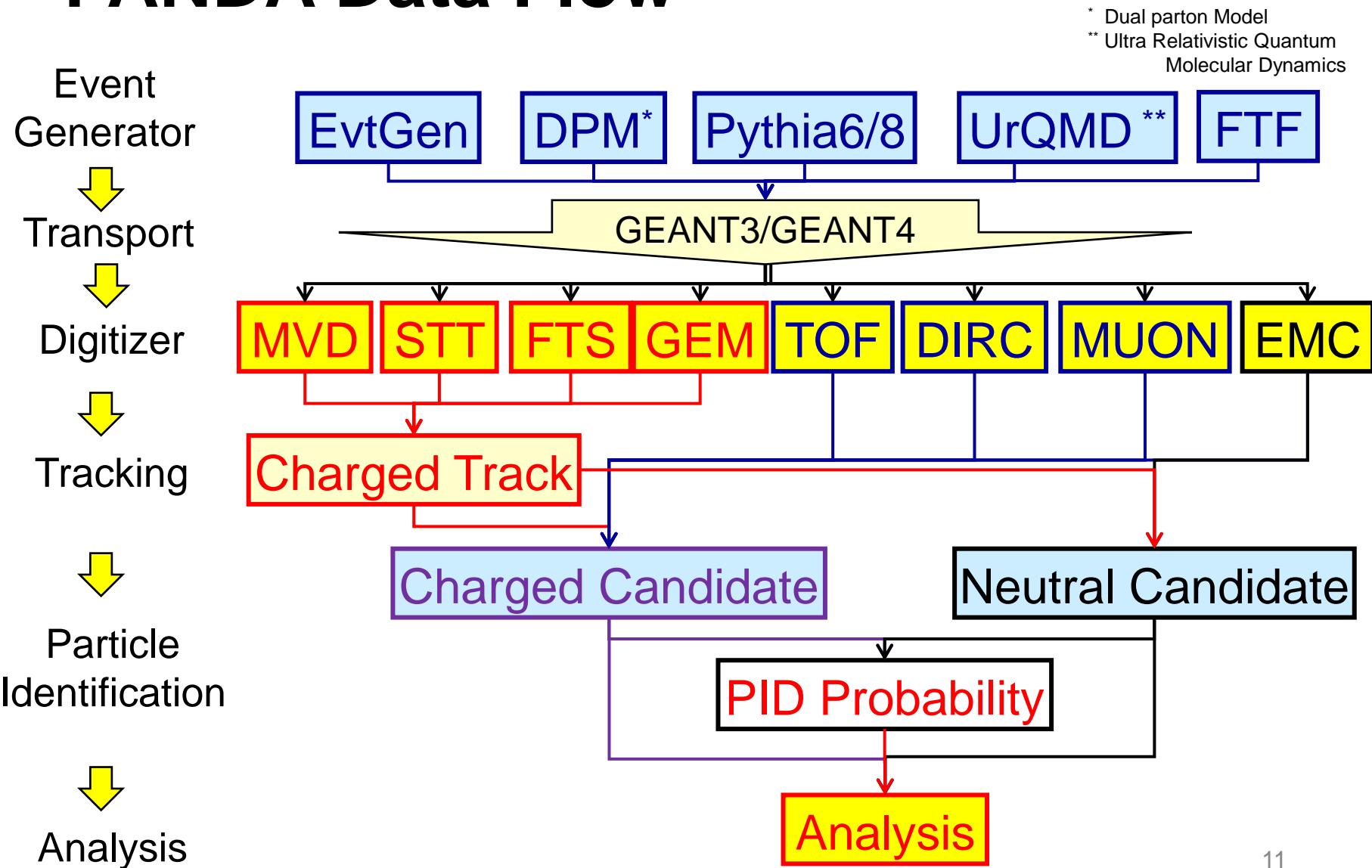


$$\frac{\sigma_E}{E} \leq 1.3\% \oplus \frac{2.8\%}{\sqrt{E[\text{GeV}]}} \oplus \frac{3.5\%}{E[\text{GeV}]}$$

