



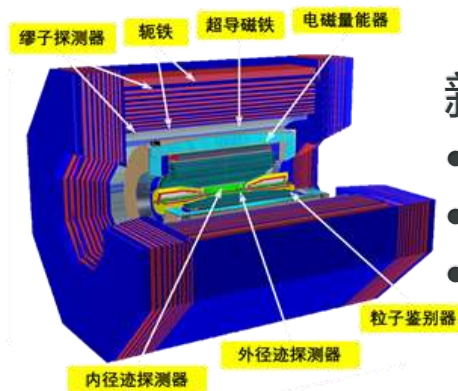
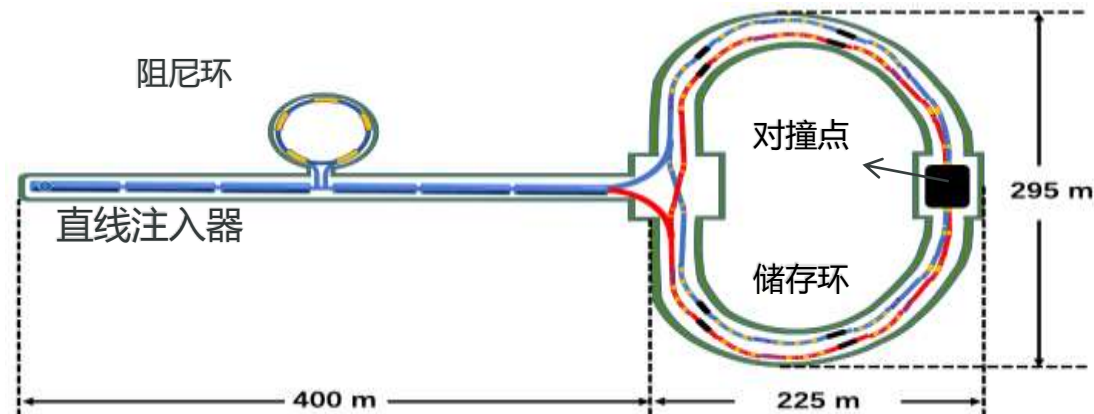
中国科学技术大学
University of Science and Technology of China

STCF径迹重建

周杭

代表STCF径迹重建软件工作组

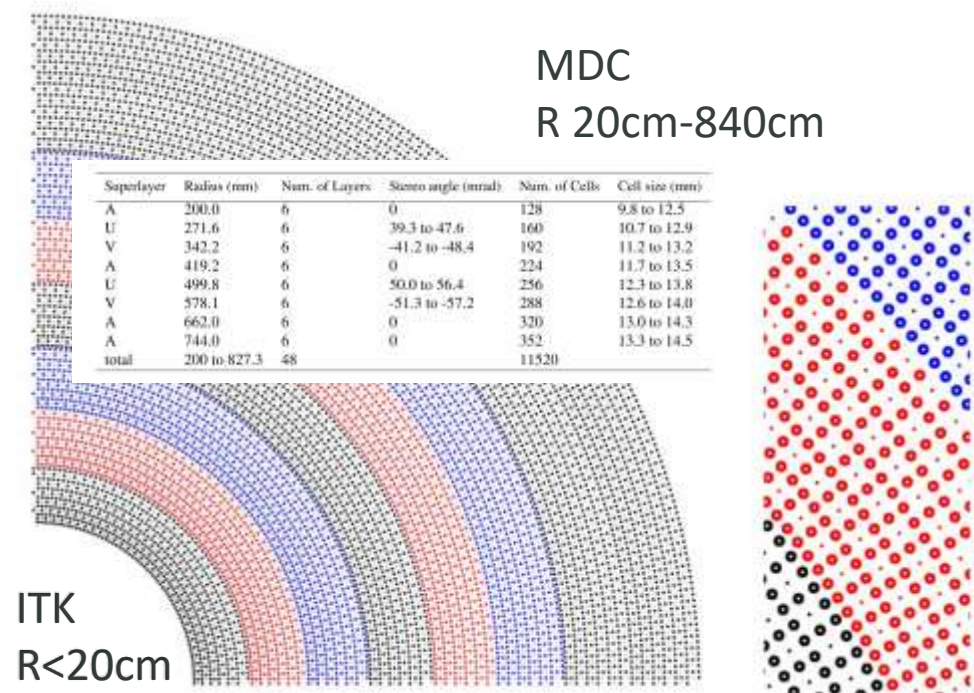
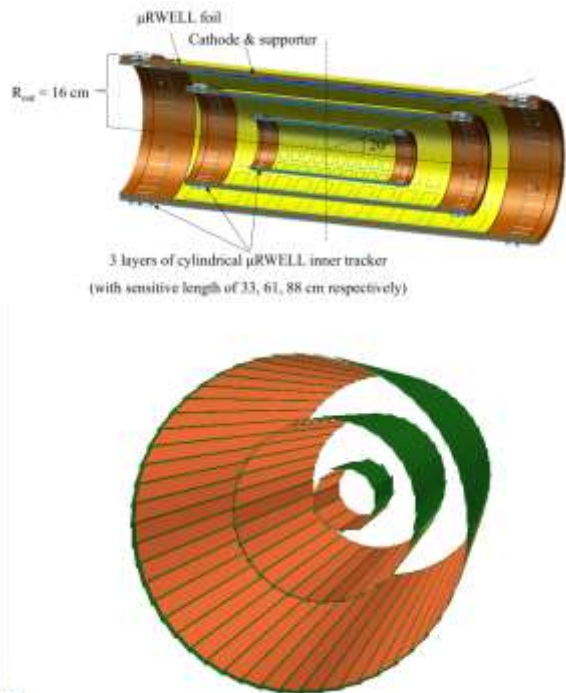
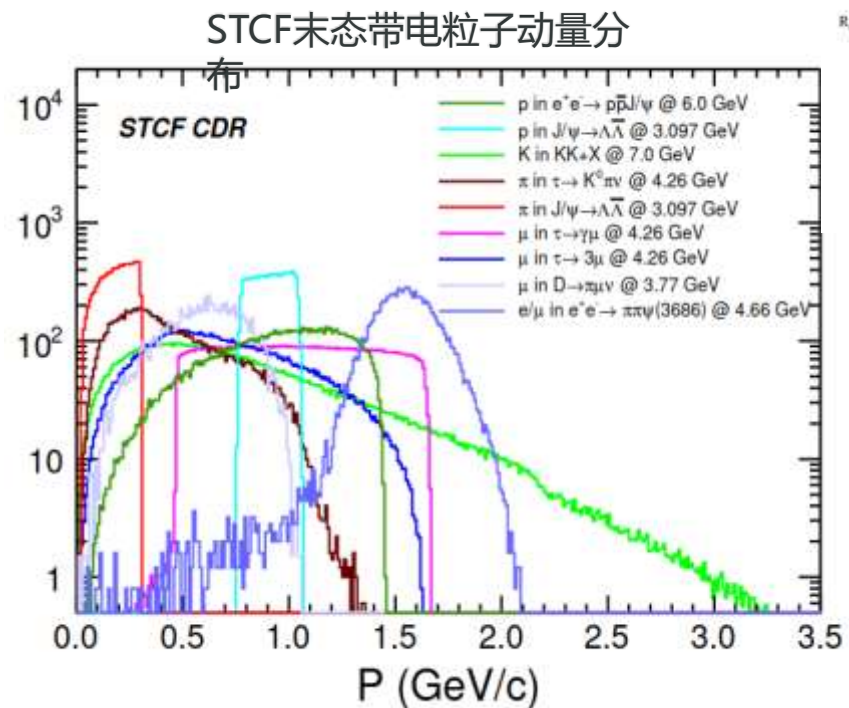
2024.05.17 郑州



新一代正负电子对撞机

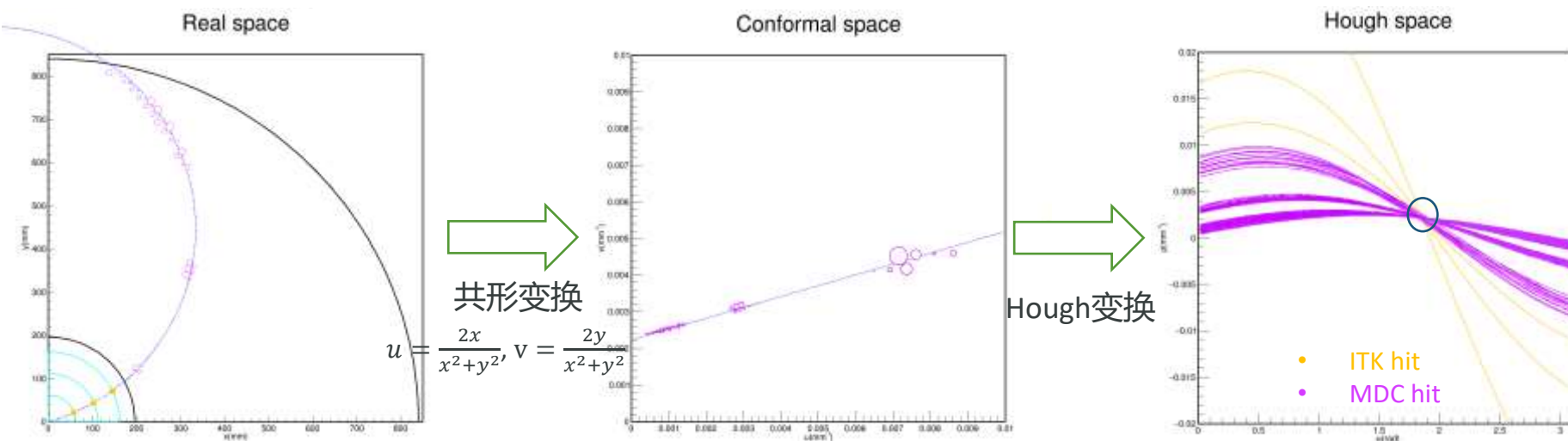
- 质心能量范围 $E_{cm} = 2-7 \text{ GeV}$
- 峰值亮度 $>0.5 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1} @4\text{GeV}$
- 保留提升亮度和实现极化束流的可能

- 量子色动力学(QCD)非微扰和微扰的过渡区域，探索 QCD 色禁闭本质的关键区域
- 丰富的共振结构，研究奇特强子态、多夸克态、胶子球及混杂态等重要平台
- 涵盖大量的强子对/轻子对的产生阈值，研究强子/轻子内部结构的独特环境



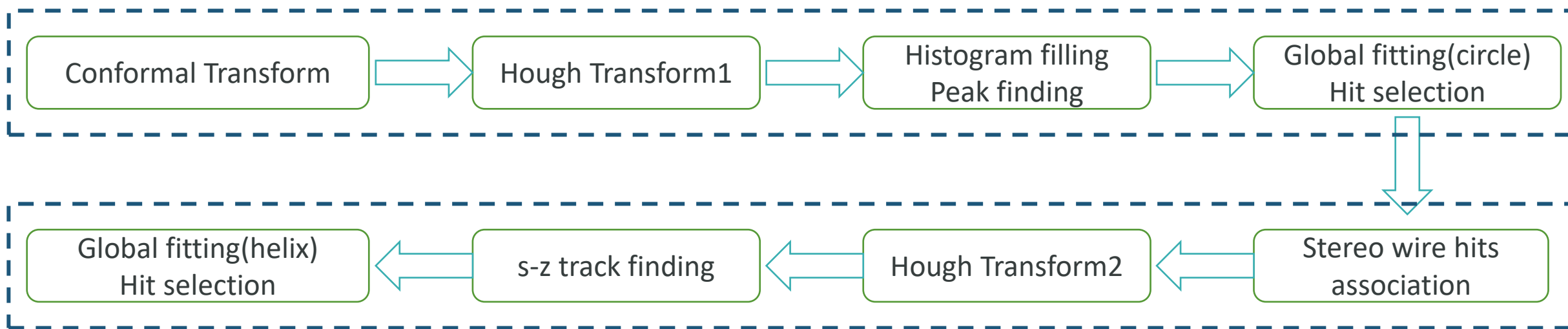
- 需要探测的带电粒子动量范围50MeV-3.5GeV

- 三层独立内径迹探测器(ITK), 单层物质质量<0.3%X₀
- 漂移室(MDC): 48层, 4个直丝超层, 4个斜丝超层
- 接收角 θ 20° -160°, 1T磁场



