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Title: Multi-Hypothesis Tracking of Charged Particles Through Drift Tube Arrays

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Form 836 (7/06)

Note on DTRA approval:

David Spears at DTRA reviewed an abstract and cleared the abstract and subsequent publications on the topic of particle tracking through the spectrometer. He explained, that from DTRA perspective clearing a paper involves whether or not it refers to the mission of active interrogation, and since neither our abstract, nor slides make any such reference, we shouldn't bother.

If you have questions regarding this approval, please contact either Konstantin Borozdin at P-25 (500-5509) or Andrew Jason at AOT-ABS (7-2842).

2010 Nuclear Science Symposium, Medical Imaging Conference and 17th Room Temperature Semiconductor Detector Workshop

October 30, 2010 – November 6, 2010 – Knoxville, Tennessee

You have 2 entries in the database.

Abstract #	Abstract Title	Conference	Status
2453	Multi-Hypothesis Tracking of Charged Particles Through Drift Tube Arrays	NSS	Accepted, PaperID: N43-7 oral, confirmed
2609	Passive Imaging of SNM with Cosmic-Ray Generated Neutrons and Gamma-Gays	RTSD	Accepted, PaperID: R05-70 poster, confirmed

Abstract #:	2453	**Conference:**	NSS	**Preferred Pres.:**	Either
Tech. Topic:	Nuclear Measurements and Monitoring Techniques			**Presenter:**	Konstantin N. Borozdin
Assignment:	N43-7, on Wednesday, Nov. 3 @ 15:15, in room: Ballroom A				

Multi-Hypothesis Tracking of Charged Particles Through Drift Tube Arrays

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We report on the application of techniques from the target tracking literature to the experimental study of the distribution of charged particles. In the experiment we have multiple planes of position-sensitive detectors able to detect location of the particle hit in each sensitive plane. The problem we address here is determining how to combine a series of particular hits into a particle trajectory. This simple task is complicated by the specifics of the measurements, missed hits and background. In the target tracking literature, the challenge of associating hits in different images is called the association problem, and current best practice is the Multi-Hypothesis Tracking or MHT. Recent work has investigated the possibility of using Markov chain Monte Carlo (MCMC) methods for addressing the multi-hypothesis challenge. In our study we report on results from both approaches and on the trade off between computational budget and accuracy. We extend the usual MHT formalism to select tracks with certain qualities and set quality flags as required by the experiment. In our presentation we describe in more detail our approach and preliminary results of its application to the experimental data.

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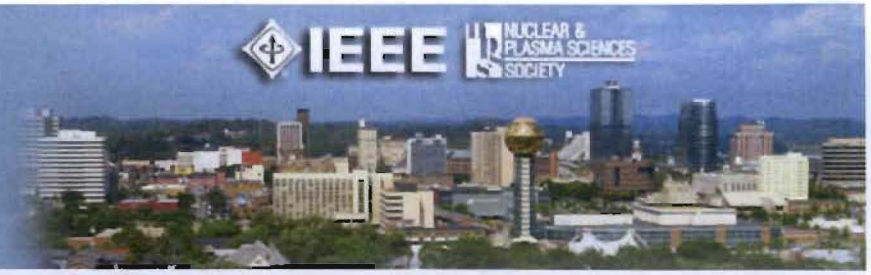
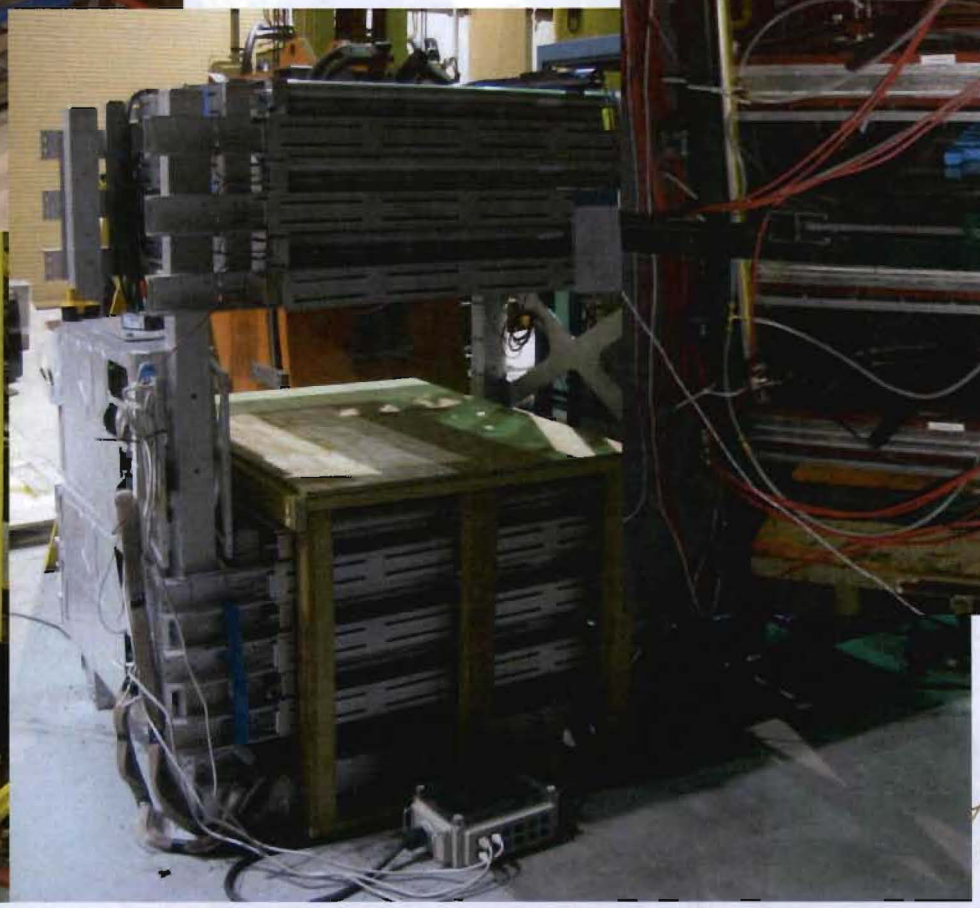


