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MarlinTPC:

Reconstruction Software for Time Projection Chambers

- **Introduction**
- **Current Status:**
 - Digitization/Simulation**
 - Field Distortions**
 - Reconstruction**
 - Analysis**
 - Gear**
- **Outlook**





MarlinTPC

Introduction

- MarlinTPC is a software tool for TPC studies:
 - Simulation/Digitization
 - Reconstruction
 - Analysis

1. Setup
2. Fieldcage
 - a) Drawing
 - b) Wall Structure
 - c) Wall Samples
 - d) HV Stability
 - e) Mechanical Stability
 - f) Gas Tightness
3. Field Strip Foil
 - a) Layout
 - b) Sample Foil
 - c) Field Calculations
 - i) Perfect Model
 - ii) Real Resistors
 - iii) Tilted Plates
 - iv) Displacement
- 4) Endplate
- 5) Schedule

Ralf Diener,
Hamburg University



MarlinTPC

Introduction

- MarlinTPC is a software tool for TPC studies:
 - Simulation/Digitization
 - Reconstruction
 - Analysis

 - Based on Marlin, LCIO, Gear and LCCD
 - Developed in an international effort





MarlinTPC

Introduction

- MarlinTPC is a software tool for TPC studies:
 - Simulation/Digitization
 - Reconstruction
 - Analysis
- Based on Marlin, LCIO, Gear and LCCD
- Developed in an international effort
- Highly modular and independent of specific detector, works for:
 - Prototypes and large ILC detector TPCs
 - MICROMEGAS, GEMs and Anode Wires
 - Pad and Pixel (TimePix) readout
 - ADC and TDC read-out electronics



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Simulation/Digitization

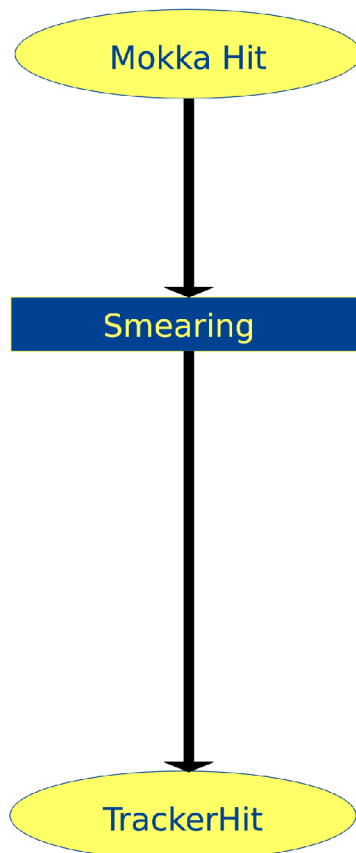
- Input:
 - Single electrons from detailed simulation (inside MarlinTPC): production, drift, amplification and pulse shaping of electronics
 - Mokka Hits:
smearing or -more detailed- electron cloud simulation
- Provides:
 - **TrackerRawData** for use in reconstruction
 - Read-out specific data
 - Event pile-up
 - Ion backdrift
 - Handling of field distortions



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Digitization: Mokka

- Not sufficient



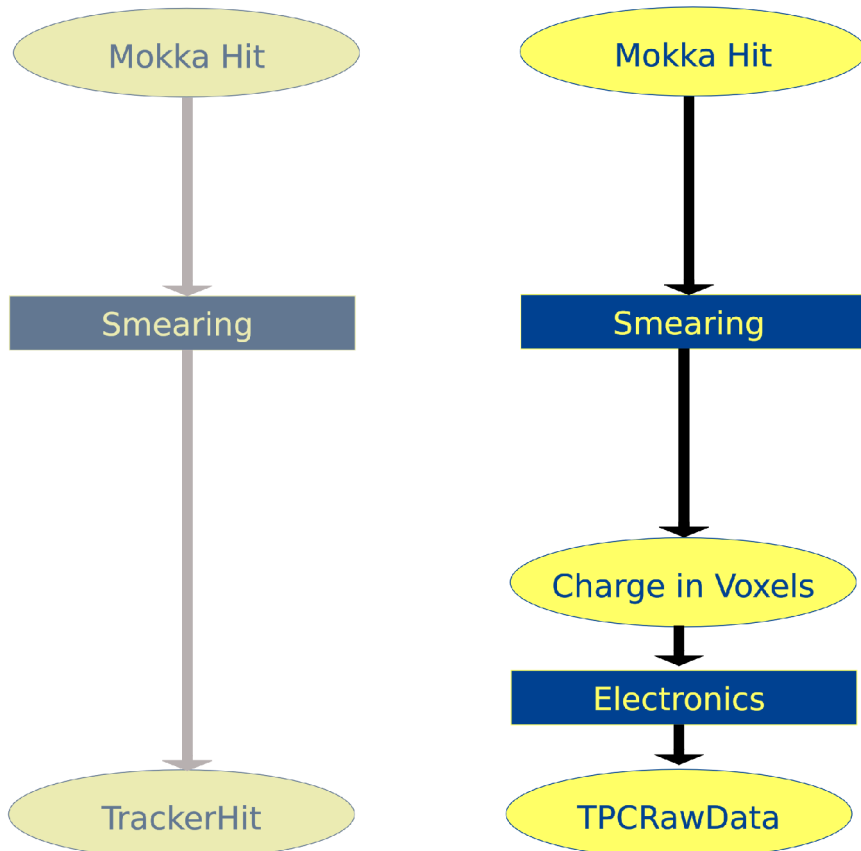


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Digitization: MarlinTPC

- By calculation charge in voxels more realism gained:

- Raw data (ADC counts)
- Pad geometry taken into account
- Whole reconstruction chain can be tested / used
- Realistic event pile-up
- Dead or noisy channels can be taken into account