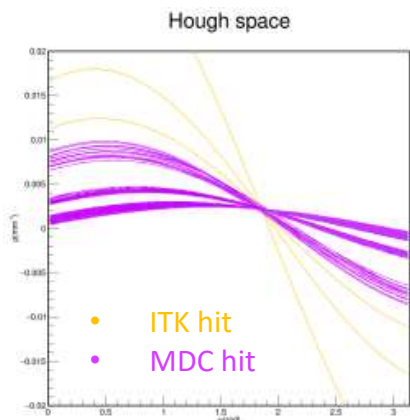
- 同时处理ITK和MDC击中
- 提供击中数更多的MDC起主导作用

2-D track finding

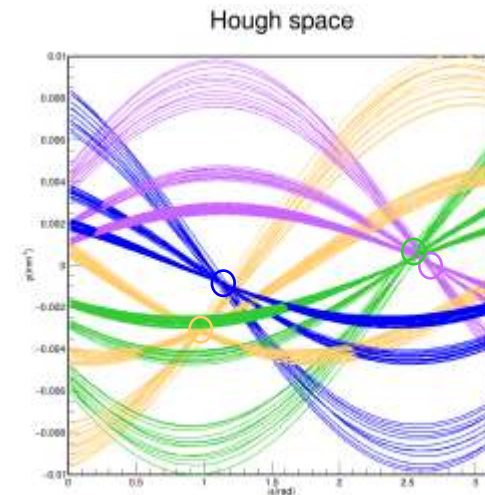
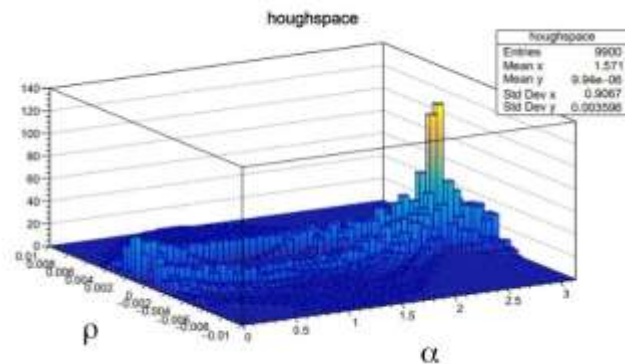


3-D track finding

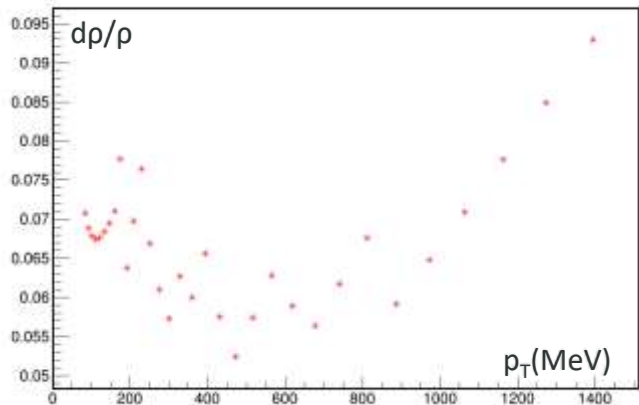
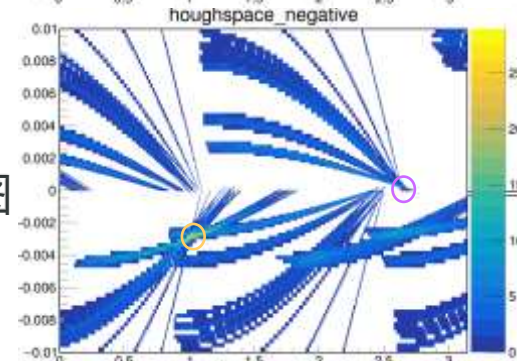
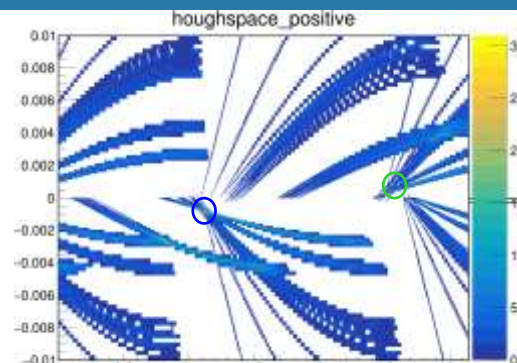
二维径迹寻找



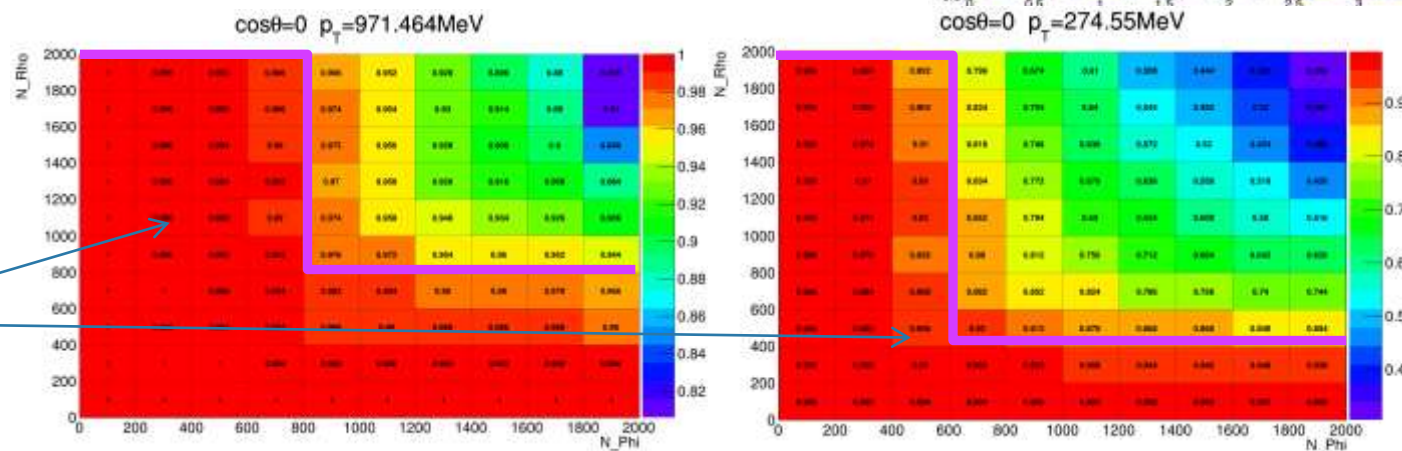
填充二维直方图, 寻找局部极值单元(peak)



依据曲线 $pdp/d\alpha$ 是否 >0 填充两个直方图
减少背对背径迹互相干扰



根据peak包含击中的效率选择bin宽
 ρ 方向非均匀分bin

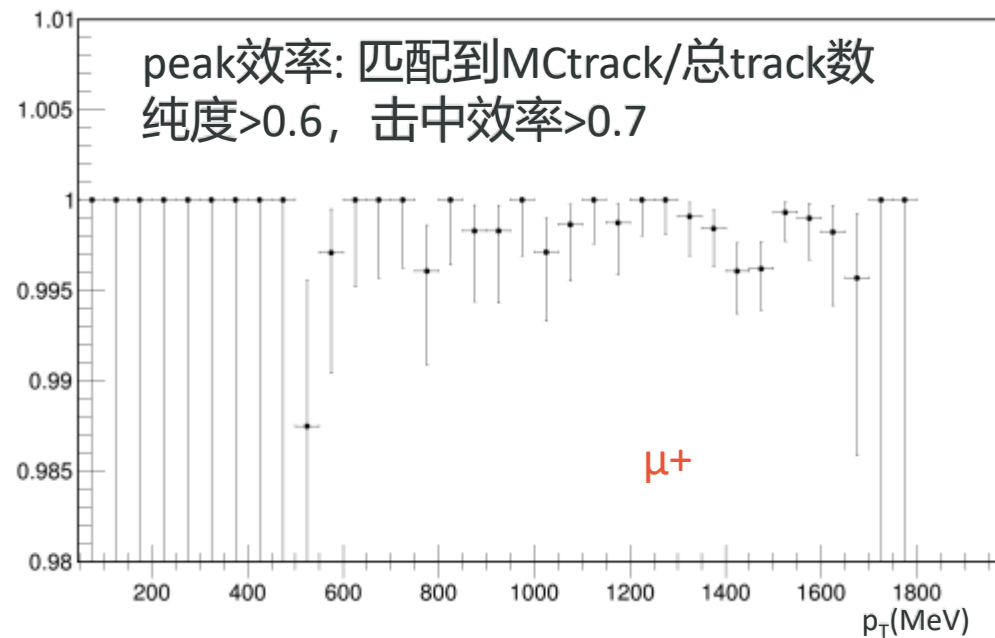


候选径迹合并/丢弃

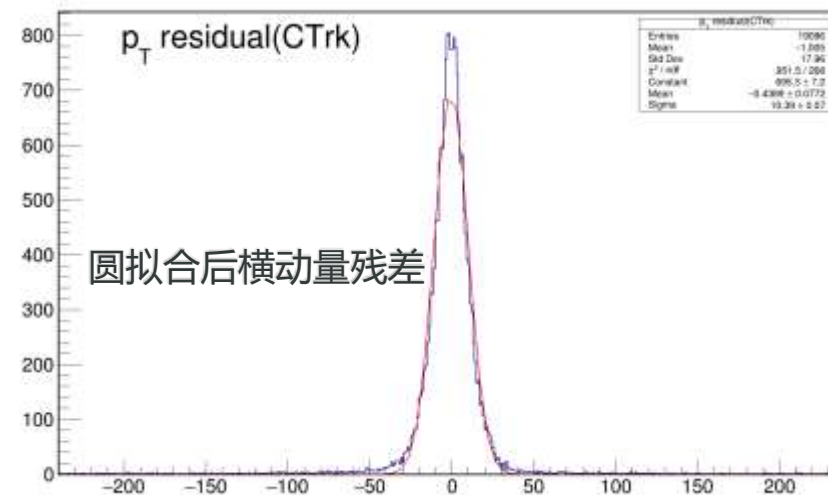
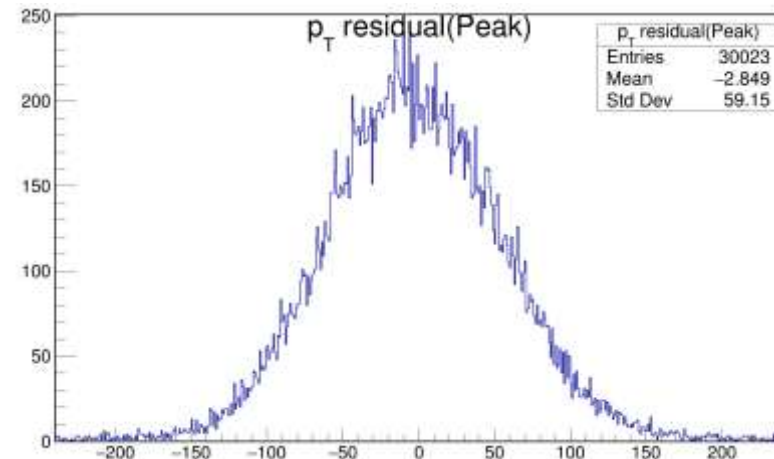
直线拟合优化参数