Tracking Charged Particles for Cosmic-Ray Muon Tomography



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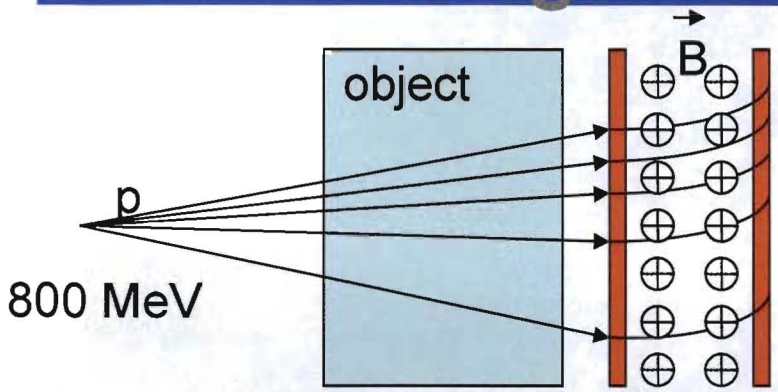
Measuring energy with magnetic spectrometer

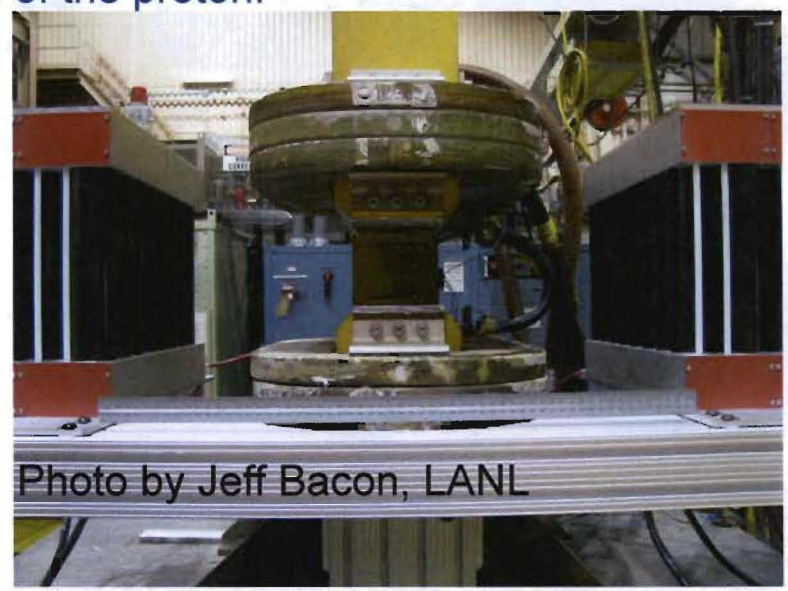


For a uniform magnetic field B(Tesla) perpendicular to the particle momentum p(MeV) radius of a curvature R(cm) is: $R = p/300qB$

If a length of a magnetic field is L(cm) then bending angle θ is given by: $\sin\theta = 300qBL/p$

By measuring θ we can get momentum and energy of the proton.