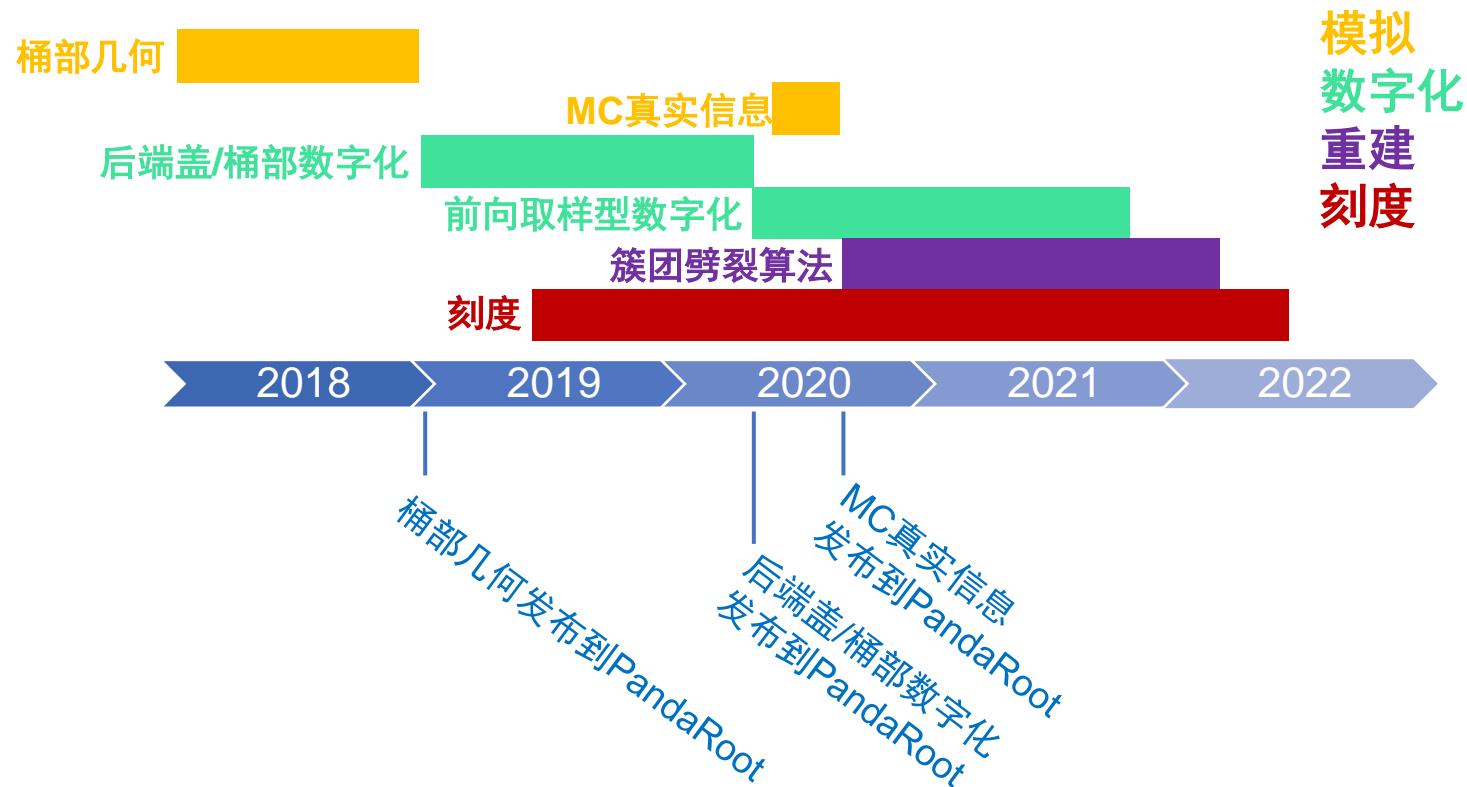
Structure of Code



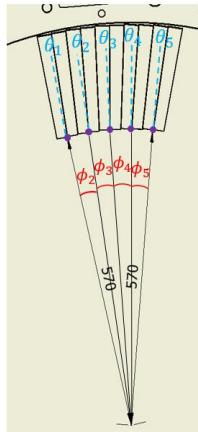
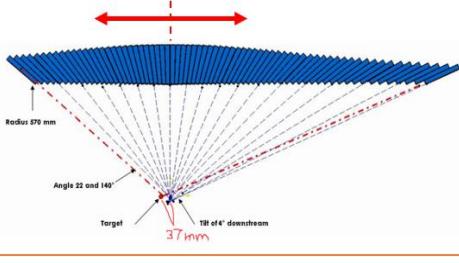
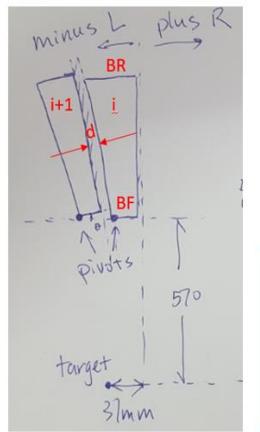
PANDA Data Flow



Roadmap of EMC Software Work

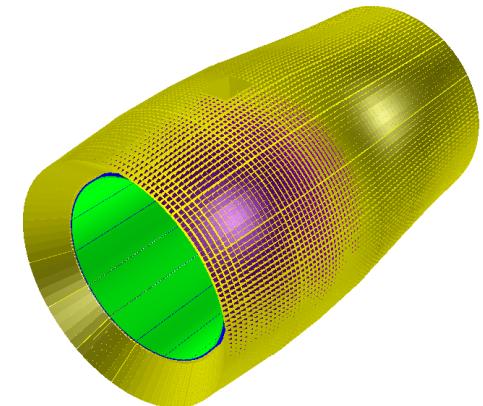
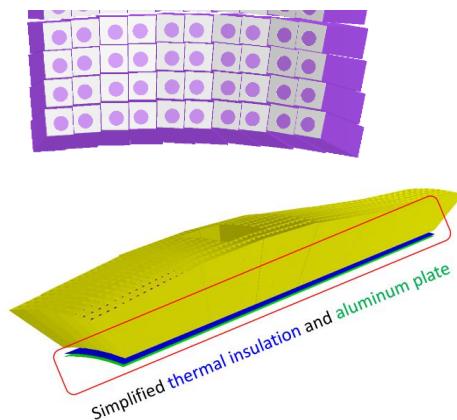
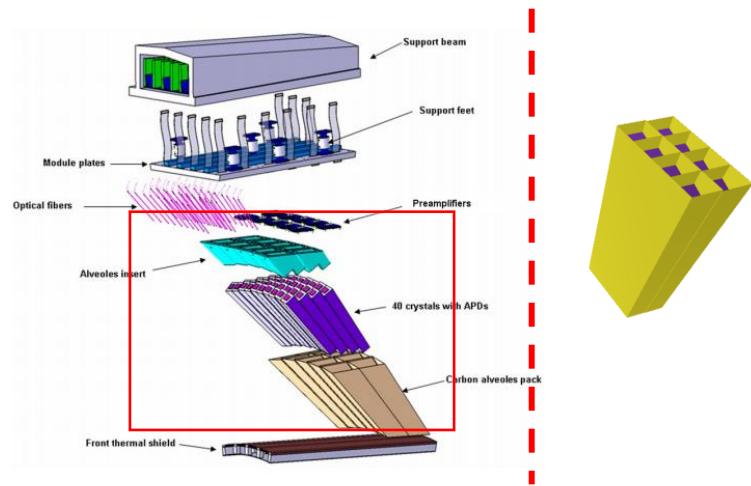