圆拟合

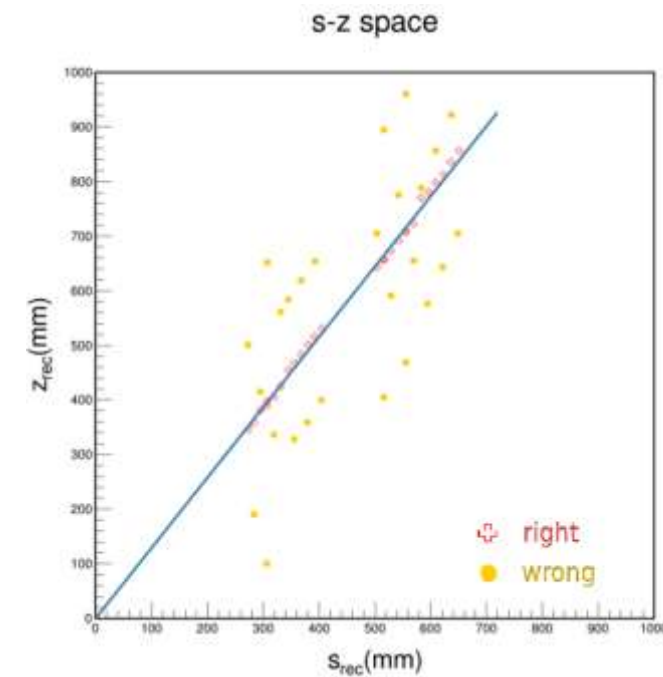
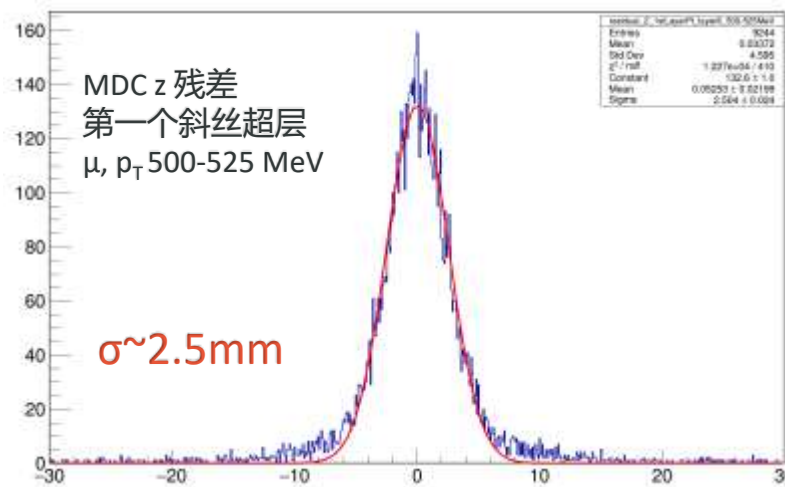
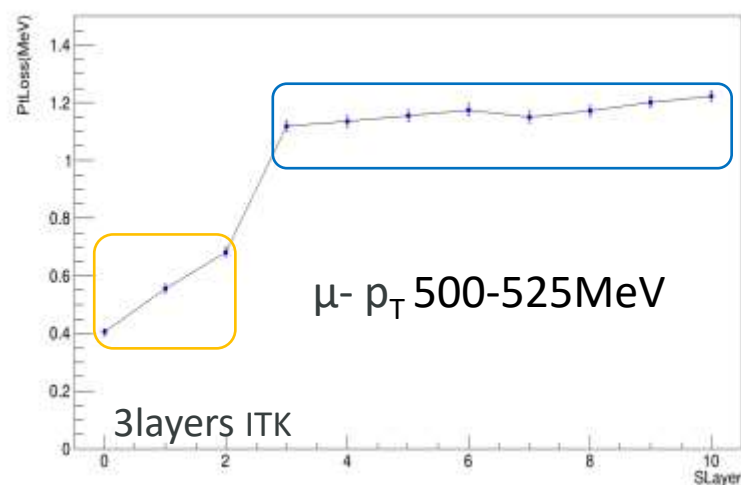
去除离径迹较远的点



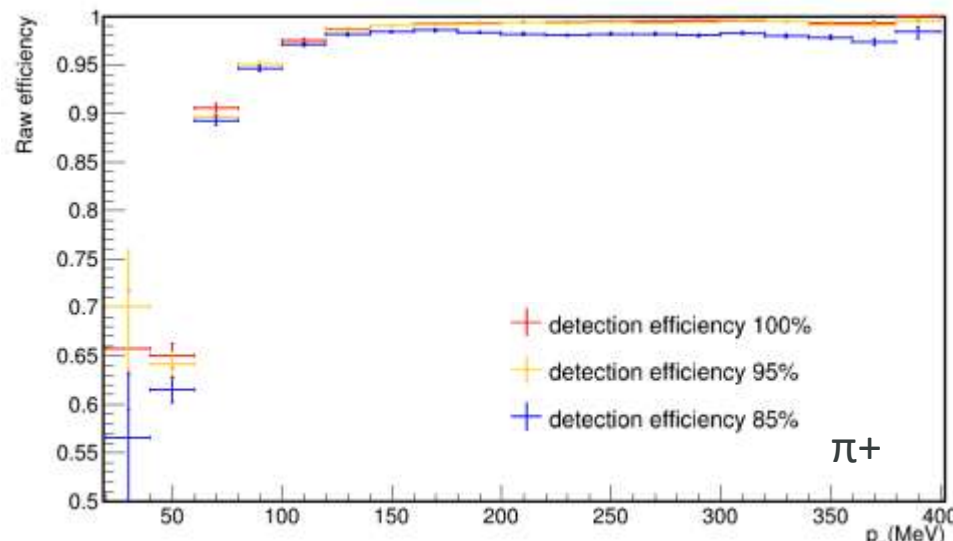
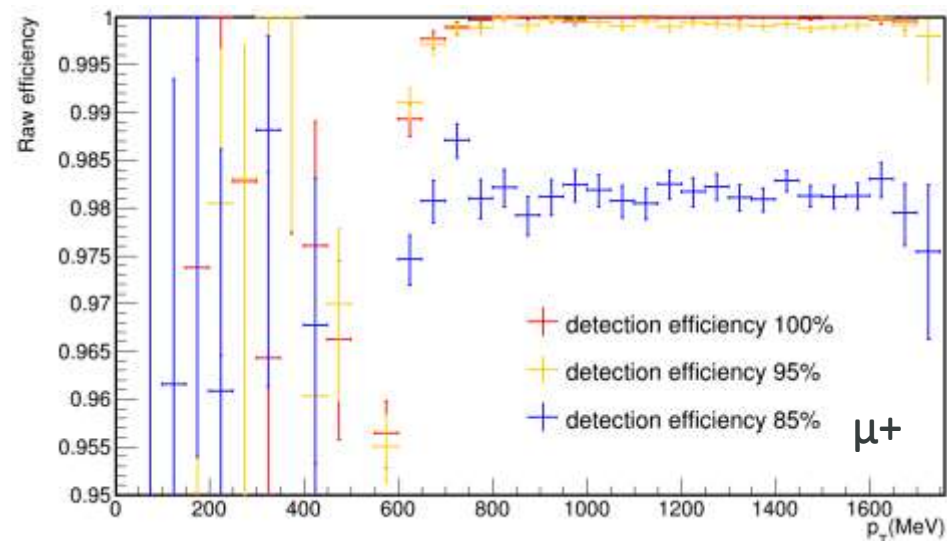
$\psi(3686) \rightarrow \pi^+\pi^- J/\psi(\mu^+\mu^-)$



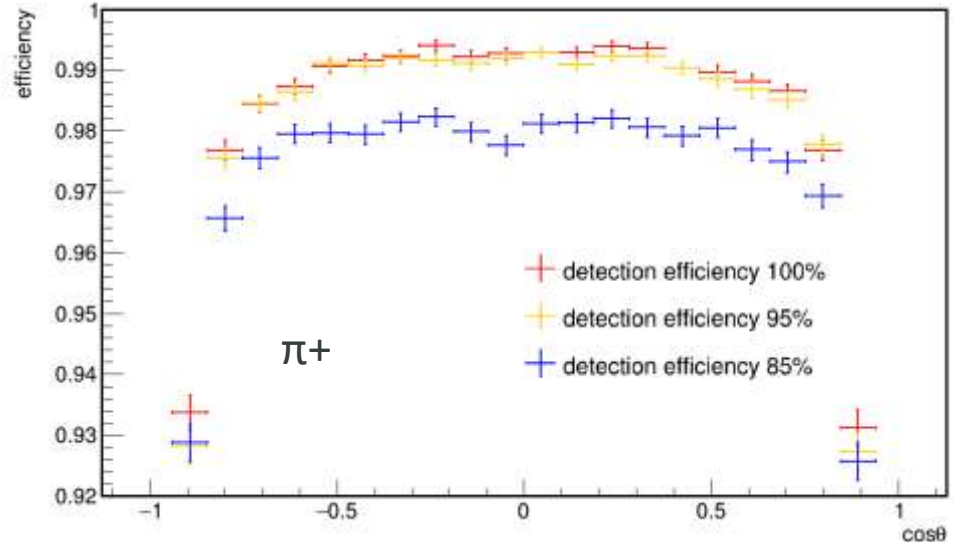
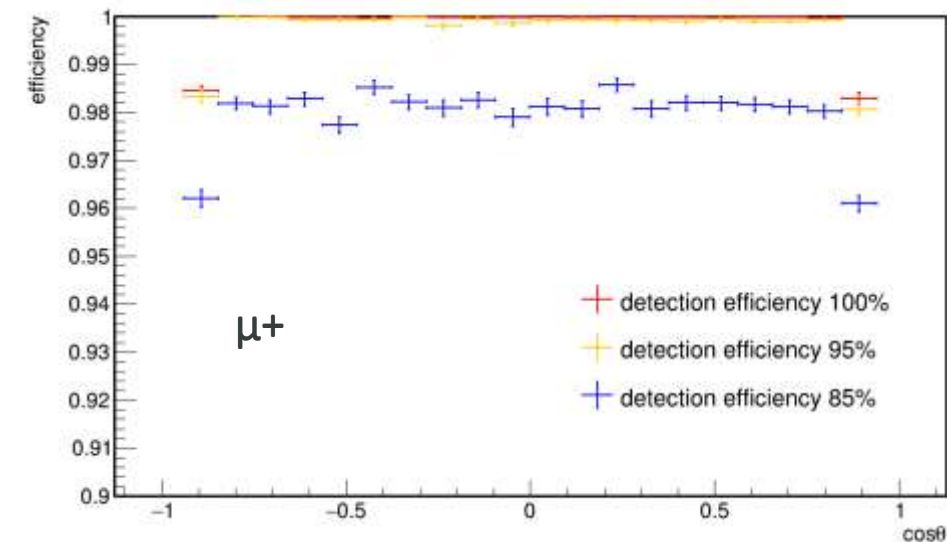
- ◆ 圆参数的准确性对计算 z 影响很大，进而影响寻迹效率
- ◆ 粒子进入漂移室前有较大能损，计算斜丝 z 时只使用MDC击中进行圆拟合
- ◆ sz 平面径迹为直线，再次使用Hough变换的方法确定参数



寻迹效率(无本底)