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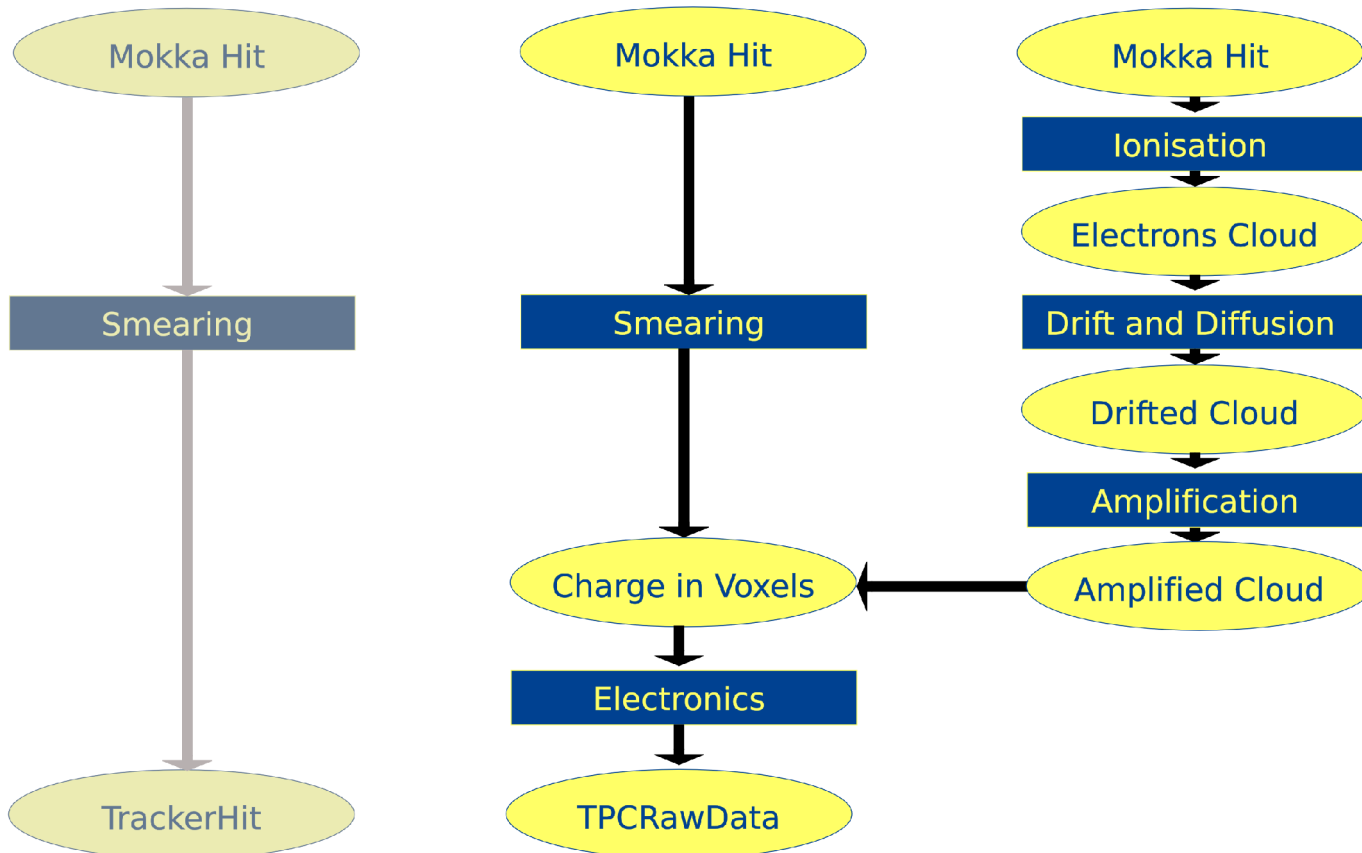
Digitization: Electron Cloud

- Simulates electron clouds instead of single electrons
- Includes ionization, drifting, GEM amplification and digitization:
 - PrimaryIonizationProcessor
 - ElectronCloudDrifterProcessor
 - ElectronCloudGEMAmplificationProcessor
 - ElectronCloudChargeDepositProcessor
 - SignalShaperGaussianProcessor
 - SignalCombinerProcessor
 - SignalDigitizerProcessor
- First test were performed with $\sim 500 \pi^-$ (single tracks, no curlers/noise, homogeneous B field):
 - Momentum resolution: $\sigma(1/p_T) \sim 1.37 \times 10^{-4} (\text{GeV}/c)^{-1}$
 - 100% reconstruction efficiency
- Still work to do: too many energy deposits crash program, add support for multiple read-out modules, more testing



MarlinTPC

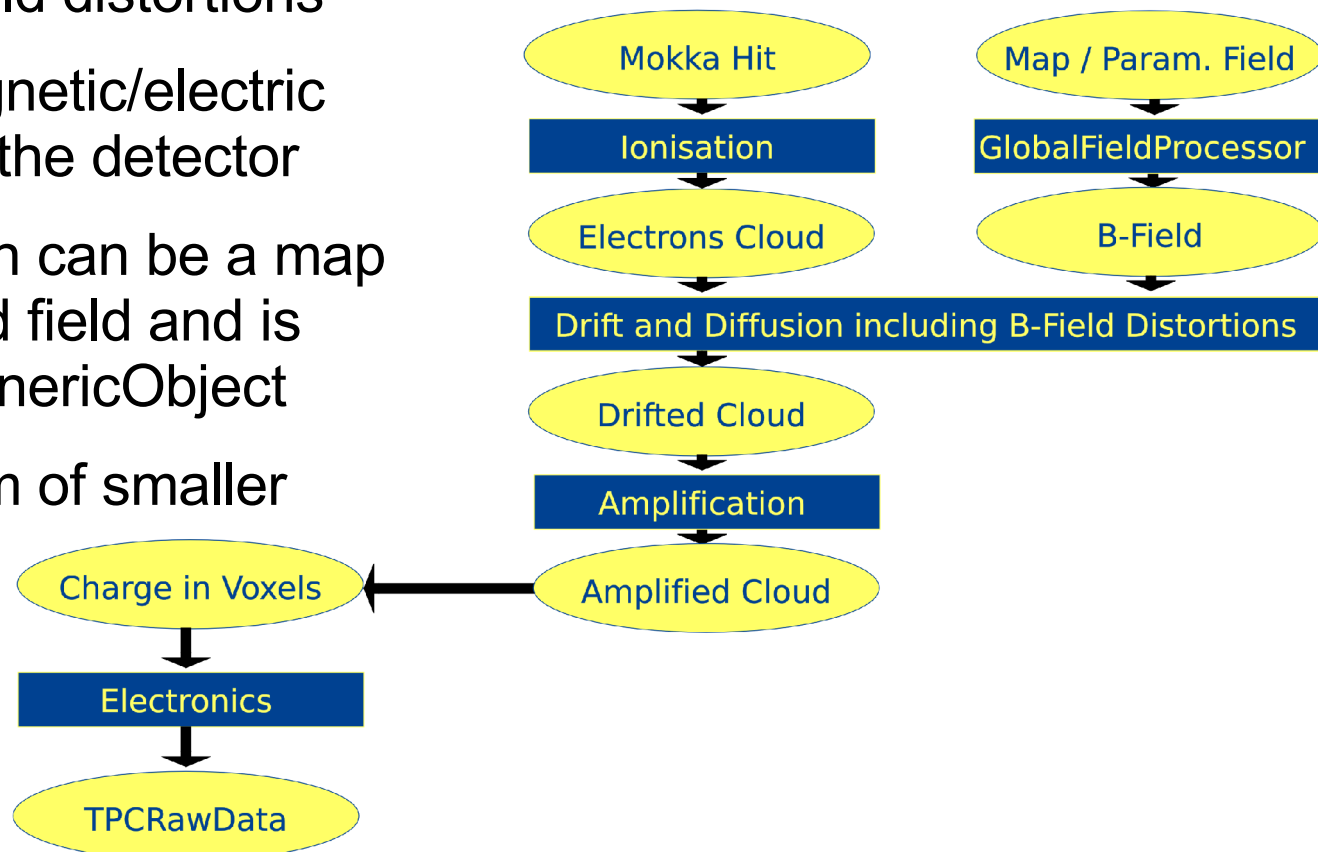
Digitization: Electron Cloud





Digitization: B-Field Distortions

- Electron cloud package can take into account B field distortions
- Query of the magnetic/electric field at a point in the detector
- B field information can be a map or a parametrized field and is stored in a LCGenericObject
- Global field = sum of smaller fields