With drift tubes we can measure coordinates in two planes and, therefore, input and output vector of the particle trajectory. These tubes are made out of thin carbon to reduce multiple scattering.



Magnetic spectrometer: bending magnet with two drift modules mounted around it at Staging Area A at LANSCE (LANL) .

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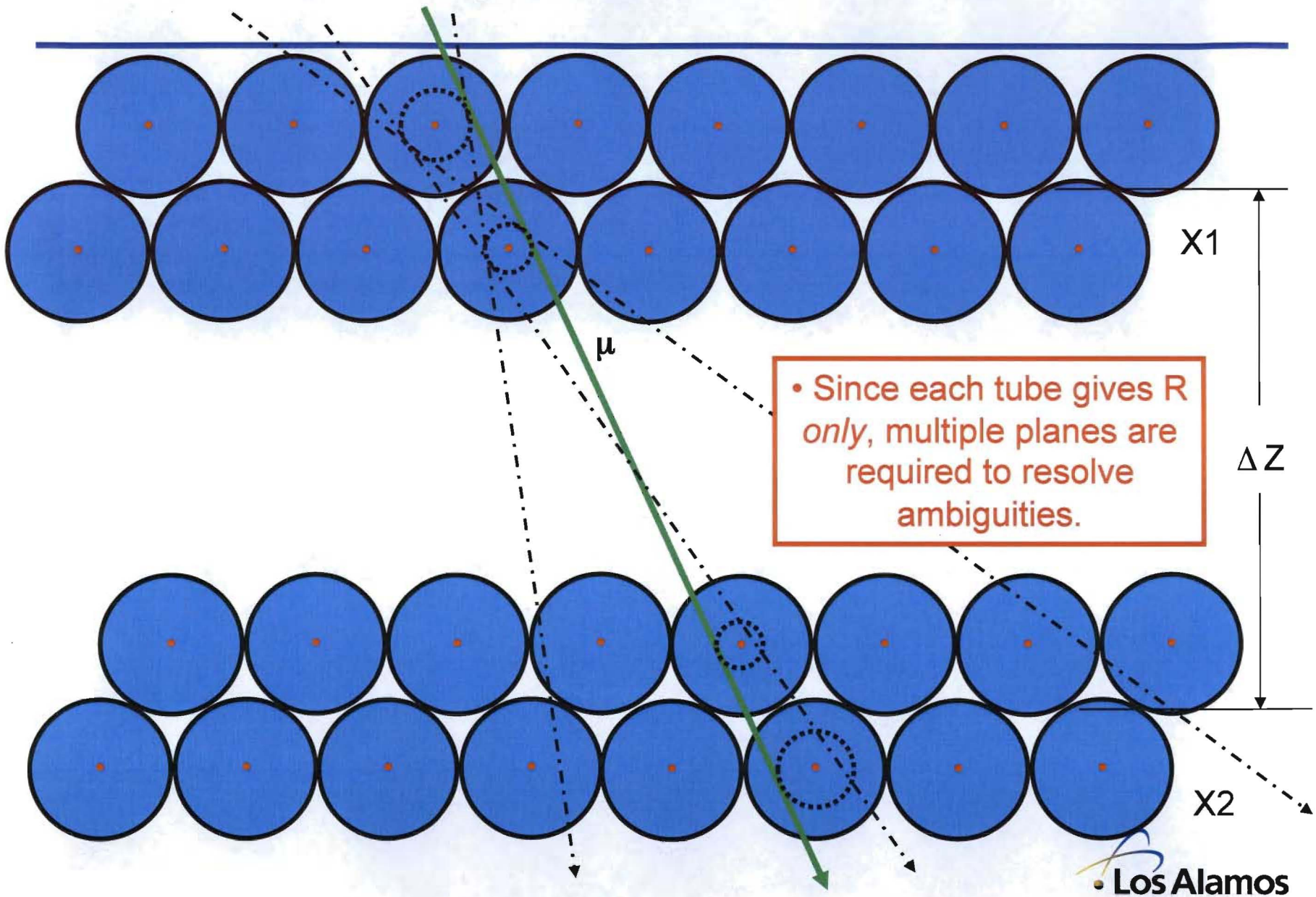
Tracking Charged Particles with Drift Tubes



- Since each tube gives R *only*, multiple planes are required to resolve ambiguities.