Barrel EMC Geometry Description

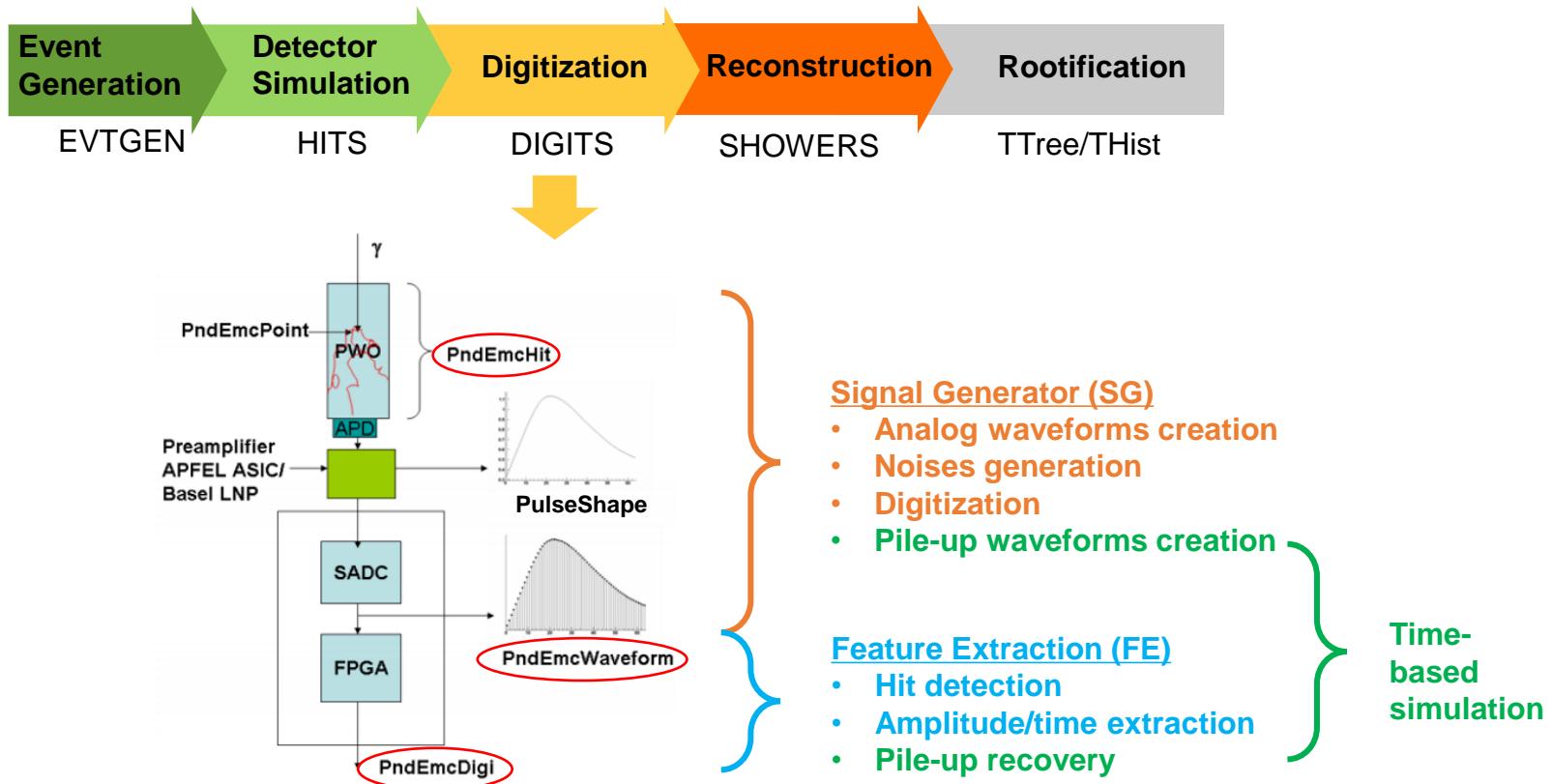


- ✓ z positions of the crystals are defined by the gap d and the crystal dimension
- ✓ For the $(i+1)^{\text{th}}$ crystal (minus)
 - ✓ $z_{i+1} = z_i - (BF + d)/\cos\theta_i$
 - ✓ where $\theta_{i+1} = \theta_i + \tan(\frac{BR_i - BF_i}{L})$
- ✓ Place the crystals from center to side one by one