- Electron cloud package can be used in the likelihood fitter:
 → track fit including distortion correction



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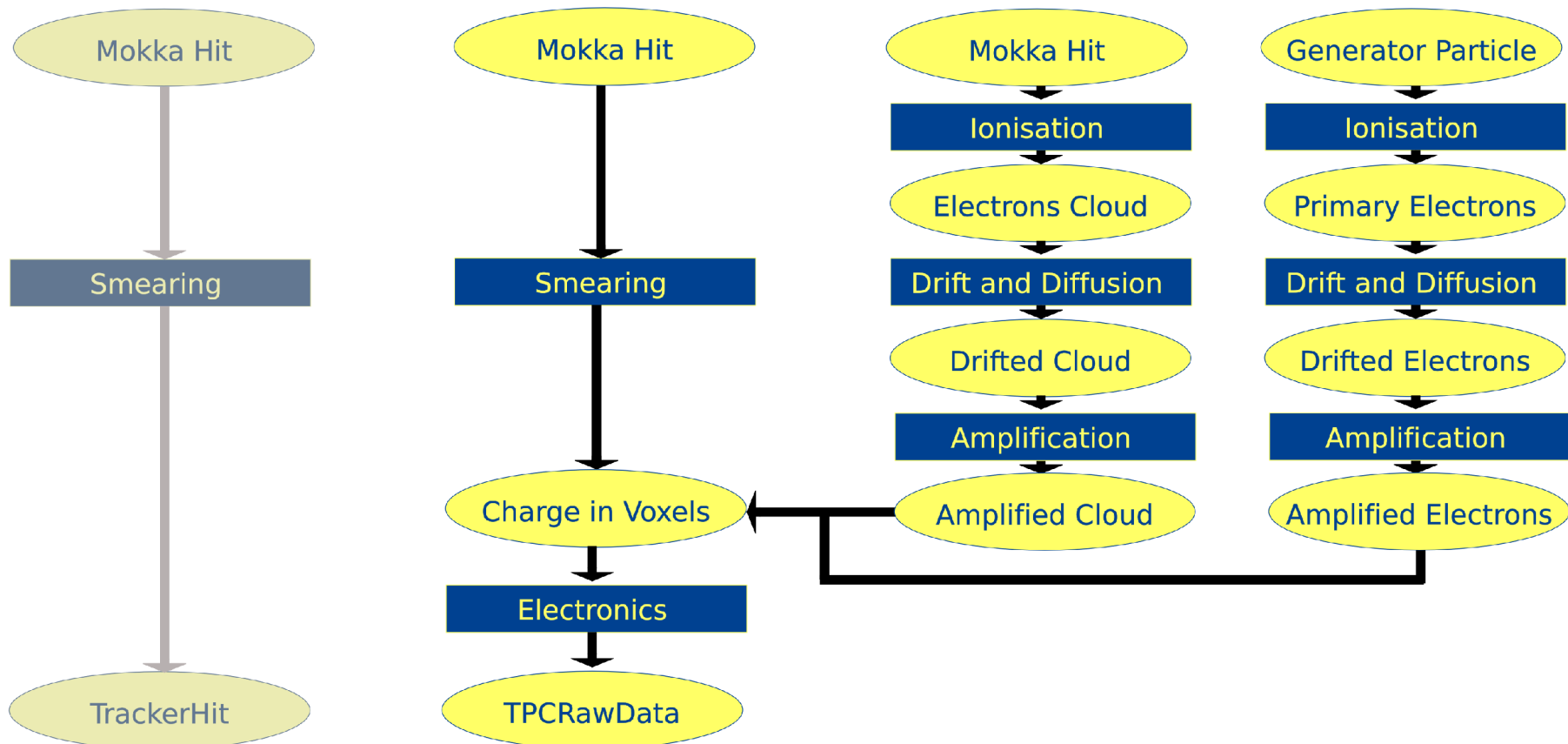
Digitization: Single Electrons Simulation

- Simulation package for detailed studies of a TPC:
- Parameterized deposition of primary electrons (from HEED): realistic clusters, delta electrons...
- Drift of electrons incl. diffusion
- Detailed simulation of amplification and charge transfer in a GEM stack, incl. gain fluctuations and collection / extraction efficiencies: only for specific gas mixtures:
Currently: P5 (Ar:CH₄/95:5), P10 (Ar:CH₄/90:10) and TDR (Ar:CH₄,CO₂/93:5:2)
- Simulation of MICROME GAS amplification still missing
- Every single primary electron is tracked in the TPC. This should provide data realistic enough for a silicon pixel readout.



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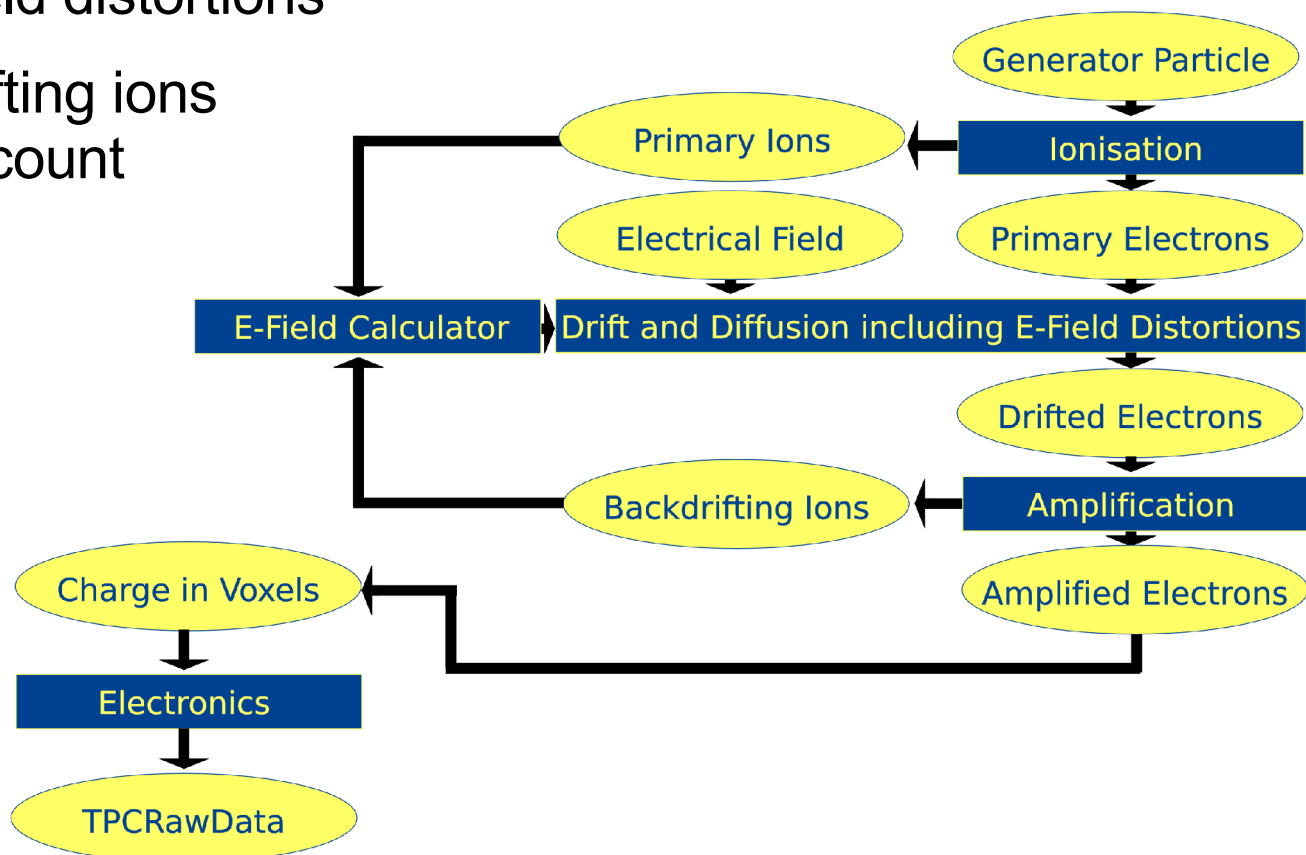
Digitization: Single Electrons





