LC-TPC R&D Overview

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Overview

- The design and construction of a TPC to meet the physics demands at the Linear Collider will be full of challenges
  - A large R&D effort has begun to tackle these now
  - Many of the R&D teams are represented here
- Rather than try to summarize the details of ongoing work, this presentation will explore the range of challenges before us
  - Goals: put the existing R&D efforts in context and remind us of the uncovered areas
  - I welcome your insight during the presentation…

LC-TPC Challenges

- To explore the challenges of the LC-TPC, step through the components that transform ionizing particles into reconstructed tracks in order:
  - 1. Drift volume
  - 2. Gating region
  - 3. Amplification region
  - 4. Sensing elements (pads/wires)
  - 5. Electronic amplification and digitization
  - 6. Data acquisition and analysis
- Much of this is described in the DESY-PRC report

1. Drift volume issues

- Gas choice
- Field cage design
- Mechanical structure
- Laser calibration system
- Magnetic field

Drift volume -> Gas choice

- Selection criteria:
  - Diffusion (transverse and longitudinal)
  - Drift velocity
  - Neutron cross section
  - Ionization statistics
  - Operating pressure

Work by Orsay/Saclay:

Investigation of Ar CF_4 mixtures

Work by DESY group:

Selection of TDR gas, on basis of dE/dx and point resolution

Work needed:

Re-examination of gas options – with view to optimize momentum resolution (high p)

Drift volume -> Field cage

- Design challenges
  - Field uniformity
  - Alignment
  - Stability of HV and structure
  - Low mass
  - Cathode plane

Work at DESY:

Current prototype has low mass field cage

Work by St. Petersburg:

Simulation studies to optimize field cage design

Work needed:

Determine required tolerances so as not to degrade p resolution

Prepare designs for the full size TPC according to these tolerances – design and construct a large scale prototype accordingly

Drift volume -> Mechanics

- Mechanical structure requirements
  - Low mass in barrel walls (< 3% X_0) and endcap walls (< 30% X_0)
  - Strength to hold amplification structures under tension
  - Stable against mechanical/thermal motion
  - Moveable to service other subdetectors

Work needed:

Determine requirements/tolerances

Full size design with FEA

Drift volume -> Laser

- Laser calibration system
  - Is it necessary?
  - Is it useful?
  - Can it be easily incorporated?

Can we agree now that a laser system is not needed?

Drift volume -> Solenoid field

- Solenoid requirements
  - Uniformity
  - Field strength

Work completed for TDR:

Physics demands large field strength 3 – 4 T

Work required:

Determine tolerances on field uniformity: How well can non-uniformities be mapped and accounted for?

2. Gating region

- Is gating necessary?
  - May depend on choice of amplification technology
  - Goals:
    - reduce ion feedback into drift volume – reduce distortions
    - proper termination of electric field in drift volume (important near edges) – reduce distortions
- Is gating feasible?
  - Better suited to low duty-cycle beam structure
  - High duty-cycle + no trigger -> no gating

Gating region

- Possible gate devices:
  - Traditional wire grid
  - Low/unity gain GEM

Work by
Novosibirsk group:

Investigation of
gating with GEM

Work needed:

Incorporate GEM gate into
a small scle prototype –
verify that tracking
resolution is unaffected

3. Amplification region

- Technology optimization:
  - GEM
  - Micromegas
  - Wires
- Technology choice
- Gas choice

Amplification -> optimization

- Optimization criteria:
  - stability, reliability, longevity, resolution, two particle separation, gain uniformity, ion feedback…
- GEM
  - Hole spacing and geometry
  - Number of GEMs
- Micromegas
  - Mesh pitches and separation to pad plane
- Wires
  - Minimize spacing

Prototypes working in many places:

GEM: Aachen, Carleton, Victoria, DESY, Karlsruhe, NIKHEF, Novosibirsk

MM: Carleton, Orsay/Saclay

Wires: MPI

Simulation of GEM amplification stage underway at Aachen

Amplification-> choice

- Selection criteria:
  - Stability: against HV breakdown
  - Reliability: against breakage
  - Longevity: against aging
  - Resolution: reduced **E** × **B**, good use of ionization statistics: good transparency, narrow gain distribution
  - Two particle separation: narrow signals (space and time)
  - Gain uniformity: dE/dx
  - Low ion feedback
  - Light mechanical loads
  - Cost – commercial production?

Work at Aachen to understand transparency and gain distributions

Work at Aachen, Novosibirsk and Orsay/Saclay to understand ion feedback

Need more work on two particle separation power: test beam studies

Amplification -> Gas choice

- Selection criteria:
  - High gain
    - Keep surface fields to a minimum
  - Attachment
    - Concern for CF_4 mixtures for GEM
  - Defocusing
    - Important consideration for GEM
  - Aging

Krakow group working to find optimum gas

Prototype systems need to begin to explore wider selection of gas mixtures

4. Sensing elements

- Pads for direct charge collection
  - GEM
  - MM
- Defocusing mechanism

Sensing elements -> Pads

- Pad structure
  - Shapes
    - Rectangle vs. Chevron debate continues
  - Sizes
    - Maximum size so as not to degrade resolution
    - Tiny digital pixels to maximize information
  - Layout
    - Stagger to improve sampling information

Prototype and simulation work in Canada, DESY, and NIKHEF are focused on these questions

Sensing elements -> Defocusing

- GEM
  - Diffusion between GEM foils

Victoria/DESY shows that defocusing with GEMs works

- Micromegas
  - Resistive anode

Carleton studies on resistive anode look promising

- Wires & pads
  - Induction signals on pads already too broad

5. Electronics

- Large numbers of channels / high density
  - ~10^6 channels azimuthally separated by 2 mm

Victoria, Karlsruhe, Orsay/Saclay groups getting experience with STAR electronics – thanks to LBNL

- FADC or ADC/TDC type
  - Cost/data size a concern

Rostock and Montreal groups looking at low cost readout designs

- Cooling
  - Pulse power between bunch trains?

6. Data Acquisition and Analysis

- DAQ frameworks
- Standardized data formats
- Calibration requirements
  - Monitoring and correcting distortions with precise points outside of TPC
- Modern programming techniques
- Track finding algorithms
- Track fitting algorithms

Individual efforts on these issues by many groups

Needed: more collaborative efforts to avoid unnecessary duplication

Summary

- A tremendous amount of work is necessary to build the TPC we want for the LC
  - We have a good start on new technologies:
    - Showing how the new MPGDs can be used
    - Use of OO methodology
  - Not so far along on the old fashioned problems
    - Mechanical and field cage designs
    - Calibration

- Need to continued & expanded efforts, so that we will be ready to build when the time comes…