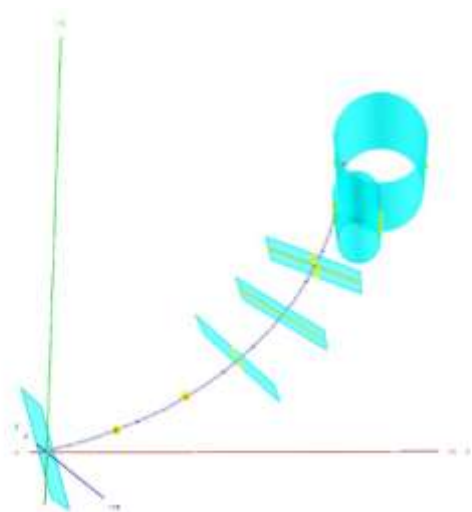


寻迹效率(不要求通过卡尔曼拟合)
粒子在探测器留下击中>5
蒙特卡动量 $20^\circ < \theta < 160^\circ$
不考虑粒子衰变

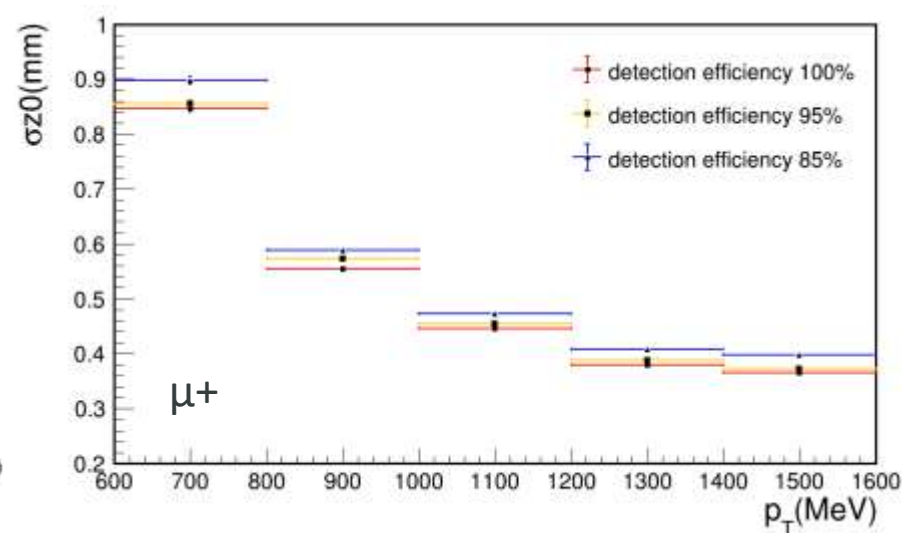
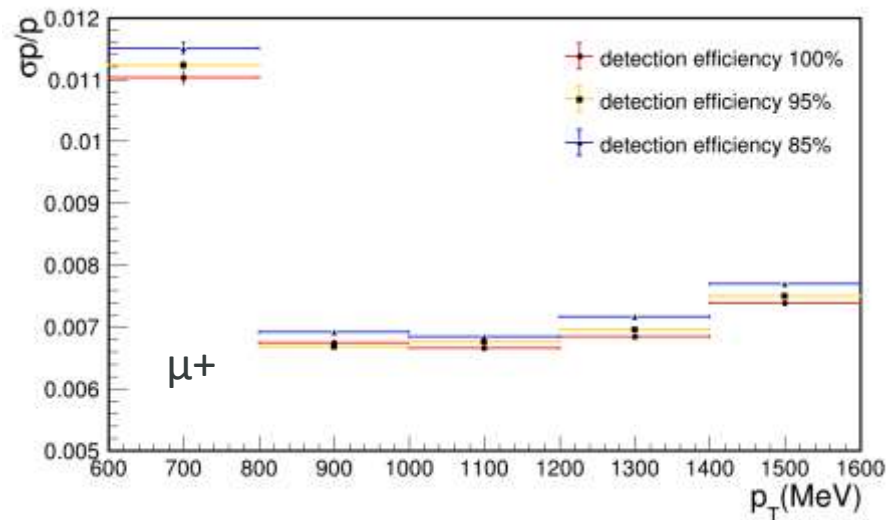
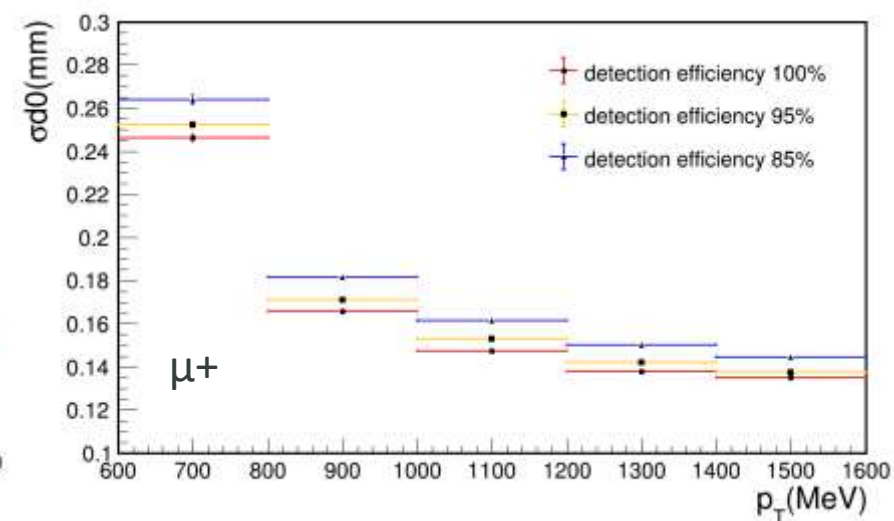
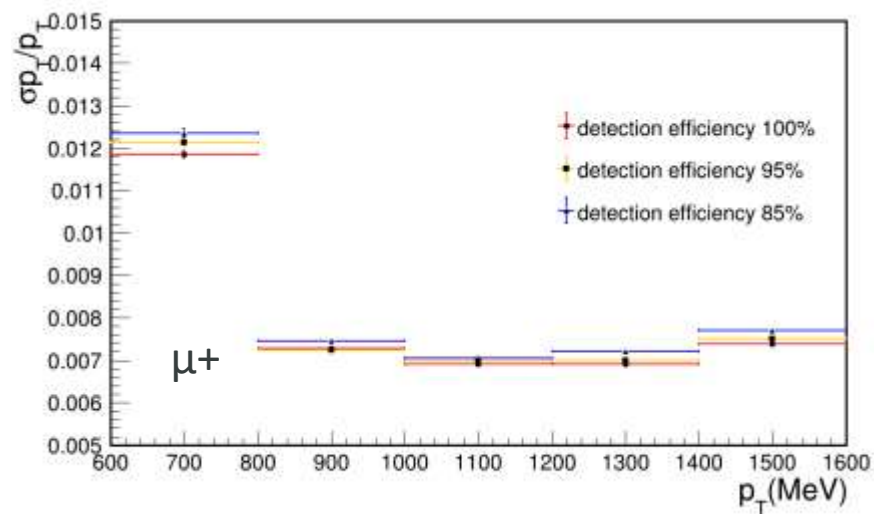


该方法对探测器探测效率敏感度较低
假定探测效率85%的情况下
仍有较高寻迹效率

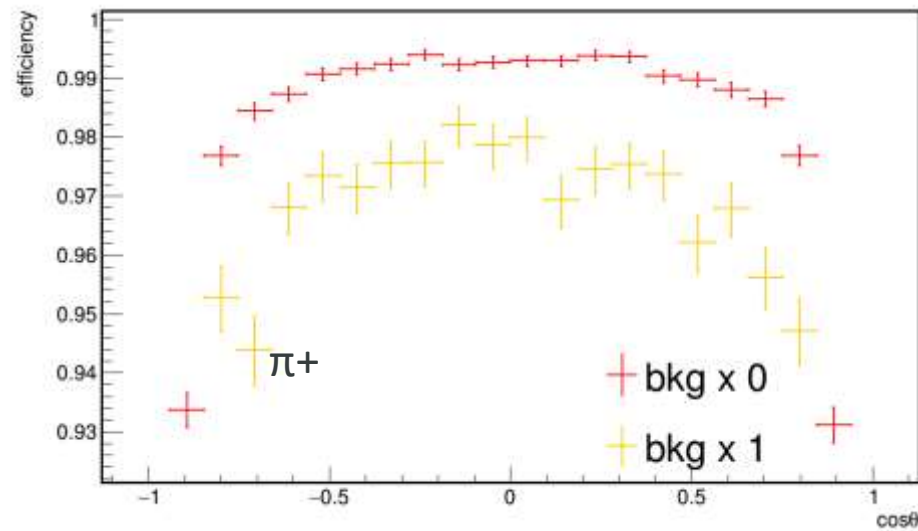
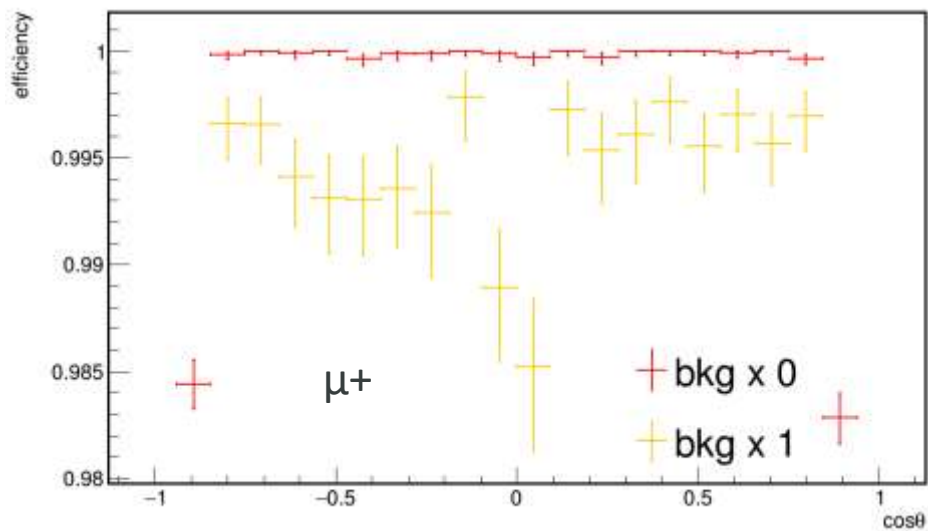
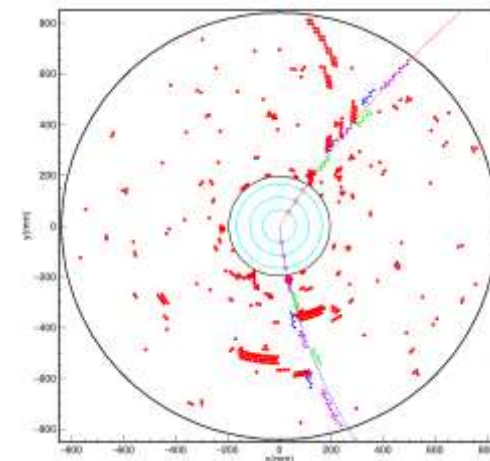
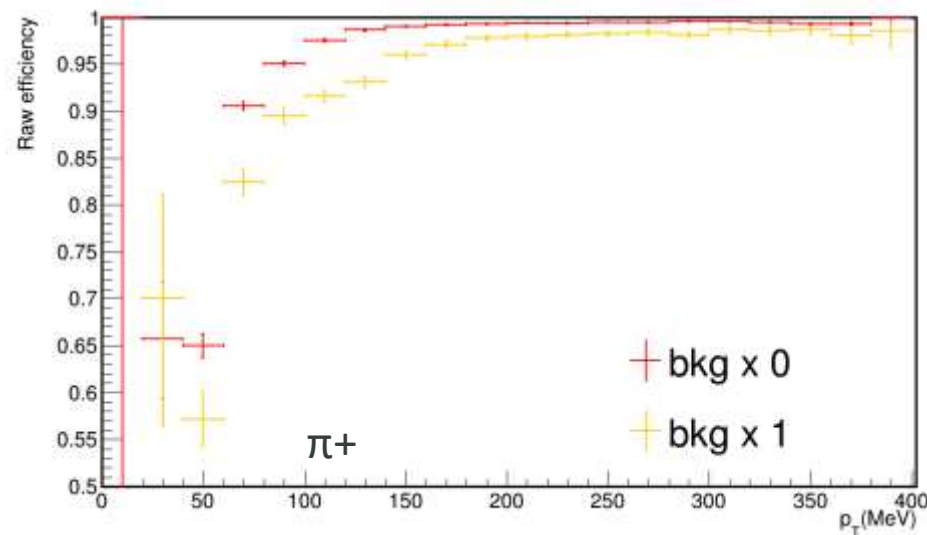
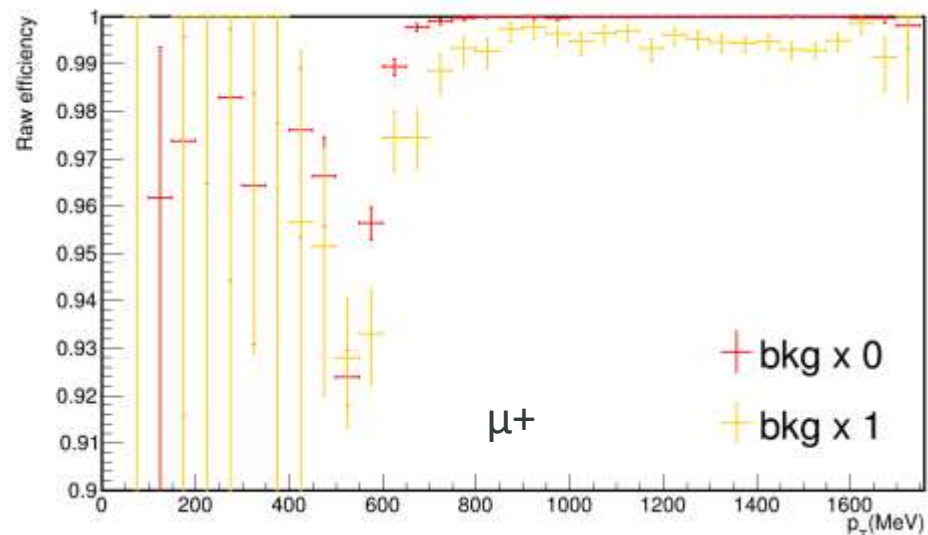
$$\psi(3686) \rightarrow \pi^+\pi^-\ J/\psi(\mu^+\mu^-)$$