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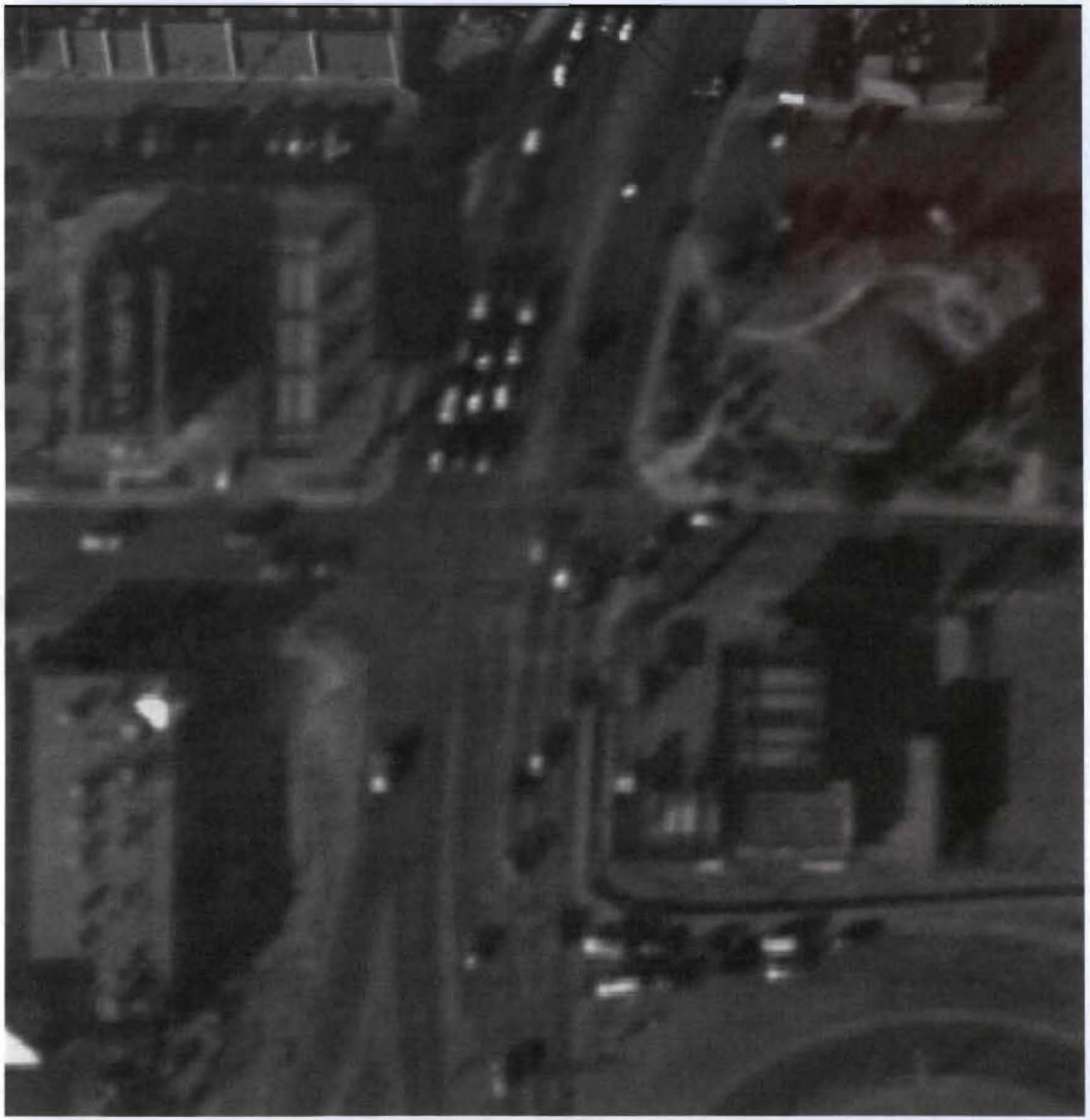