Digitization: E-Field Distortions

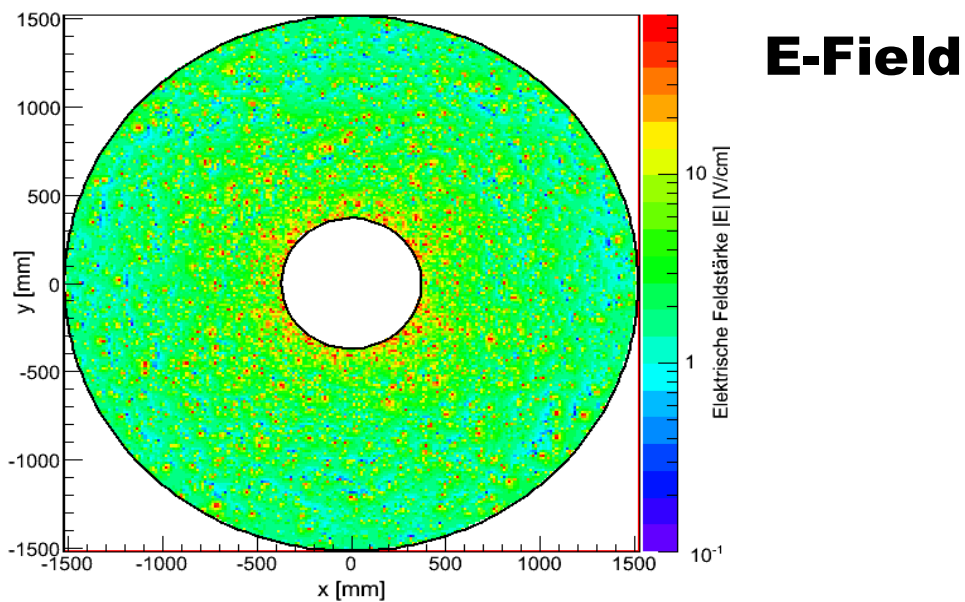
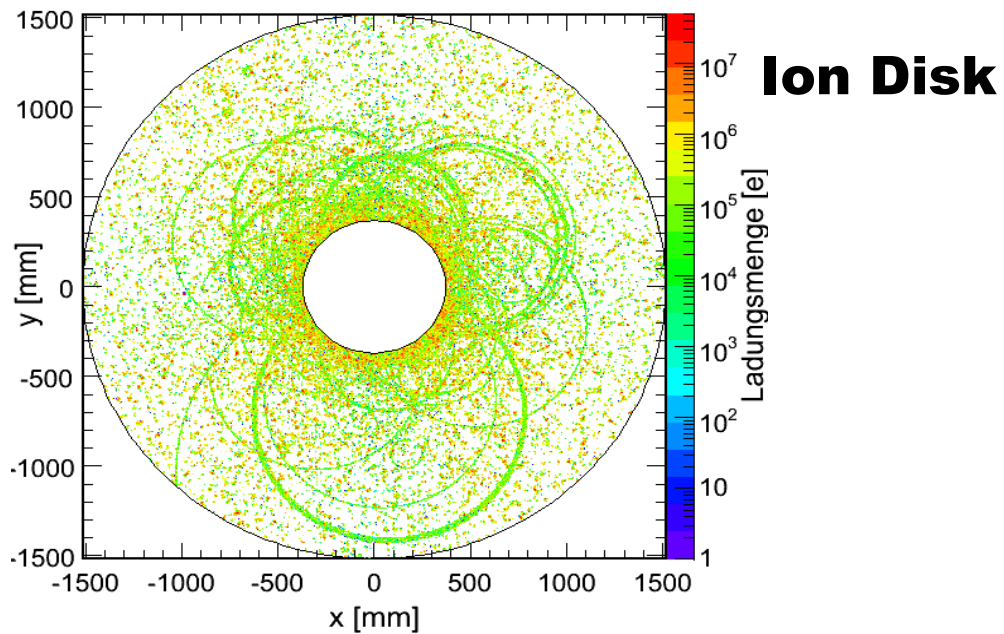
- Single electron drifter can take into account E-field distortions
- Distortions by drifting ions are taken into account



- Electron displacement due to distortions can be calculated

E-Field Distortions due to ILC Background

- 1000 Bunch Crossings (BX)



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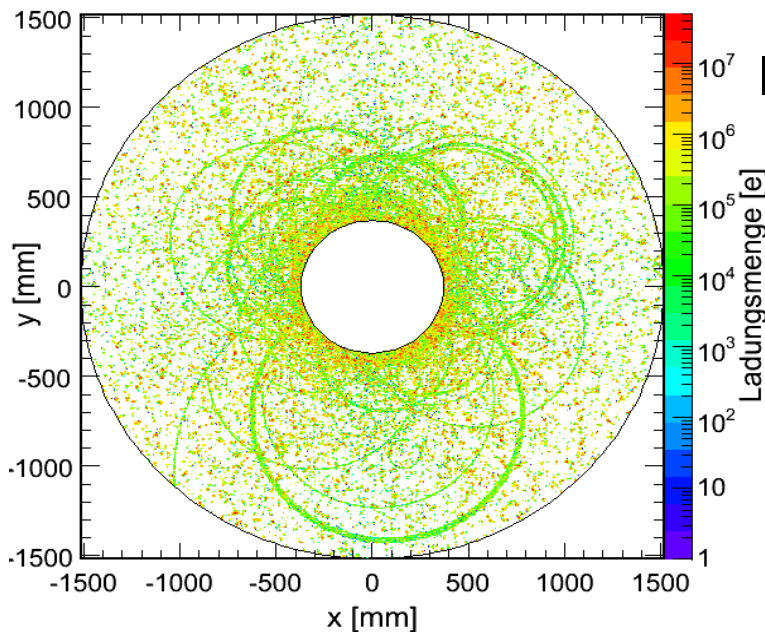