- ✓ 根据最新硬件设计，详细构建了桶部量能器的晶体和非灵敏物质。
- ✓ 完成所有几何相关的代码，发布在PandaROOT正式版本
18dec



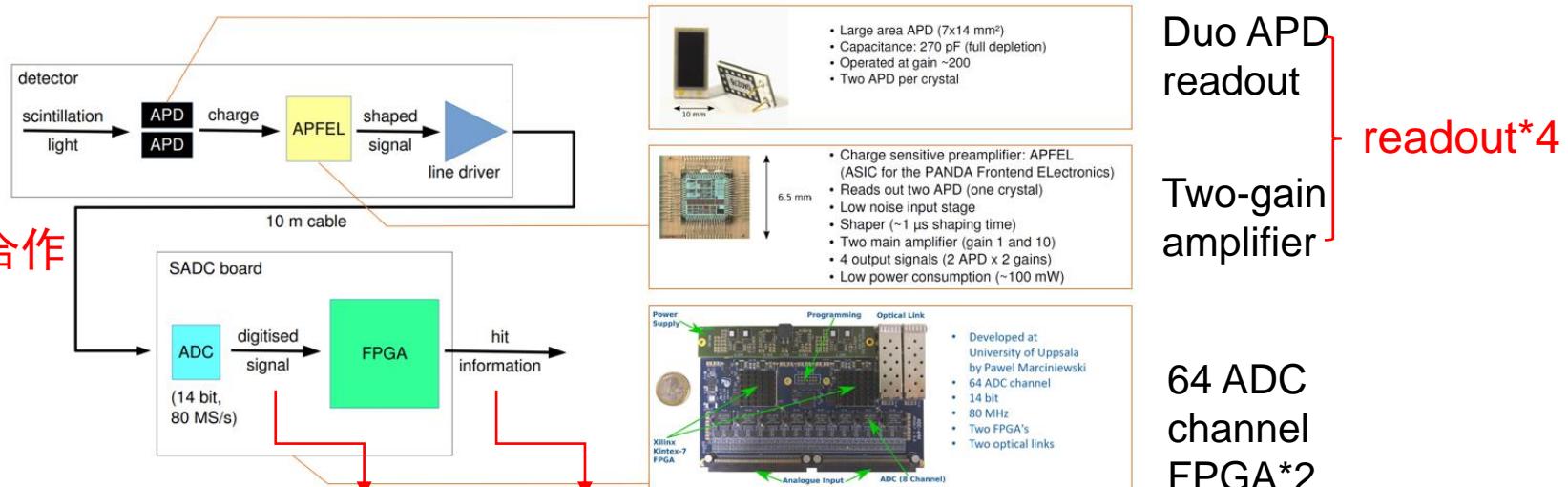
Digitization



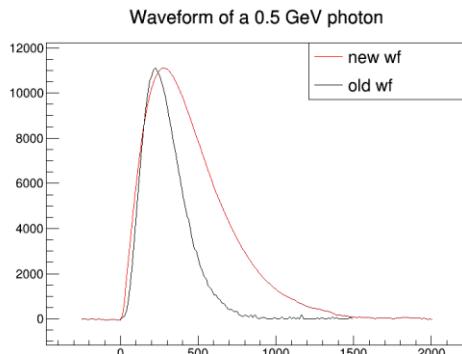
数字化：提供包含探测器和电子学真实响应的击中信息

Backward EC / Barrel EMC Digitization

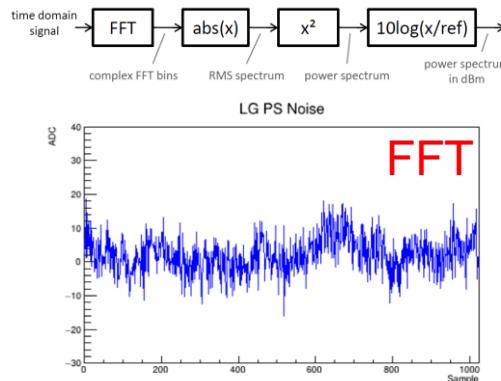
与Mainz合作



数字化：信号产生 + 特征提取



波形

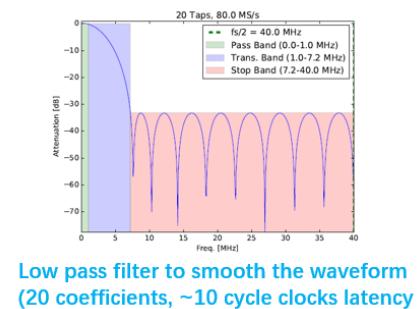


噪声

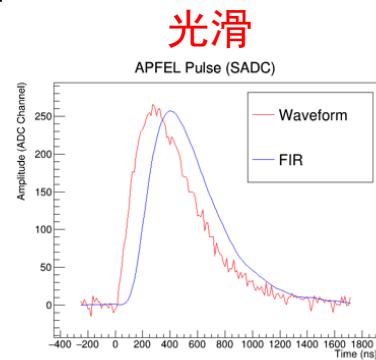
信号产生：

- 真实波型的产生
- 噪声的模拟
 - 基于FFT频谱分析
 - 重点优化了软件速度
(复杂度 $O(n) \rightarrow O(1)$)
- 实现了4个读出的模拟

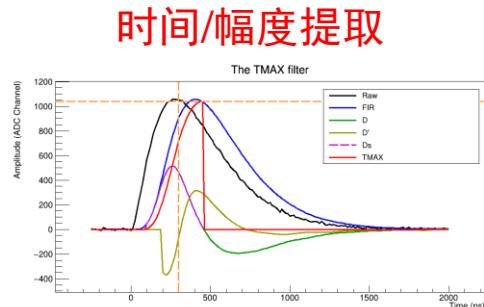
Backward EC / Barrel EMC Digitization



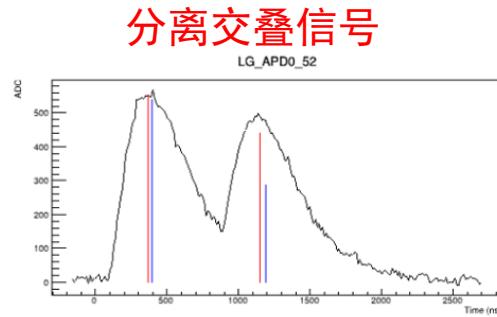
Low pass filter to smooth the waveform
(20 coefficients, ~10 cycle clocks latency)