使用Genfit2进行径迹拟合(DAF)



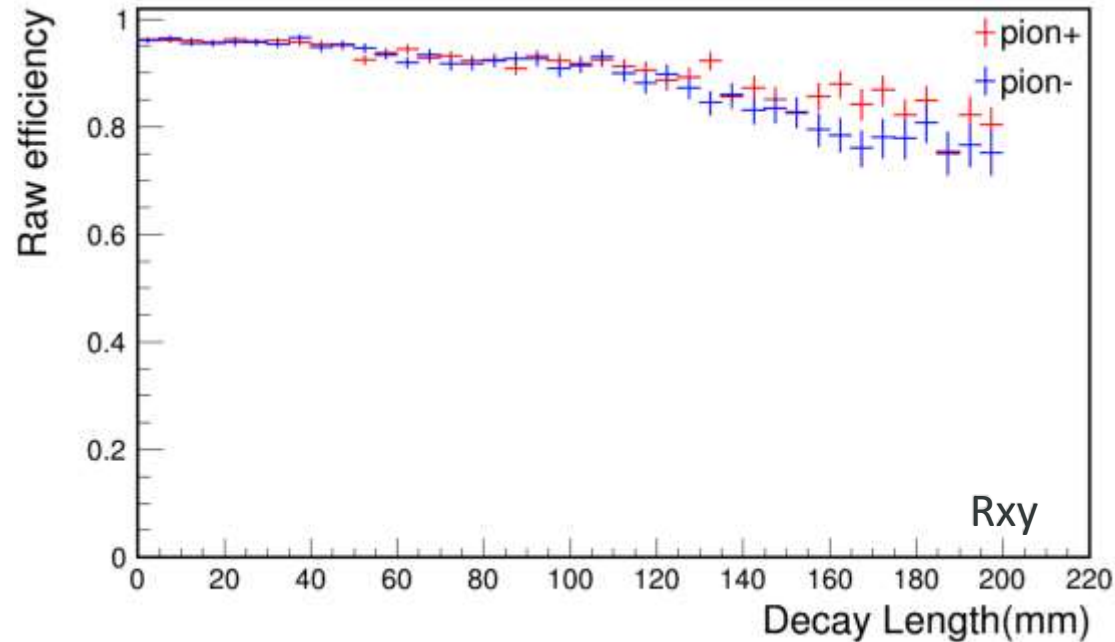
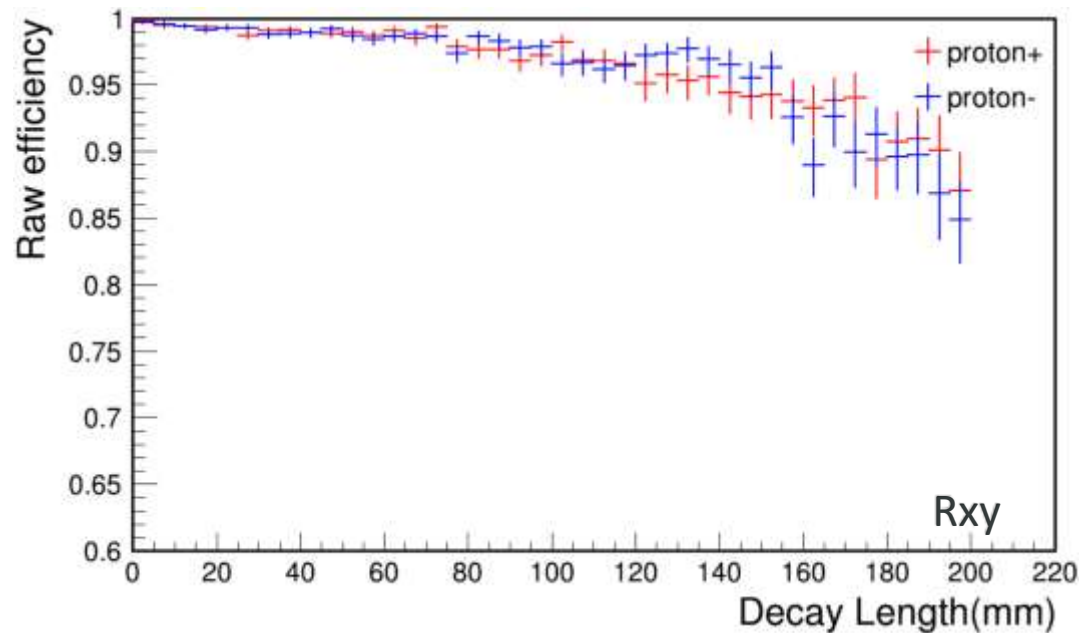
$\psi(3686) \rightarrow \pi^+\pi^- J/\psi(\mu^+\mu^-)$



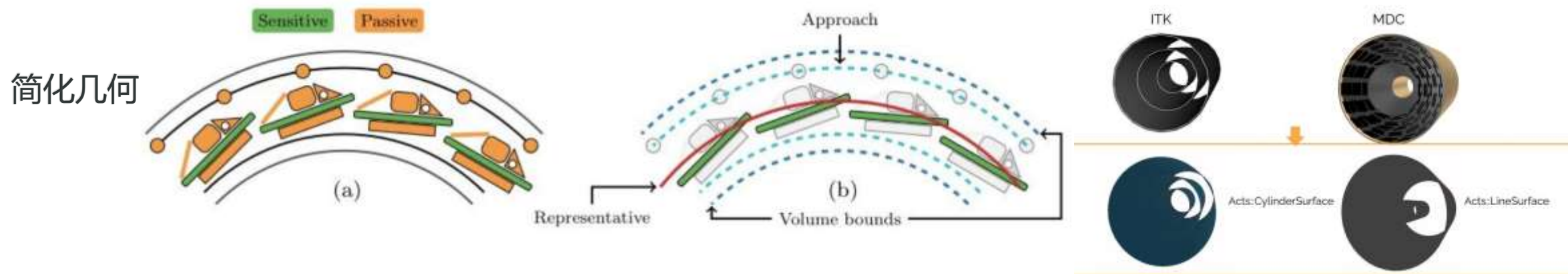
混入本底

- ◆ 1倍本底600ns窗~340Hit
- ◆ 径迹参数分辨下降
- ◆ 有较多的假径迹

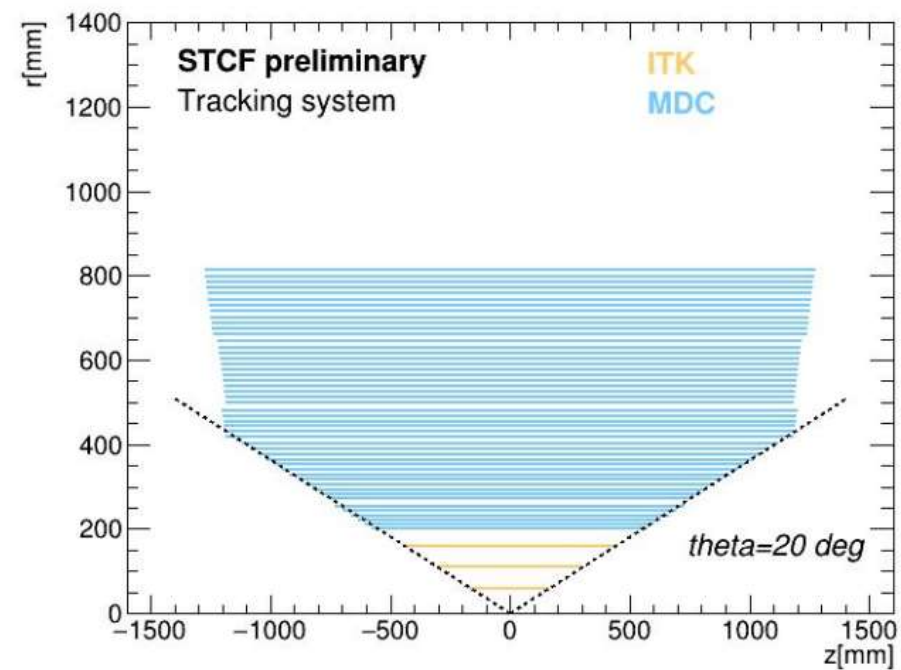
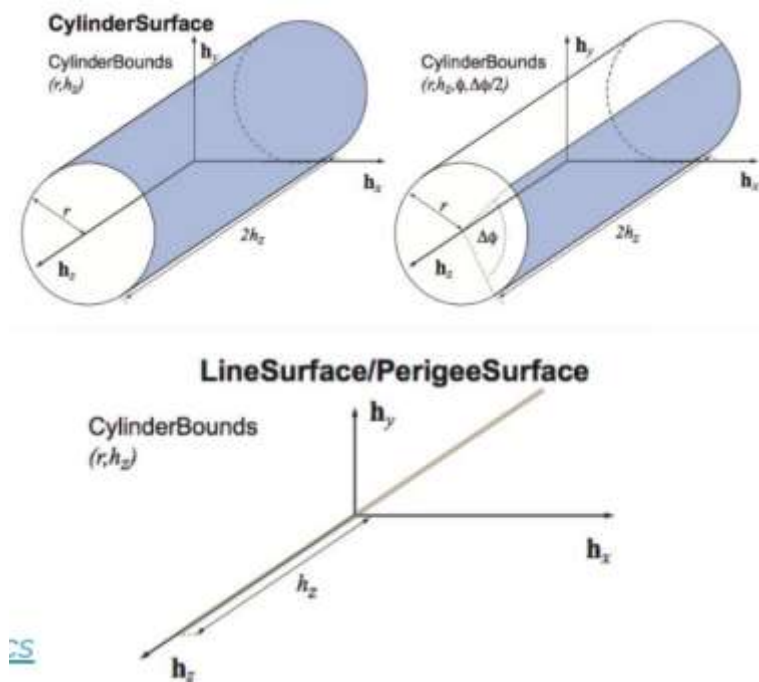
$$\psi(3686) \rightarrow \pi^+\pi^- J/\psi(\mu^+\mu^-)$$



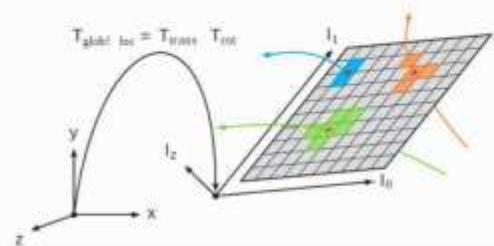
大多数次级顶点的track经过共形变换仍然是近似直线



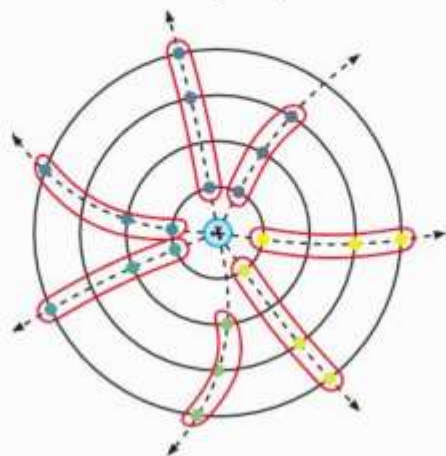
构建测量平面
ITK Cylinder/Disc
MDC Line



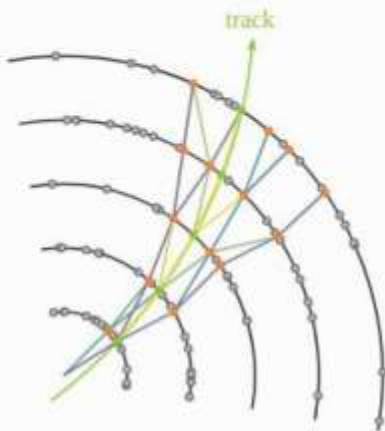
space point making
(ITk local coordinates → 3D global coordinates)