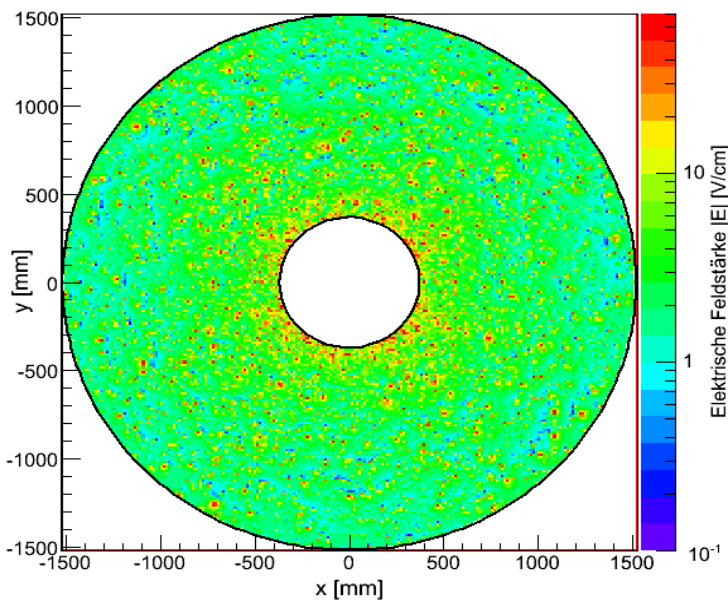
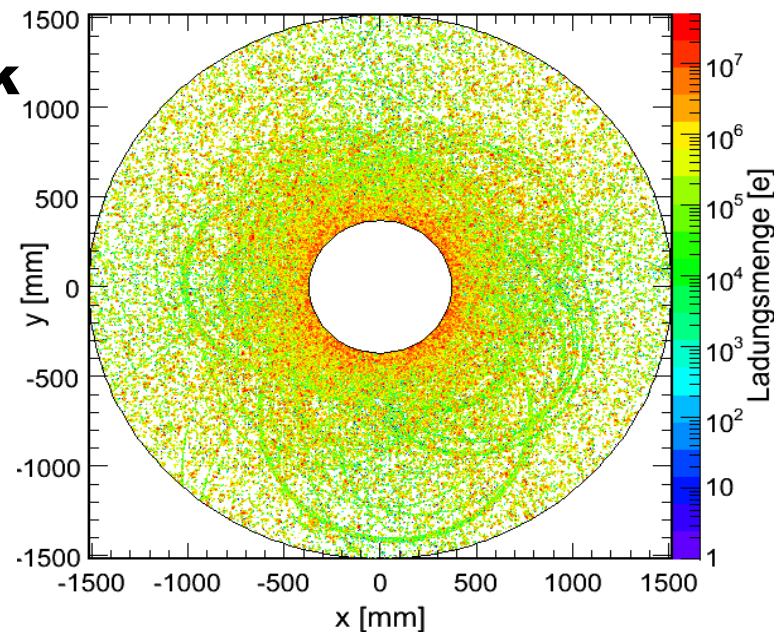
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E-Field Distortions due to ILC Background

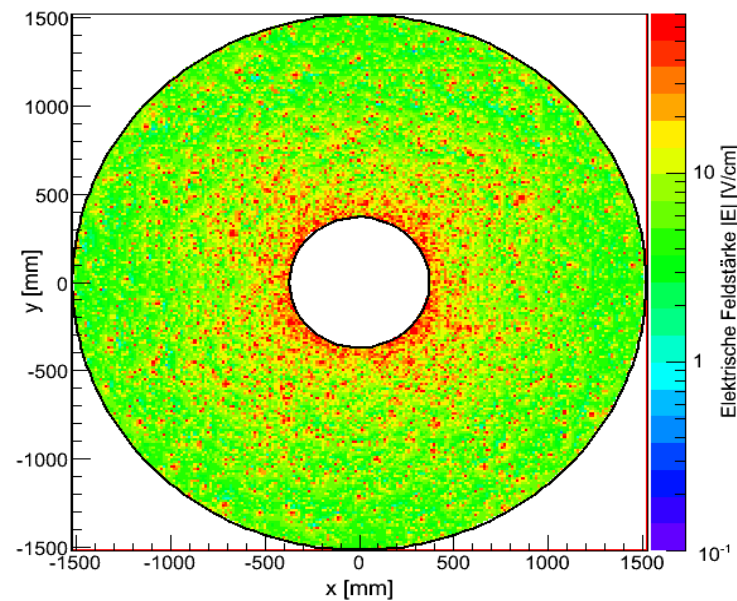
- 1000 Bunch Crossings (BX)
- One Bunch Train (2950 BX)



Ion Disk



E-Field



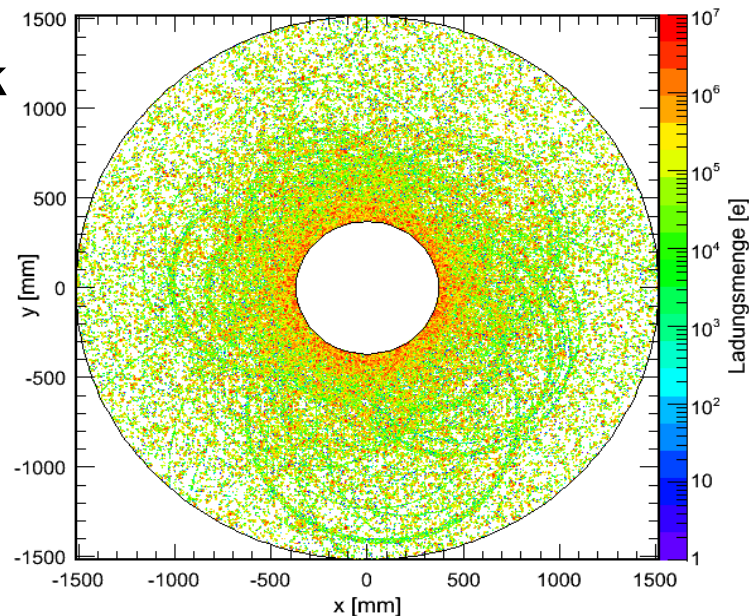
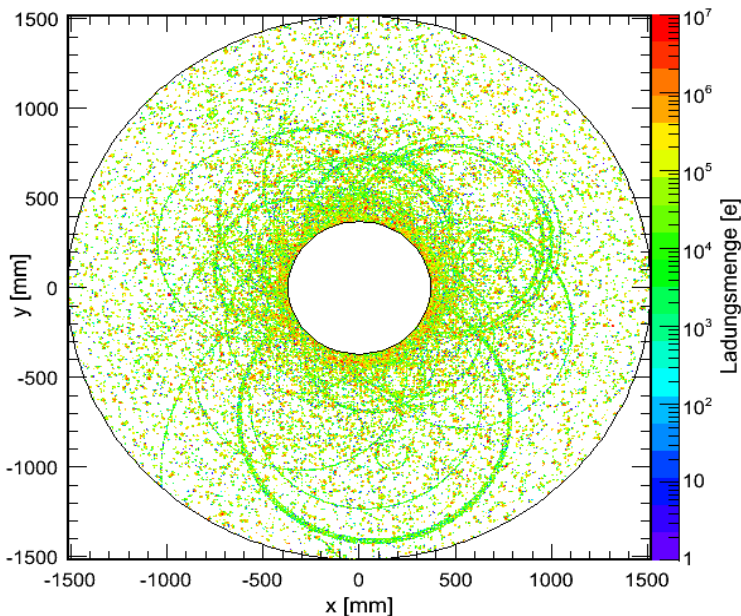