光滑



时间/幅度提取



分离交叠信号

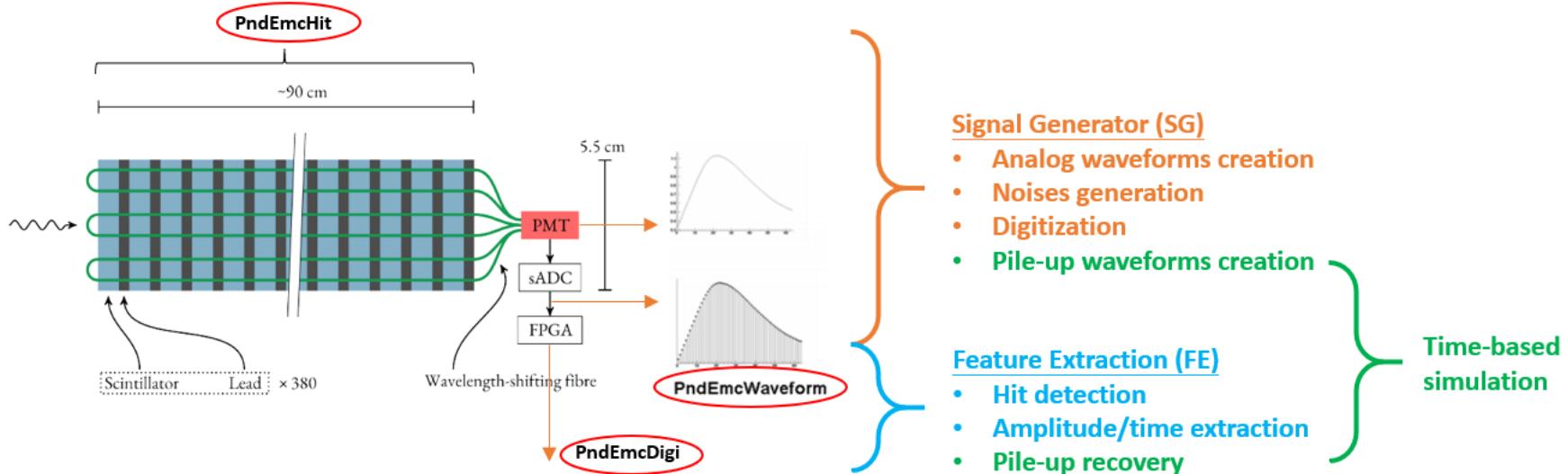
特征提取：

- 低通滤波器对波形进行光滑
- 通过FPGA算法
 - 提取波形的时间和幅度
 - 以及分离交叠信号

小结：

- 该工作与Mainz的硬件专家Oliver Noll合作
- 后端盖/桶部EMC数字化开发已完成，通过测试，代码发布到了官方离线软件PandaRoot

Digitization of Shashlyk Calorimeter



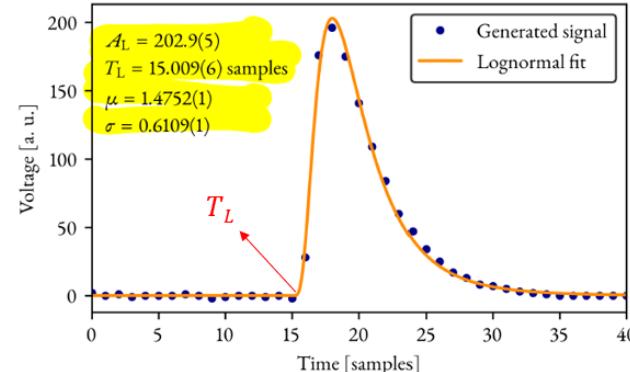
Signal Generator (信号产生)

Idea pulse shape:

$$f_L(t) = \begin{cases} \frac{A_L \exp(\mu - 0.5\sigma^2)}{t - T_L} \exp\left[\frac{[\log(t - T_L) - \mu]^2}{2\sigma^2}\right], & \text{if } t > T_L \\ 0, & \text{otherwise,} \end{cases}$$

Noise and digitizing:

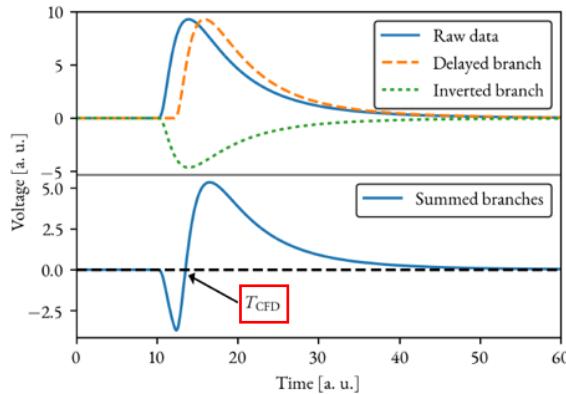
- Adding electronics noise: 1 ADC
- Digitizing: 125 MHz



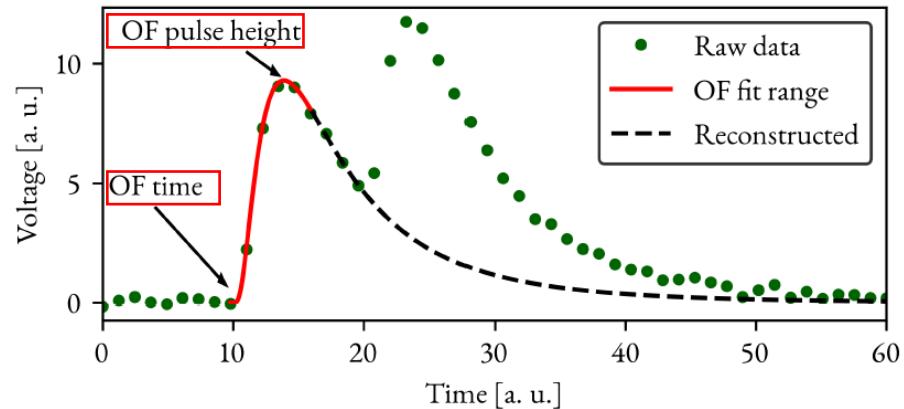
Digitization of Shashlyk Calorimeter

Feature Extraction (特征提取)