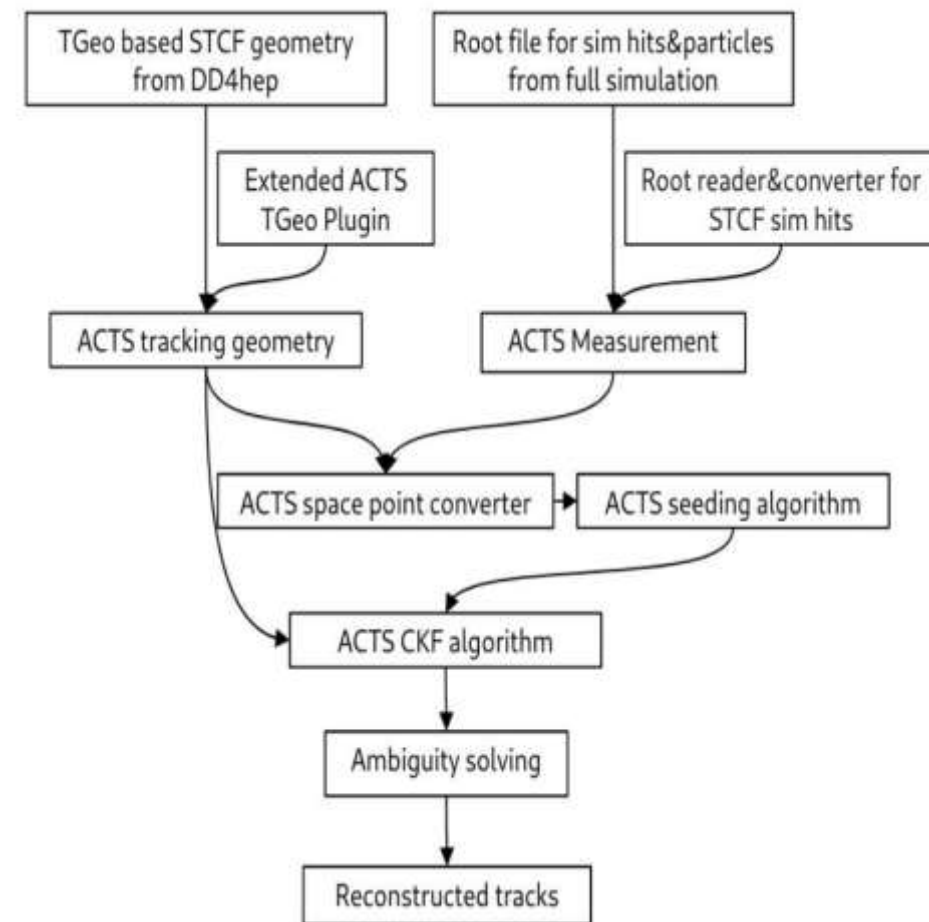
Seeding
(find seeds using hits on ITk layers)



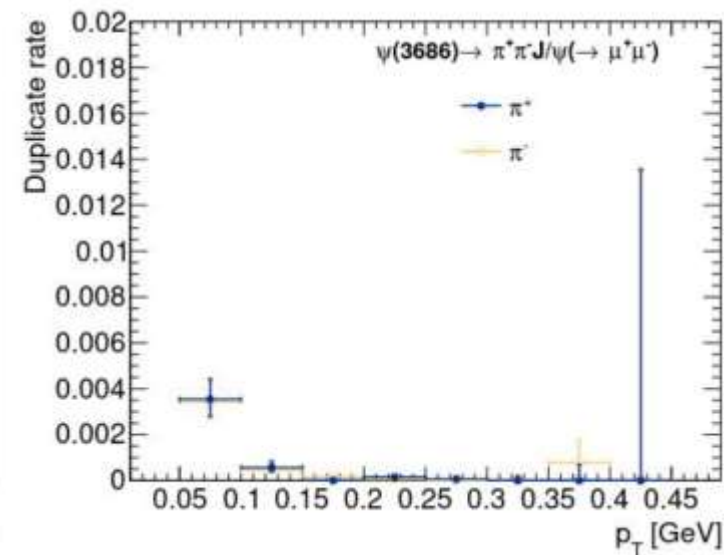
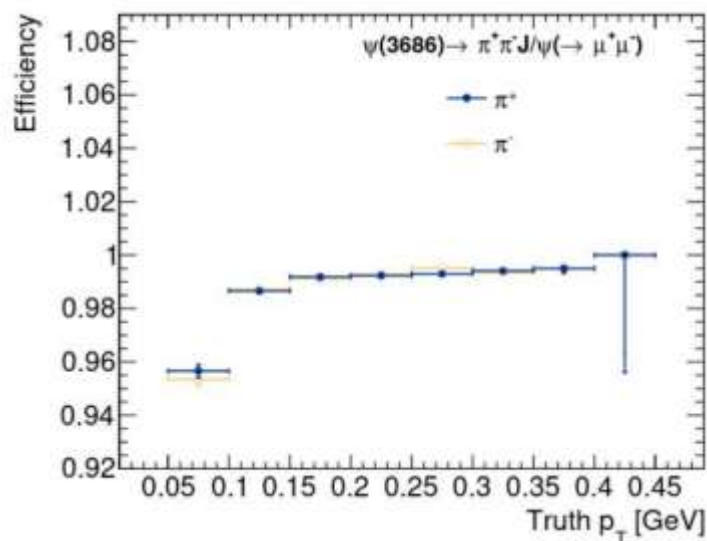
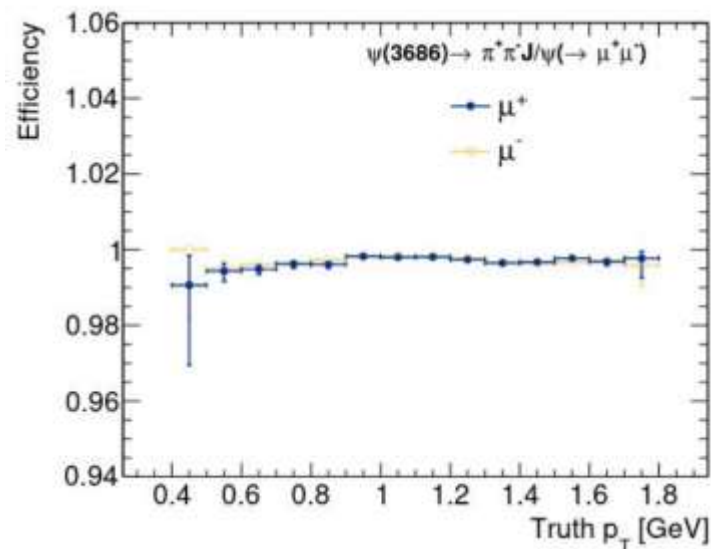
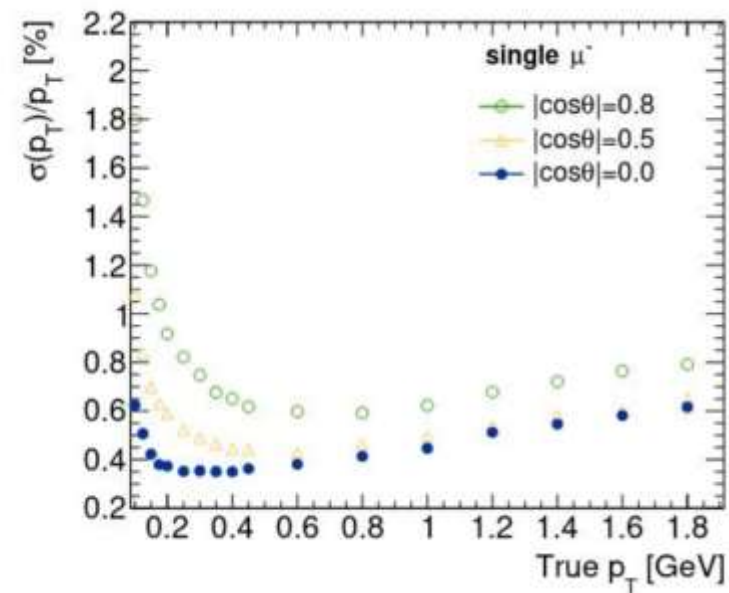
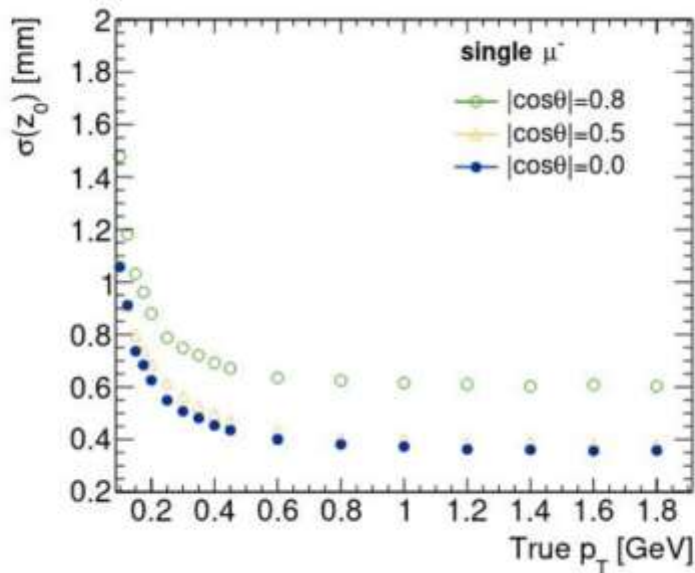
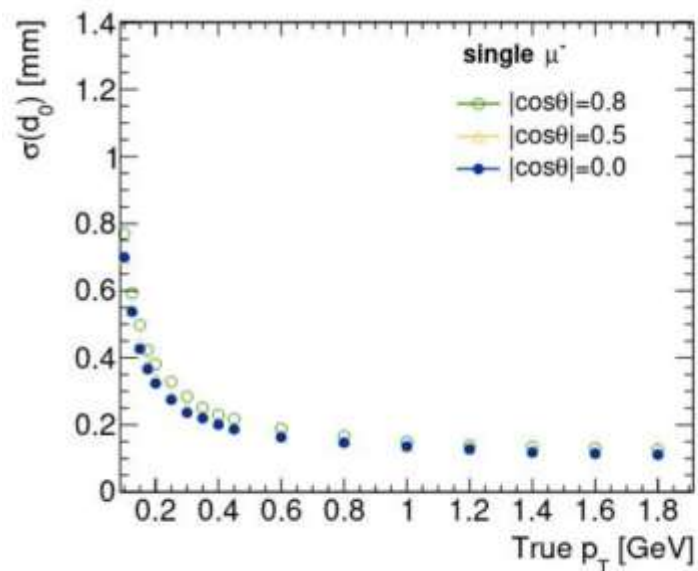
Combinatorial Kalman Filter (CKF)
(simultaneous track fitting + finding)