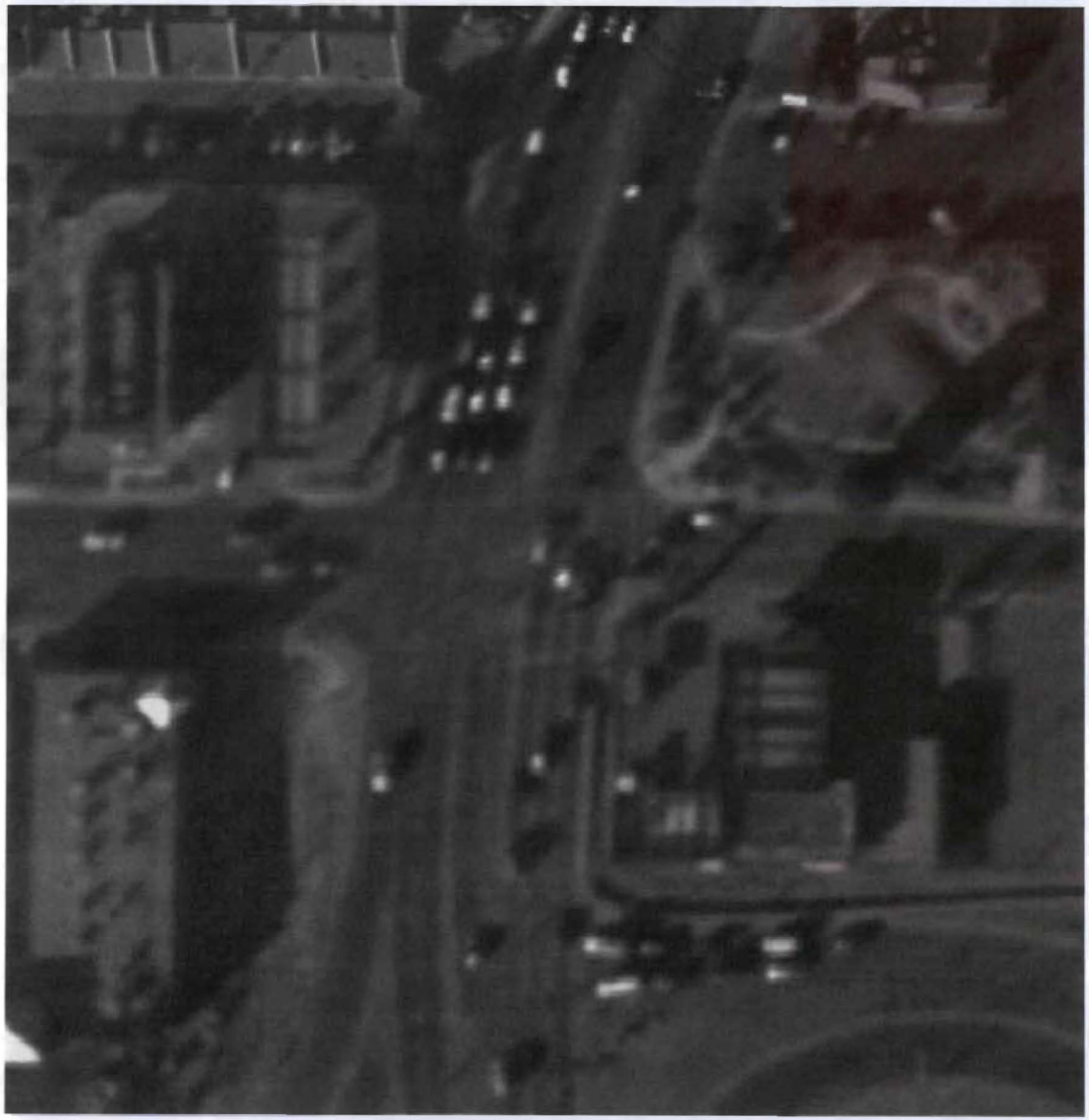
Old Vehicle Tracking Problem