MarlinTPC

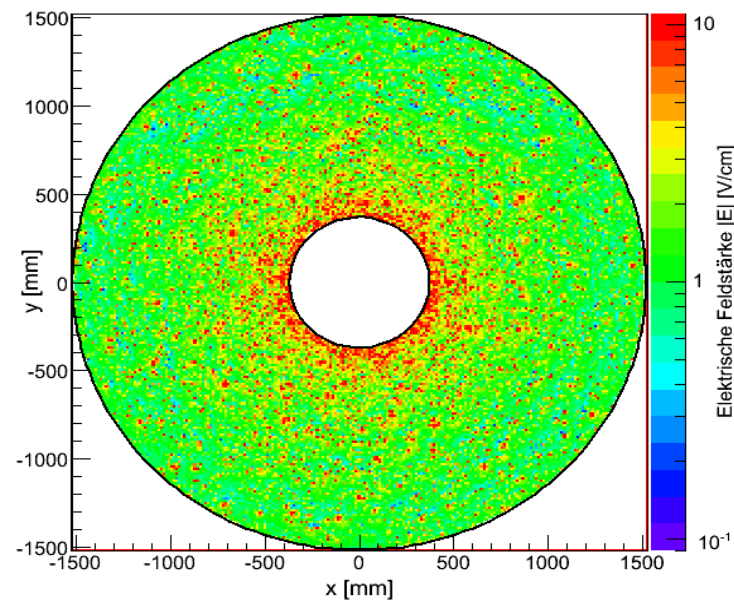
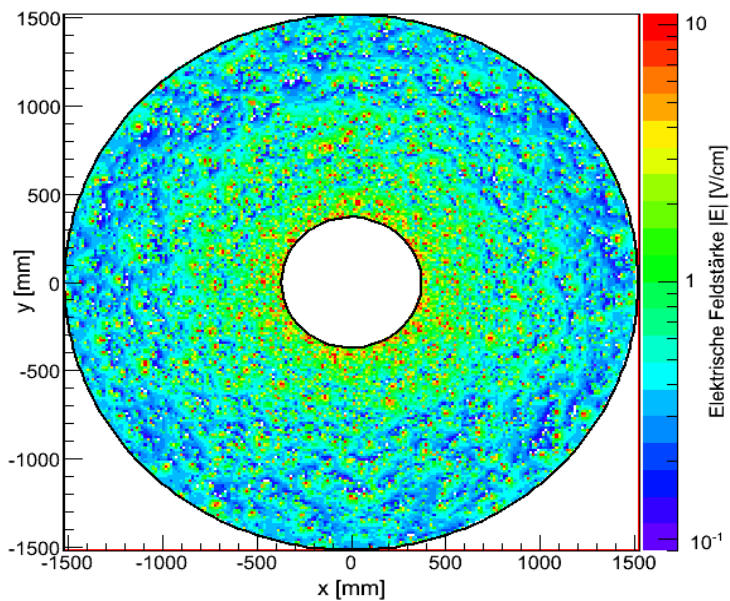
E-Field Distortions with Optimized GEM Settings

- 1000 Bunch Crossings (BX)
- One Bunch Train (2950 BX)