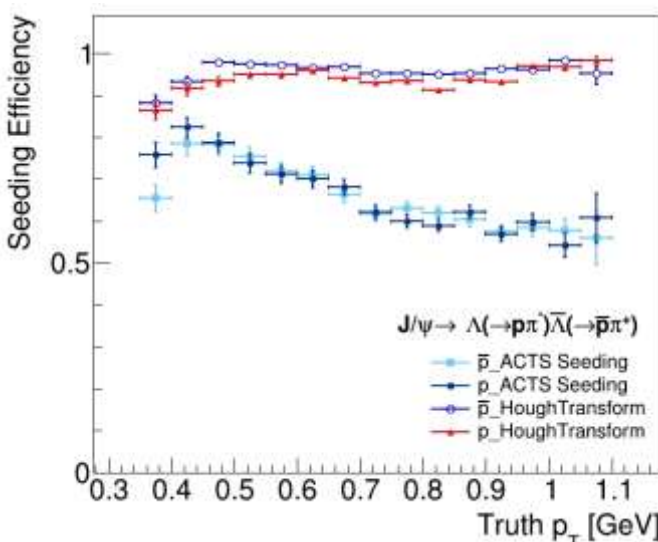
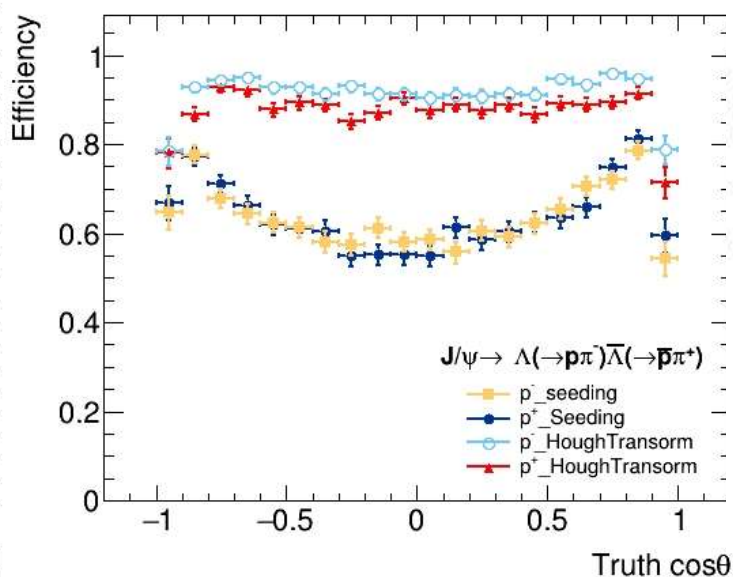
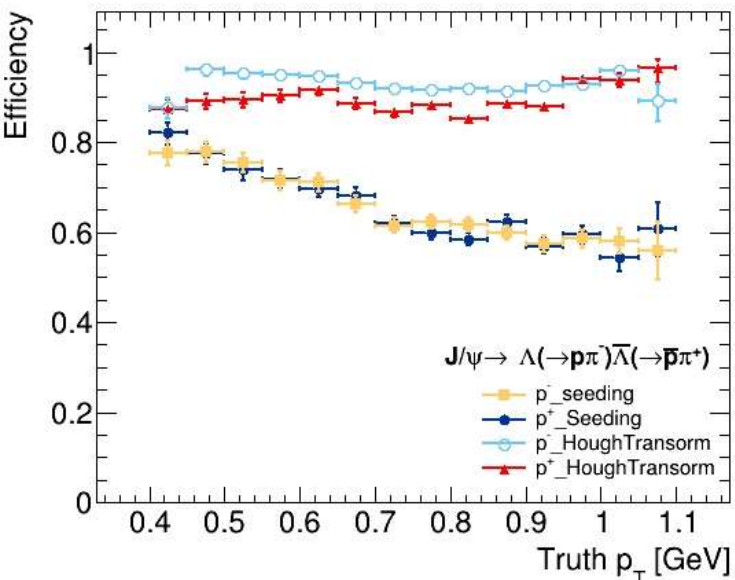
ACTS寻径流程



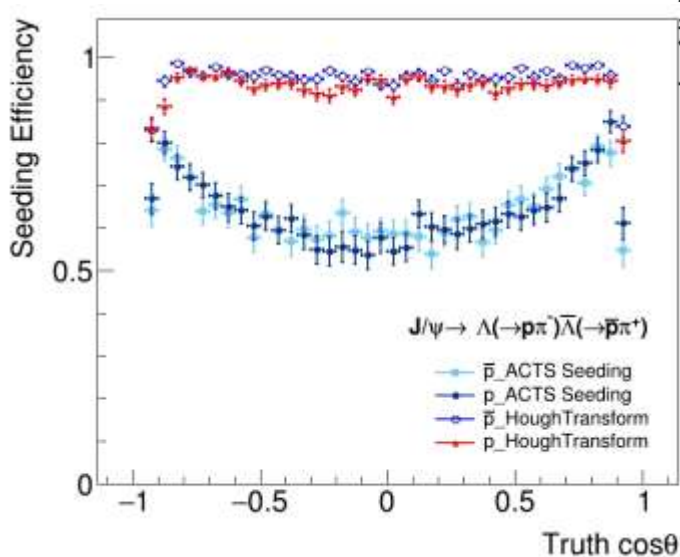
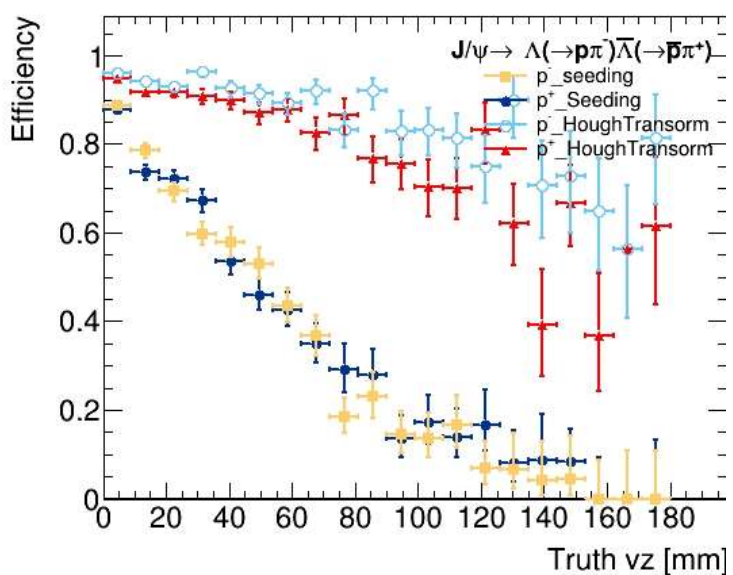
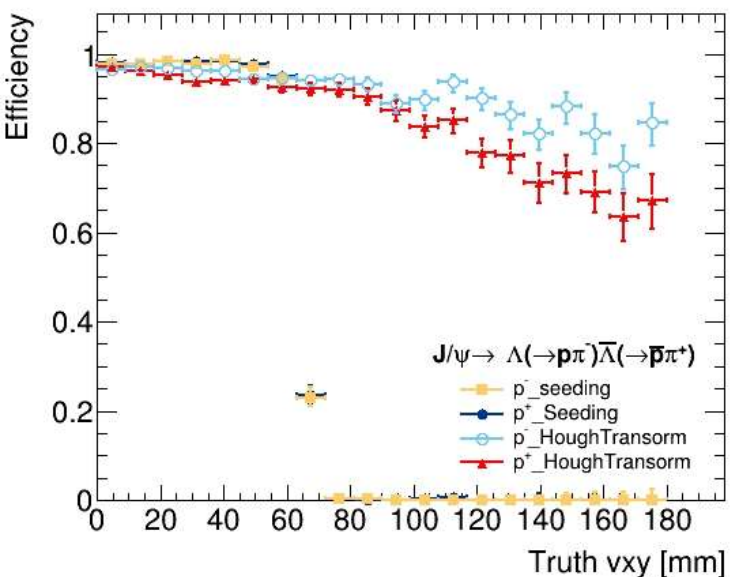
读取STCF几何和模拟数据，使用ACTS寻迹 (STCF软件框架外完成)



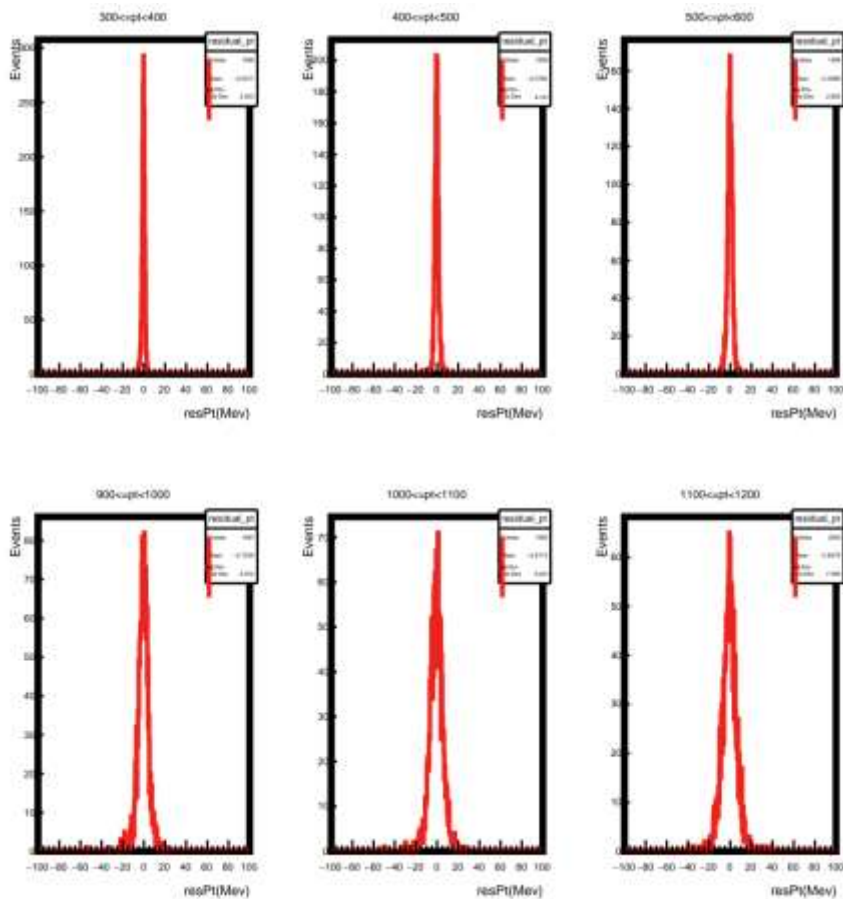
ACTS与STCF霍夫寻迹结合



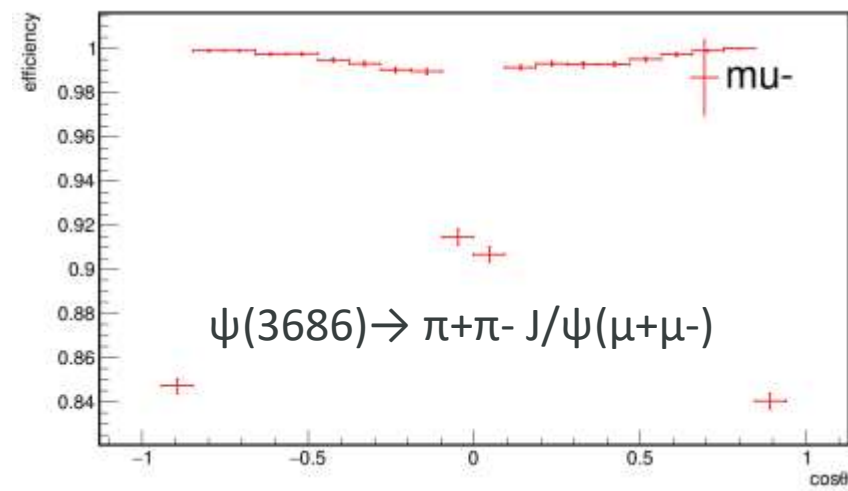
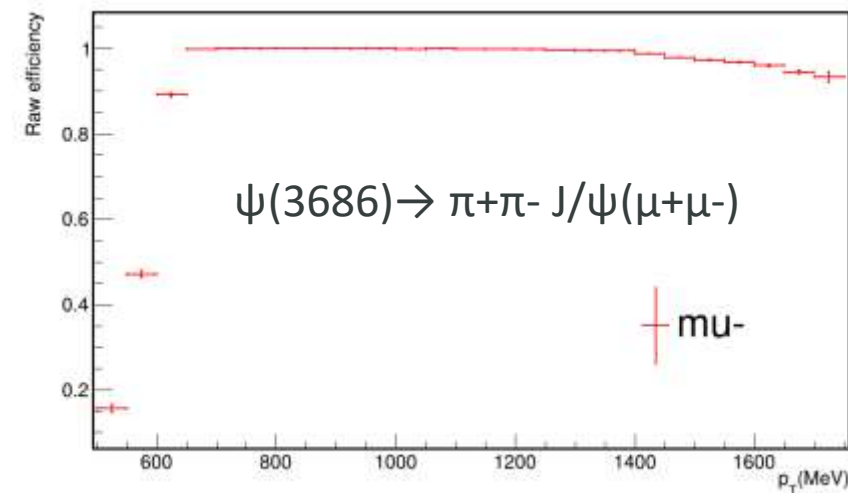
STCF ITK只有三层，如果衰变顶点 $R > R_{itk1}$ ，ACTS seeding算法失效，利用STCF Hough算法寻找种子