MHT Results



Easier to Track Pions than Vehicles:

- Not so many pions in our scenes
- Dynamics easier to model: They move in straight lines or on circular arcs

Rough Idea:

- Propagate stories right $\rightarrow$ left
- Prune implausible stories
- After reaching left most plane backtrack left $\rightarrow$ right to smooth most plausible story

Notation

Input: List of **hits** $\{\tau_i(p)\}$ for each plane p

$$\tau_i(p) = \text{Pulse delay} \rightarrow \text{Radius}$$

Output: List of **tracks** for each **particle**

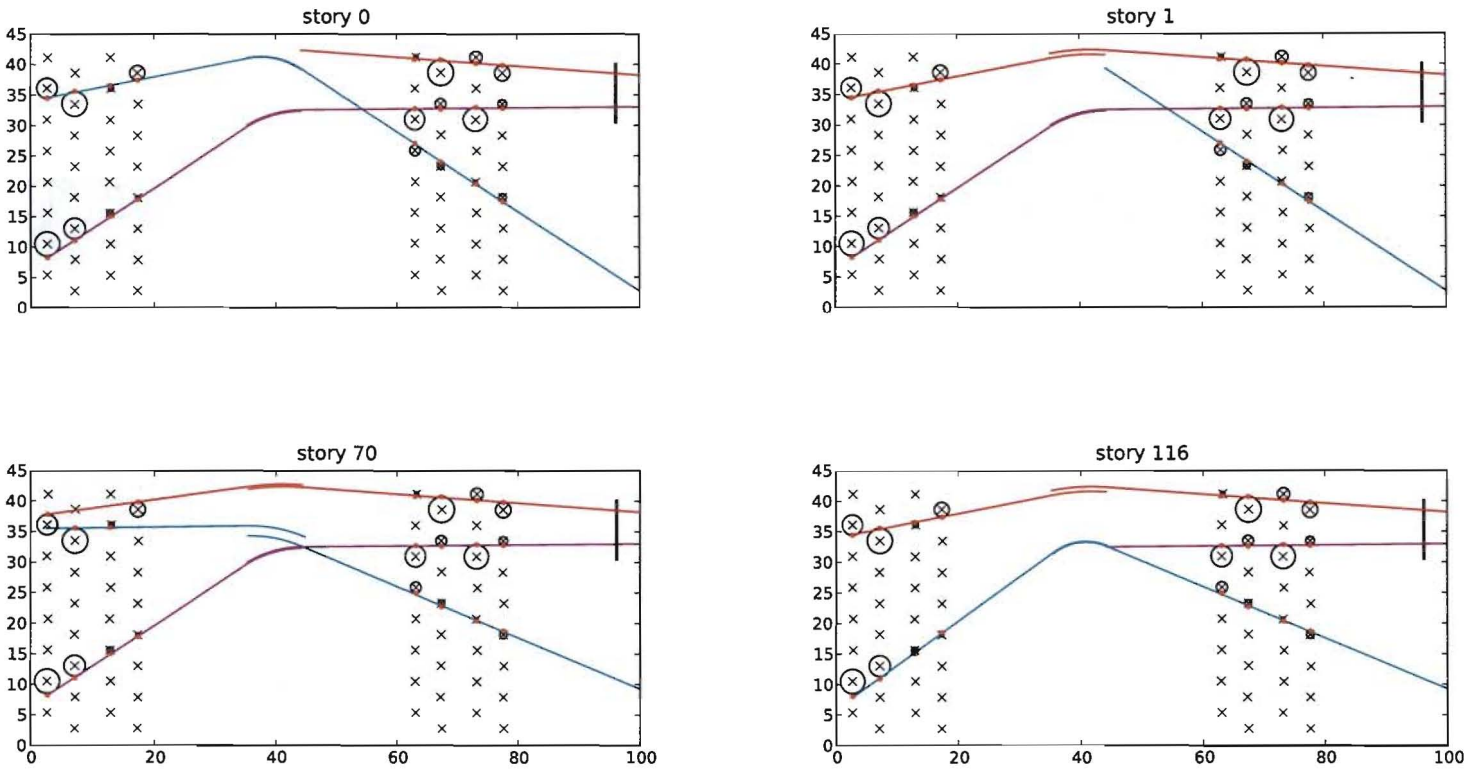
$$\{s_j(p) : P_i \leq p \leq P_f\}$$

where

$$s_j(p) = \text{Position \& Slope}$$

Example

Challenge: Several different *stories* can explain the same data



Solution: Approximate maximum a posteriori probability (MAP) via *Multi-Hypothesis Tracking* (DB Reid IEEE Trans AC 1979)