Ion Disk



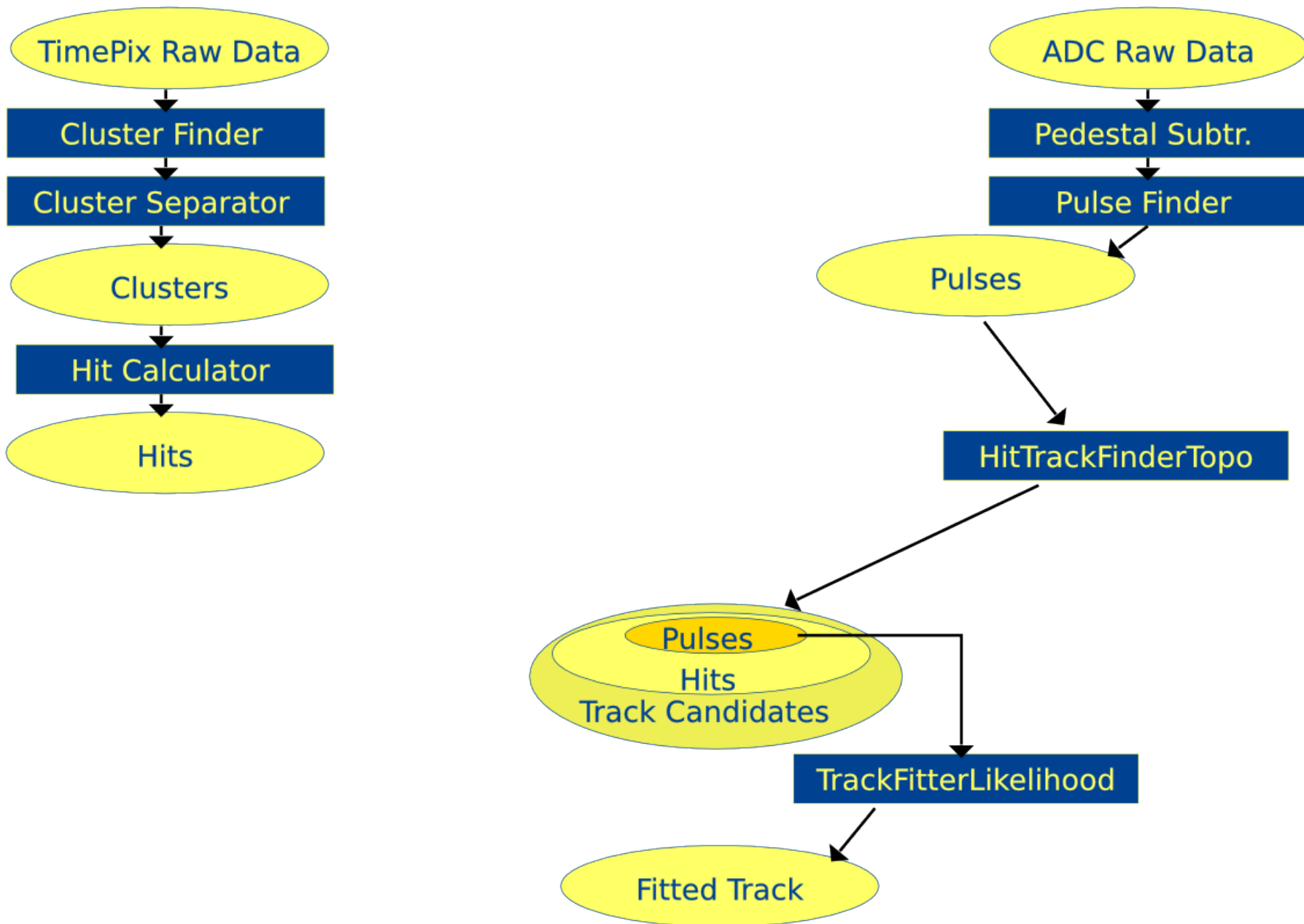
E-Field





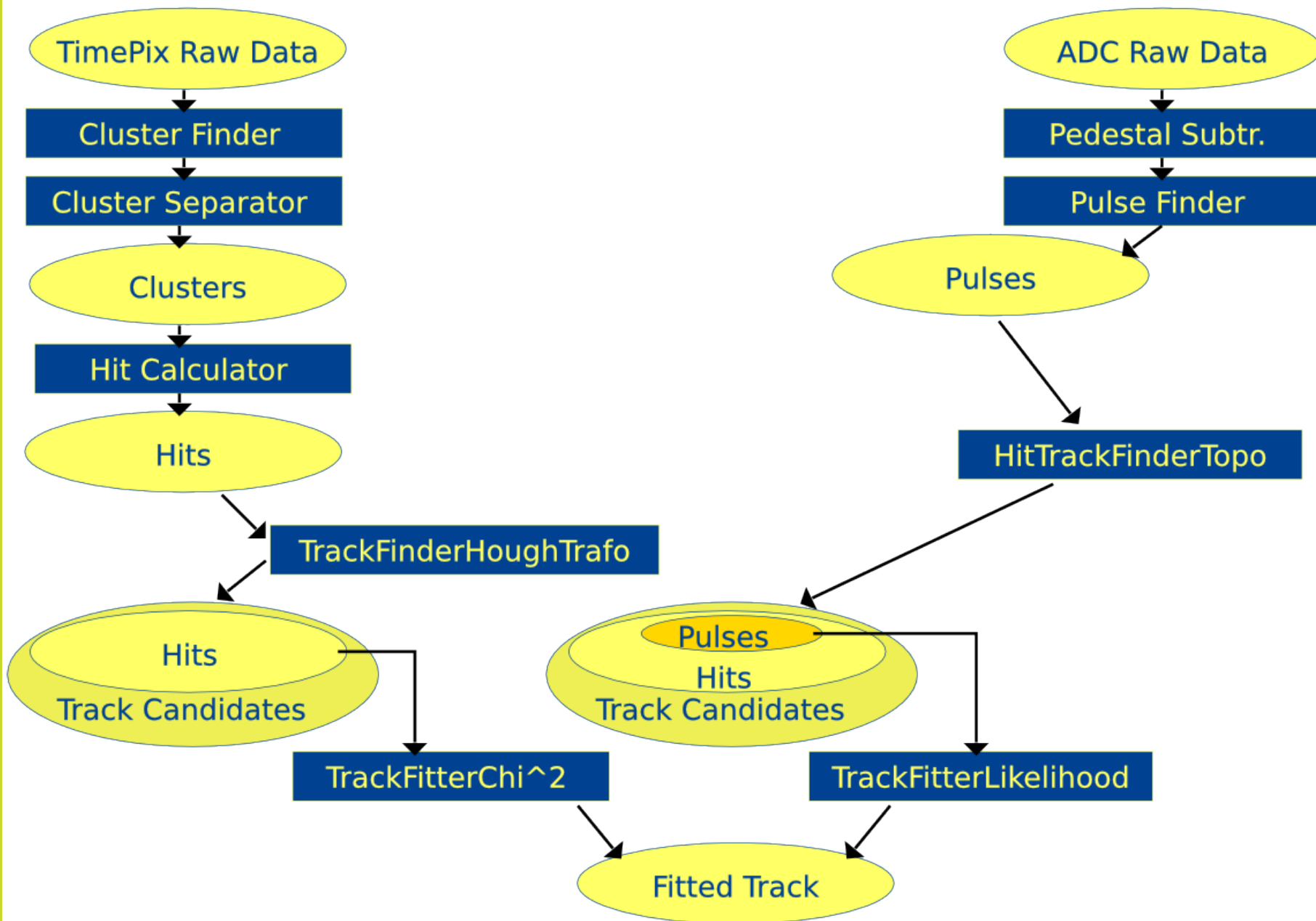
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Reconstruction: Status Last Year