- ◆ ACTS依赖的软件所需版本较新，目前标准版本OSCAR外部库不支持安装
- ◆ 更新依赖后将ACTS作为外部库安装
- ◆ 编写OSCAR风格软件包，调用ACTS功能模块
- ◆ 实现利用ACTS在OSCAR进行径迹拟合和寻迹

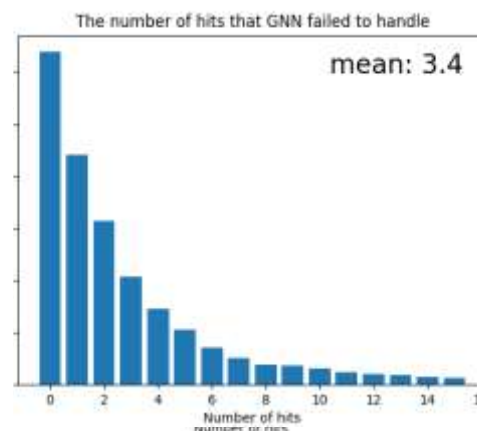
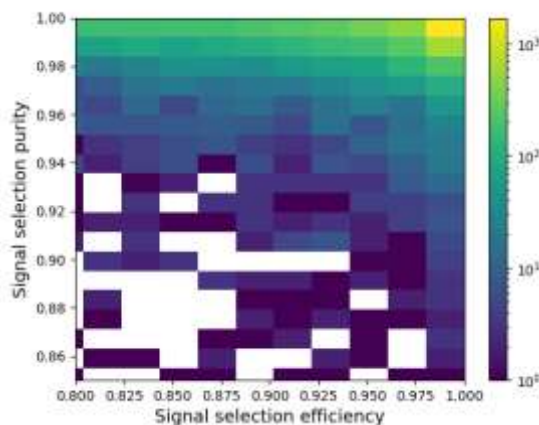
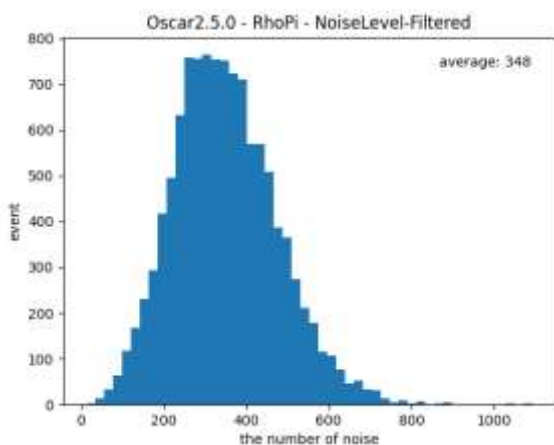
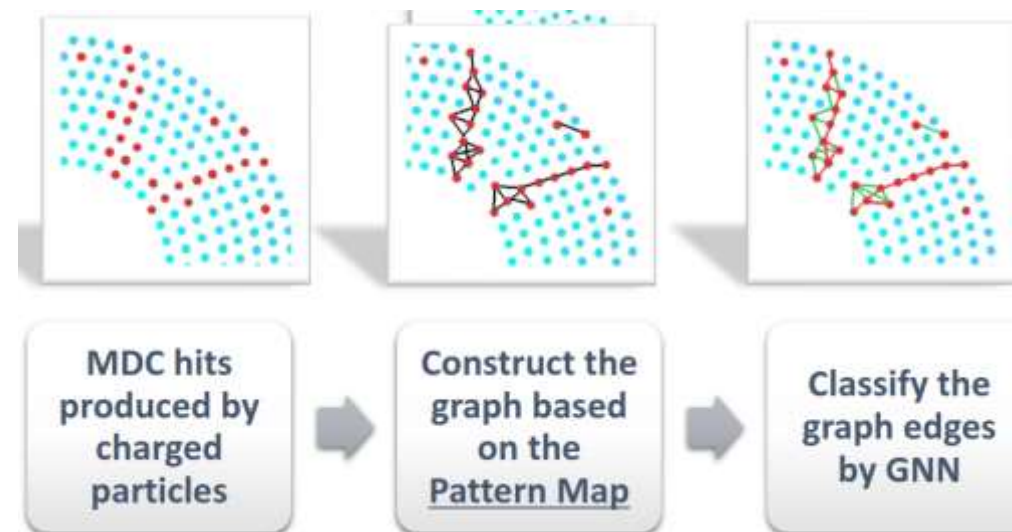


初步寻迹结果



◆ Graph Neural Network edge classifier

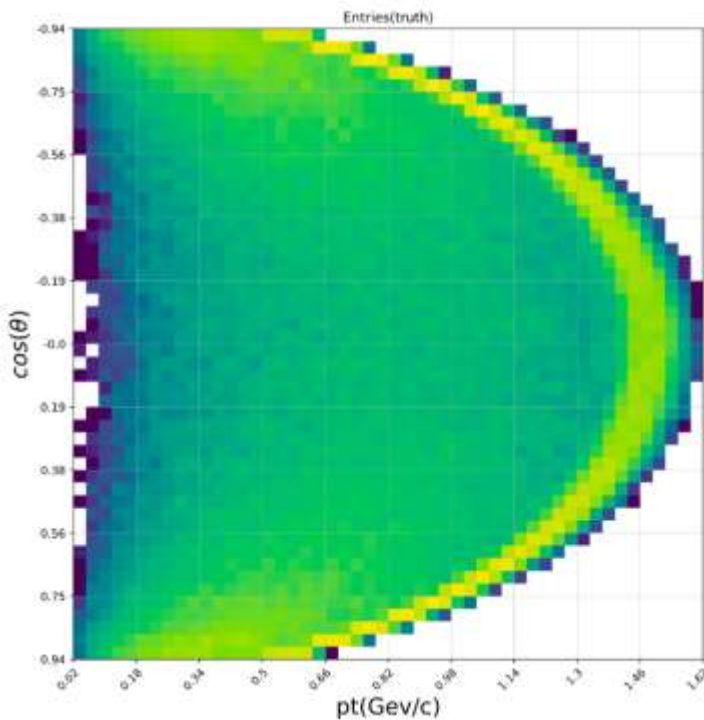
- Nodes \rightarrow Hits, edges \rightarrow track segments
- Model structure: input network, node network, edge network
- Input: node features(drift distance, coordinate of signal wires)
- Output: hits classification and edge score,
- Selecting hits depending on score



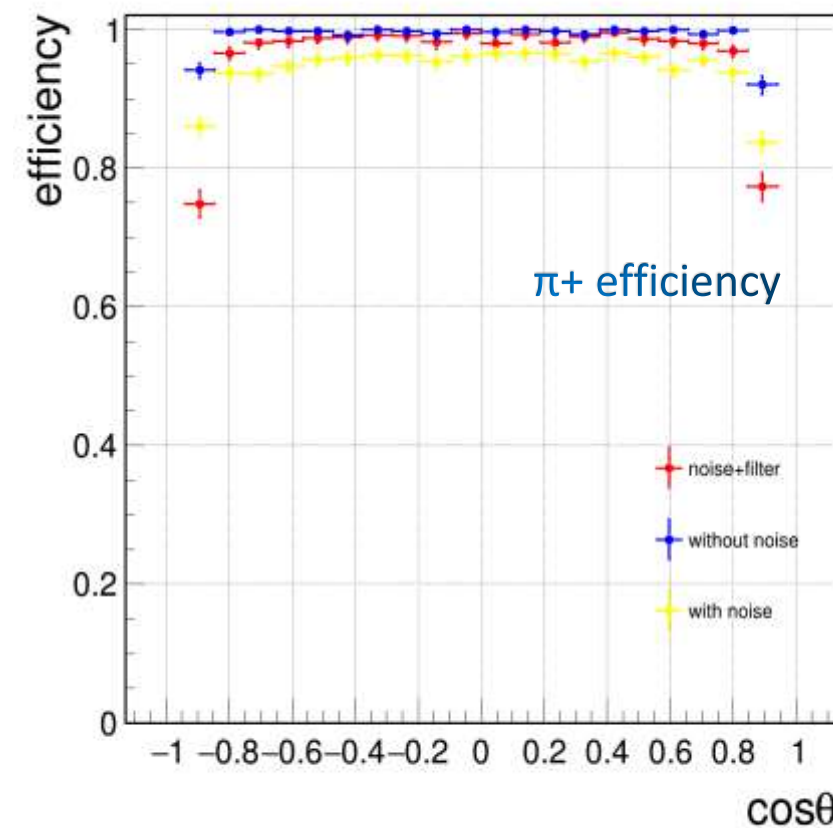
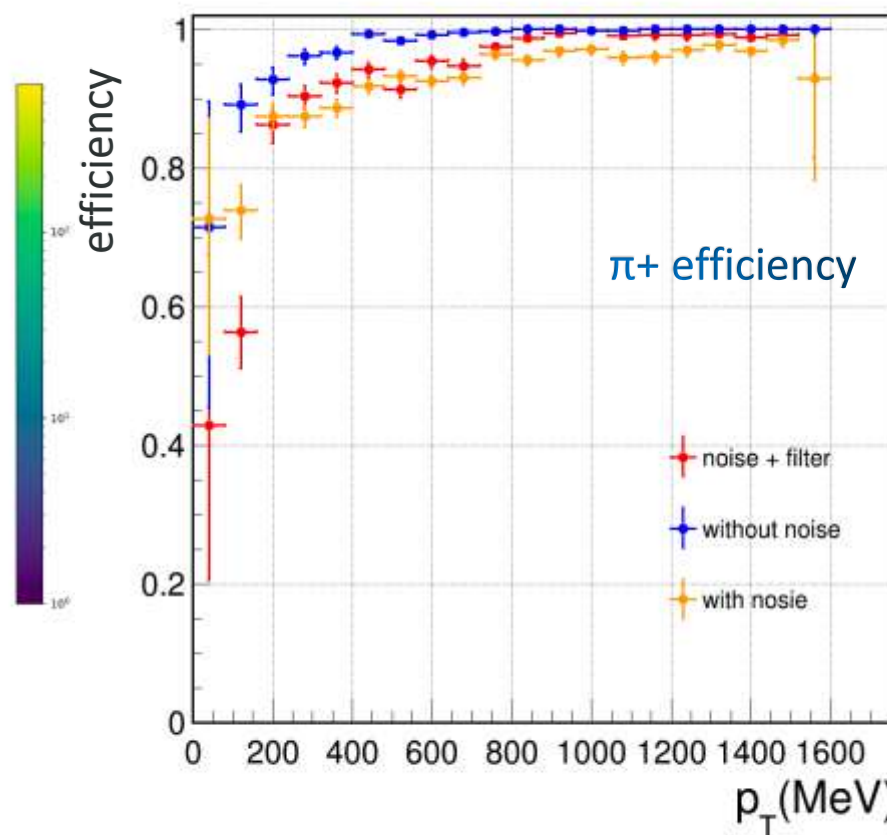
Signal selection performance

- Selection Efficiency : 91.7%
- Selection Purity : 97.0%
- Remove noises rate: 99.0%

Simulated $J/\psi \rightarrow \rho \pi \rightarrow \gamma \pi^+ \pi^-$ events, noise hits of ITK are not added (early result)



truth p_T - $\cos\theta$ distribution of π



- ◆ At large $|\cos\theta|$, the tracking efficiency decreases due to less hit

基于Hough变换的全局寻迹算法

- ◆ 对于局部探测效率不敏感，探测器探测效率较低时仍有较高寻迹效率
- ◆ 容易产生假径迹和重复径迹，尤其是面对高本底时
- ◆ 速度可能较慢，与总击中数和对径迹最少击中数的要求相关
- ◆ 粒子动量较低时找到的径迹可能主体为MDC击中，漏掉ITK击中

ACTS, 种子寻找+CKF

- ◆ 对低动量径迹较友好，一定能找到ITK击中确保较好的顶点分辨
- ◆ 速度较快，假径迹和重复径迹更好控制
- ◆ 探测器局部击中缺失可能导致找到的径迹只包含一部分击中
- ◆ 可用于寻找种子探测器层数不够/探测效率下降会导致找不到种子而寻迹失败

谢谢

针对目前的本底模拟数据以及未来可能面临的更高本底，开发使用GNN的噪声过滤算法



BACK UP