Solution Strategy

Want to characterize:

$$P(s_1^F|\tau_1^F) = \sum_{A_1^F} P(s_1^F, A_1^F|\tau_1^F)$$

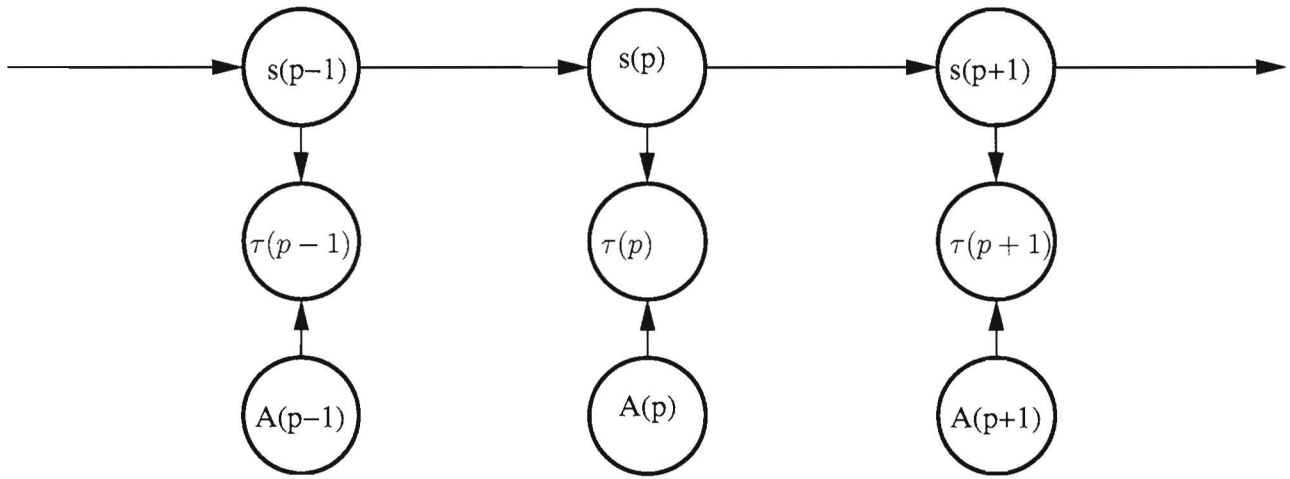
Approximate: with sequence of states $\otimes$ *associations*:

$$\hat{s}_1^F, \hat{A}_1^F = \underset{s_1^F, A_1^F}{\operatorname{argmax}} P(s_1^F, A_1^F|\tau_1^F) \tag{1}$$

Association includes map from particles to hits and resolution of up/down ambiguity

State space model: Linear particle dynamics, Gaussian accelerations: $s_j(p+1) = L \cdot s_j(p) + \eta(p)$. Like Kalman filtering and Viterbi decoding

Independence Structure



Notation for Viterbi decoding

$$
\begin{aligned}
u(s_1^p) \quad & \text{Utility of state sequence } s_1^p \\
& \equiv \log\left(P(\tau_1^p, s_1^p)\right) \\
\nu(s,p) \quad & \text{Utility of best sequence ending with } s(p) = s \\
& \equiv \max_{s_1^p : s(p)=s} u(s_1^p) \\
B(s',p) \quad & \text{Best predecessor state given } s(p+1) = s' \\
& \equiv \operatorname*{argmax}_{s} \max_{s_1^{p+1} : s(p)=s \& s(p+1)=s'} u(s_1^{p+1})
\end{aligned}
$$

Insights:

- Calculate $\nu(s,p)$ and $B(s,p)$ $\forall s \& p$ recursively
- For most s_1^p, never calculate $u(s_1^p)$
- Complexity linear in number of planes

Conclusions

We report on the application of techniques from the target tracking literature to the experimental study of the distribution of charged particles. In the experiment we have multiple planes of position-sensitive detectors able to detect location of the particle hit in each sensitive plane. The problem we address here is determining how to combine a series of particular hits into a particle trajectory. This simple task is complicated by the specifics of the measurements, missed hits and background. In the target tracking literature, the challenge of associating hits in different images is called the association problem, and current best practice is the Multi-Hypothesis Tracking or MHT. Recent work has investigated the possibility of using Markov chain Monte Carlo (MCMC) methods for addressing the multi-hypothesis challenge. We extend the usual MHT formalism to select tracks with certain qualities and set quality flags as required by the experiment. We applied these theoretical techniques to experimental data and obtained promising results.