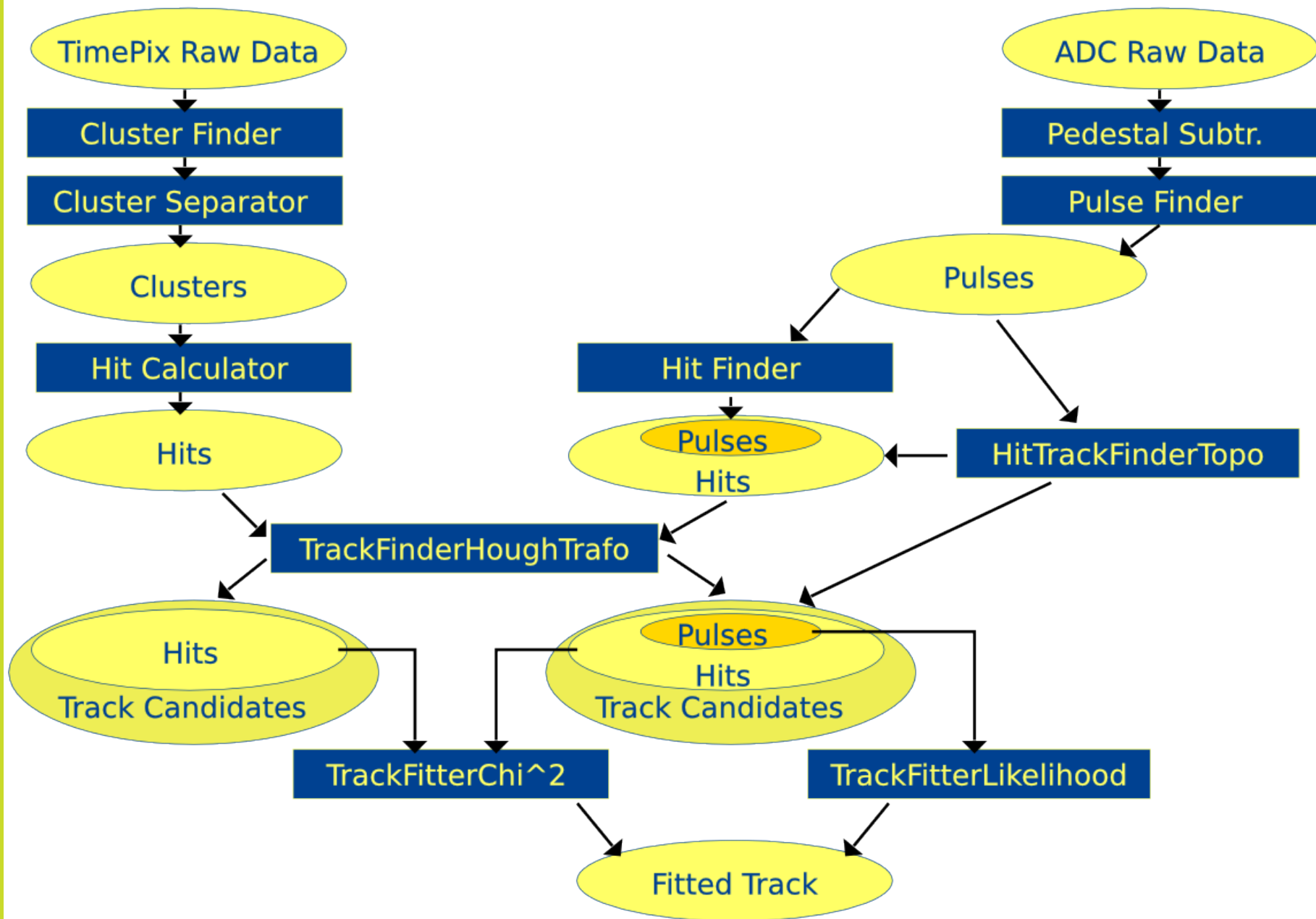
Reconstruction: Pixel Reco Update





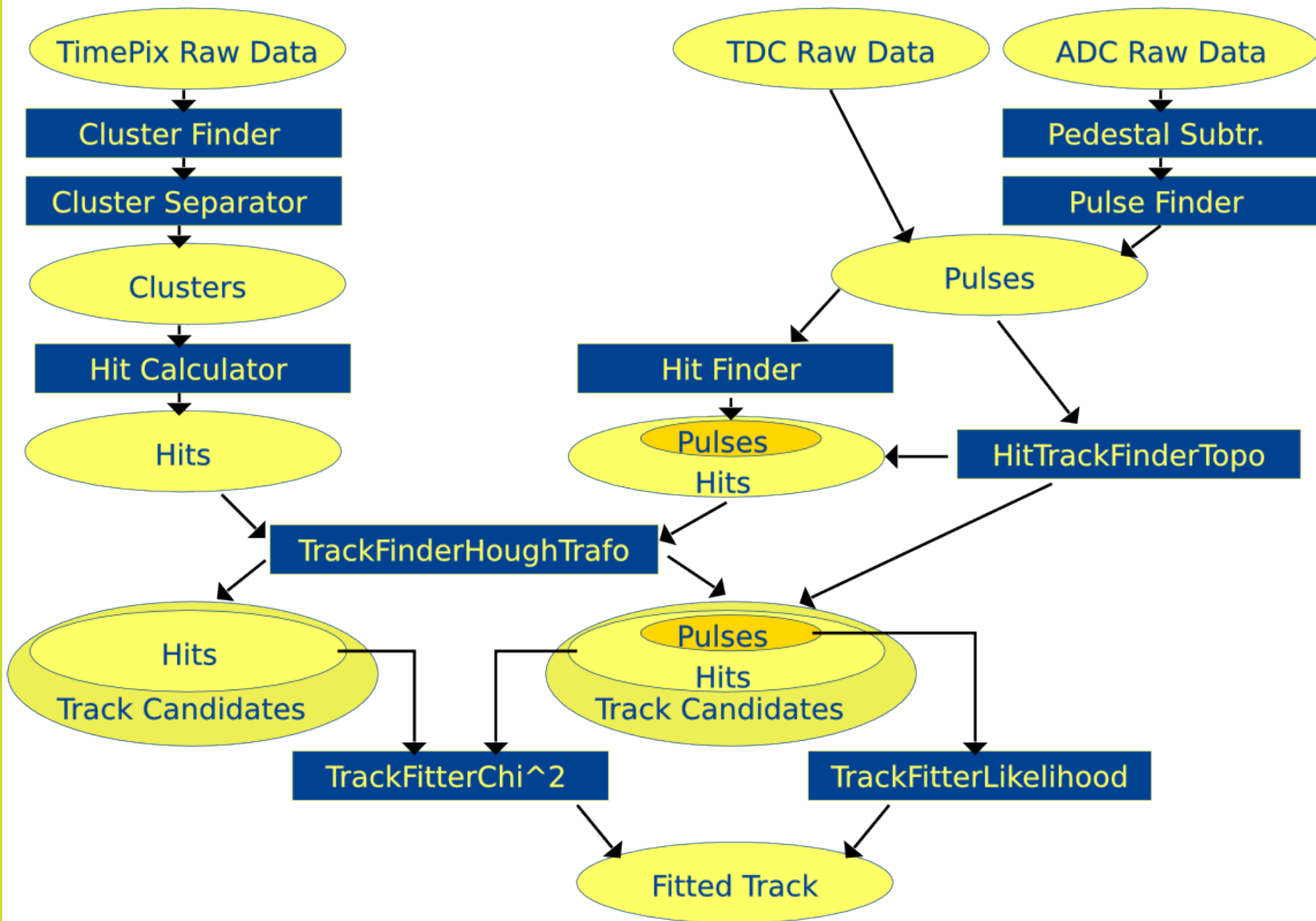
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Reconstruction: Current Status





Reconstruction: TDC data





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Other Updates

- HepRep XML output processor available
- Many analysis processors available:
 - BiasedResidualsProcessor
 - CutApplicationProcessor
 - HitAndTrackChargeProcessor
 - HitAndTrackCounterProcessor
 - TimePixClusterSizeProcessor
 - TimePixOccupancyProcessor
 - LinearThreePointResolutionProcessor
 - LinearGeometricMeanResolutionProcessor
 - TimePixTOTDistributionProcessor
 - TrackParametersDistributionProcessor
 - XYZDistributionProcessor
 - XYZDistributionTracksProcessor
 - ZBinTemplateProcessor



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GEAR Update

- In current/old GEAR implementation:
 - Only one read-out module possible
 - Limited functionality of pad layouts
- Current development/plans:
 - Implementation of multiple read-out modules
 - Extend functionality of pad layouts
 - Stay backwards compatible
- Status:
 - Classes are defined and implemented (without functionality)
 - XML parser defined and implemented (untested)
- Todo:
 - Finish class implementations
 - Extend functionality of pad layouts based on feedback of TPC R&D groups



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Conclusions and Outlook

- Field distortions:
 - Basic functionality implemented
 - First tests promising, but more testing needed
 - Still work to do (bugfixing, “mixing” E and B field distortions)
- Pixel reconstruction:
 - Basically ready and complete (is in use at least at the Bonn group)
 - Also more testing needed
- Pad reconstruction:
 - Basic chain ready and complete (can be extended)
 - Revision of some implementations and testing needed
- “Data Challenge” is planned: testing with MC and prototype data
- Extend analysis processor collection to cover complete standard analysis tasks
- Finish and test GEAR extension