恒比定时: 确定起始时间

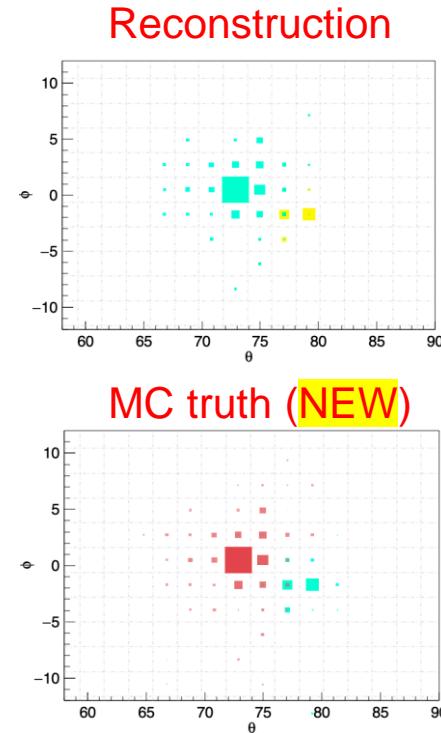
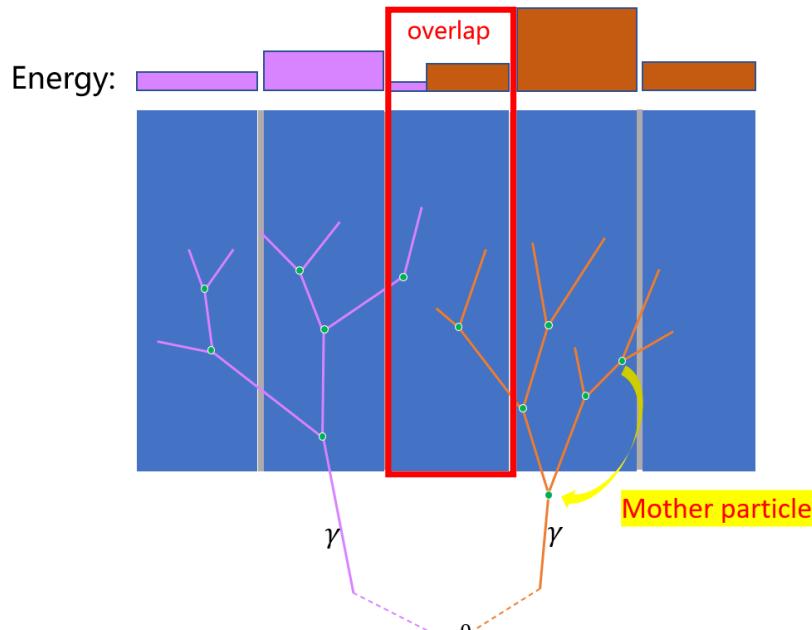


最优滤波: 精确提取时间和幅度, 处理堆积信号



- ✓ 该工作与Stockholm University的硬件专家Markus Preston合作完成
- ✓ 所有基于束流实验的结果和固件的数字化算法, 均已在Panda离线软件PandaRoot中实现

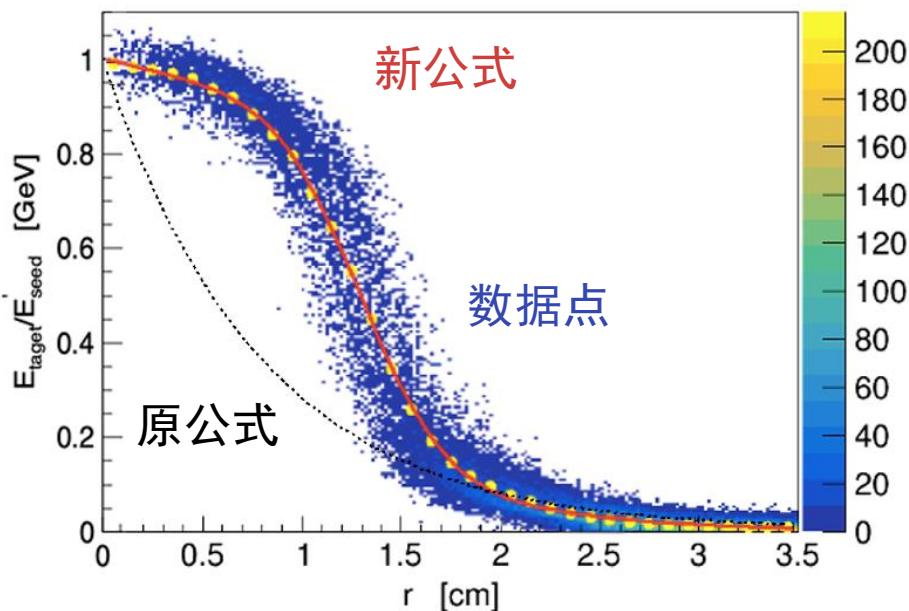
MC Truth Match



- 实现了step级别能量和母粒子信息的存储
- 更方便用户进行“重建簇团-MC真实粒子”的匹配
- 能够区分“有多簇团能量沉积晶体”的能量来源→簇团劈裂算法的研究
- 已经发布到PandaRoot

Study of Energy Splitting

- 簇团劈裂算法是量能器重建的核心算法之一
- 簇团劈裂的性能尤其影响高动量pi0的重建，从而影响物理事例的重建



主要工作：

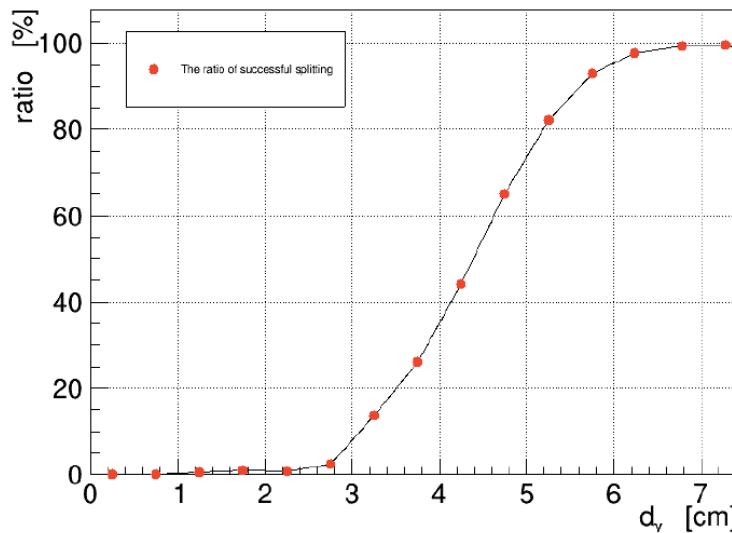
簇团劈裂算法中，原有的簇射横向发展公式：

$$E_{target} = E_{seed} \times e^{-2.5r/R_M}$$

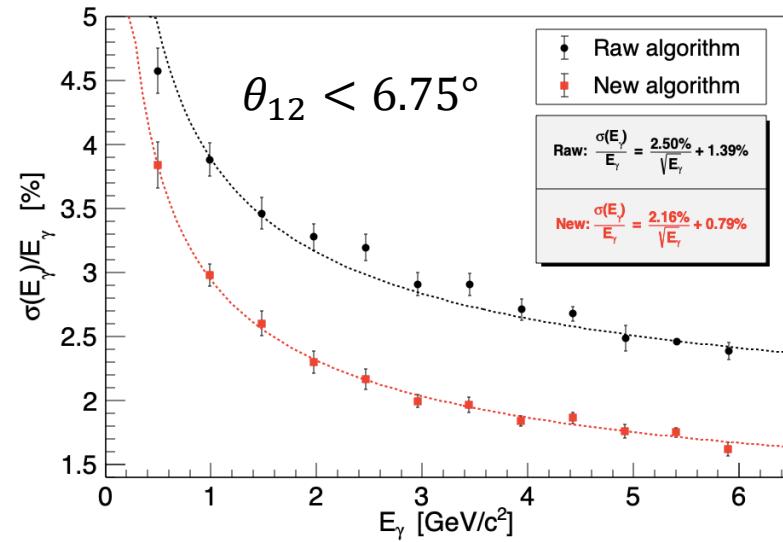
未考虑探测器颗粒度，不能描述数据。因此重新测量横向发展公式。

Study of Energy Splitting

光子劈裂效率



小夹角两个光子事例的能量分辨



- 更新和改进了簇团劈裂算法
- 对于小夹角光子的能量分辨提升明显

Calibration Algorithm

Based on π^0 mass

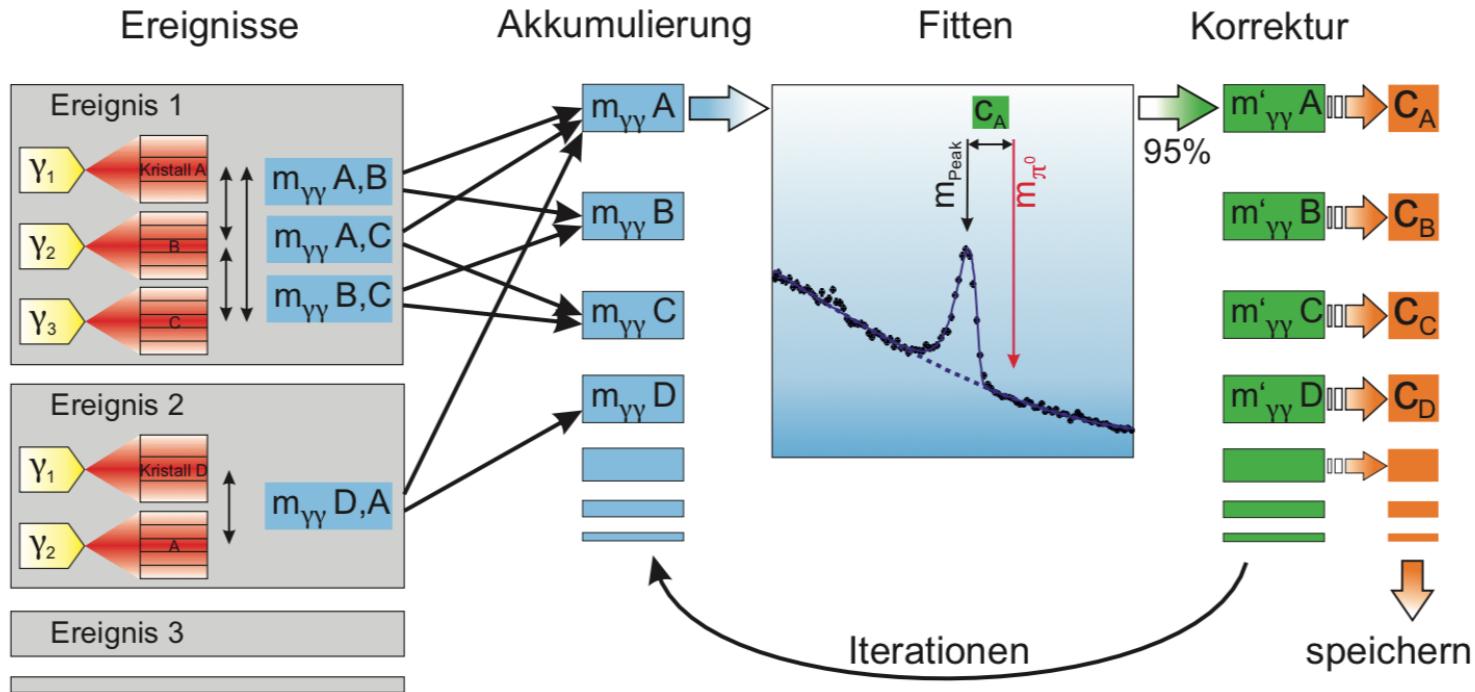
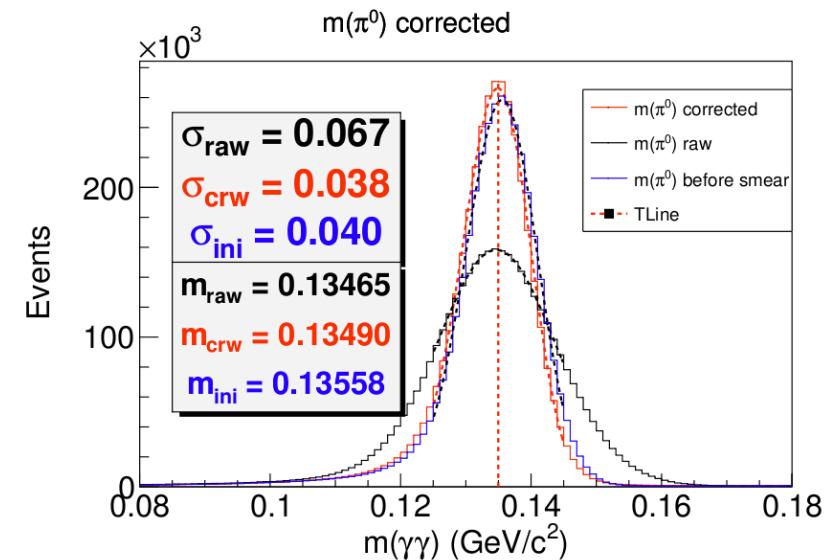
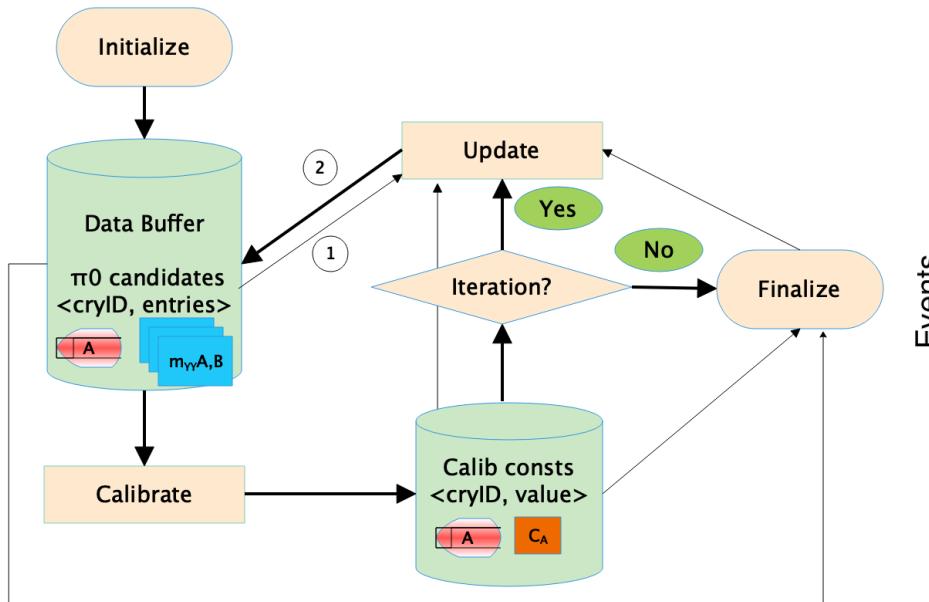


Abbildung 6.1: Schematische Darstellung des iterativen Verfahrens zur Kalibrierung des elektromagnetischen Kalorimeters.

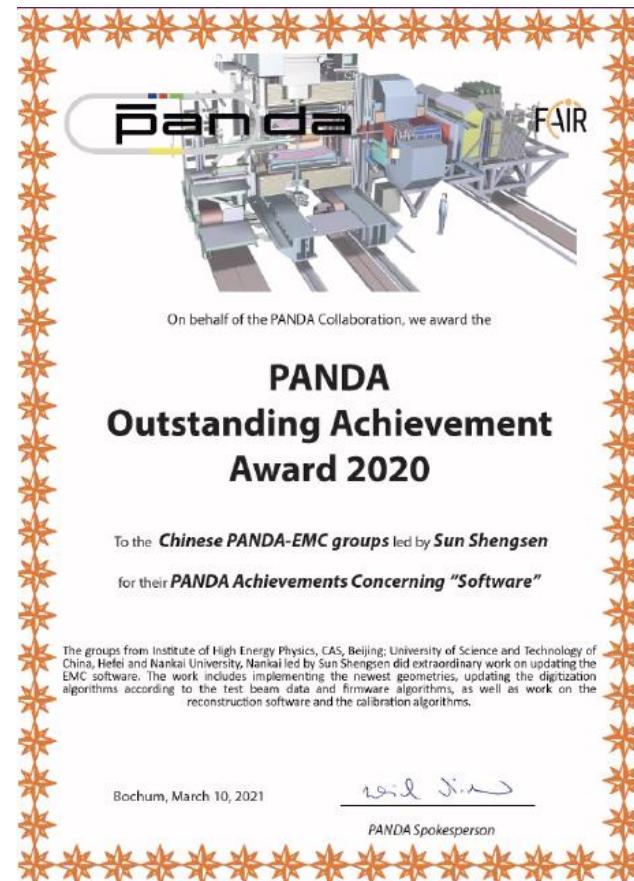
Calibration Algorithm



- Input / Output check: output consistent with input gain fluctuations
- Multi-threads implementation

Summary and Plan

- **Geometry / Digitization / Reconstruction / Calibration**
- **Extend the energy splitting algorithm from barrel to whole EMC**
- **Boundary effect is close to be solved of calibration algorithm for barrel part, and calibration algorithms for two Endcaps and Shashlyk**
- **Update and optimize reconstruction algorithm**
- **Time-based simulation**



Thank you !