Belle Fragmentation activity

	RIKEN/RBRC	Illinois	Indiana	Titech
Unpol FFs $e^+e^- \rightarrow hX$, $e^+e^- \rightarrow (hh)X$, $(h)(h)X, hhX$	Neutral hadrons: (π^0 ,η^0) John Koster Charged di-hadrons: Ralf Seidl	Charged hadrons (π,K,P): Martin Leitgab		
Unpol k_T dependence		Martin Leitgab		
Collins FFs $e^+e^- \rightarrow (h)(h)X$	$\pi\pi^o$: John Koster $\pi\rho^0$: Ralf Seidl $\pi\pi$: Ralf Seidl	πK,KK: new Postdoc?	$\pi\rho^{\pm}$: ?	
k_T dependence	$\pi\pi^o$: John Koster	New postdoc?		
Interference FF: $e^+e^- \rightarrow (hh)(hh)X$	Charged $\pi\pi$: Ralf Seidl		Charged $\pi\pi$: Anselm Vossen $\pi\pi^o$: Anselm Vossen	Charged πK, KK: Nori-aki Kobayashi
Local ₱ : Λ(polFF,SSA) : Jet-jet asy:			Anselm Vossen	

Black: about to start
Green: ongoing
Grey: finished

Backup Slides

Towards a global transversity analysis: Chiral –odd Fragmentation functions

RHIC and SIDIS experiments measure:

Transversity $\delta q(x)$ X

Collins Fragmentation function $H_1^{\perp}(z)$

or Interference Fragmentation function (IFF)

2 Unknown Functions measured together

•Universality understood
•Evolution ?

Transversity

Belle measures:

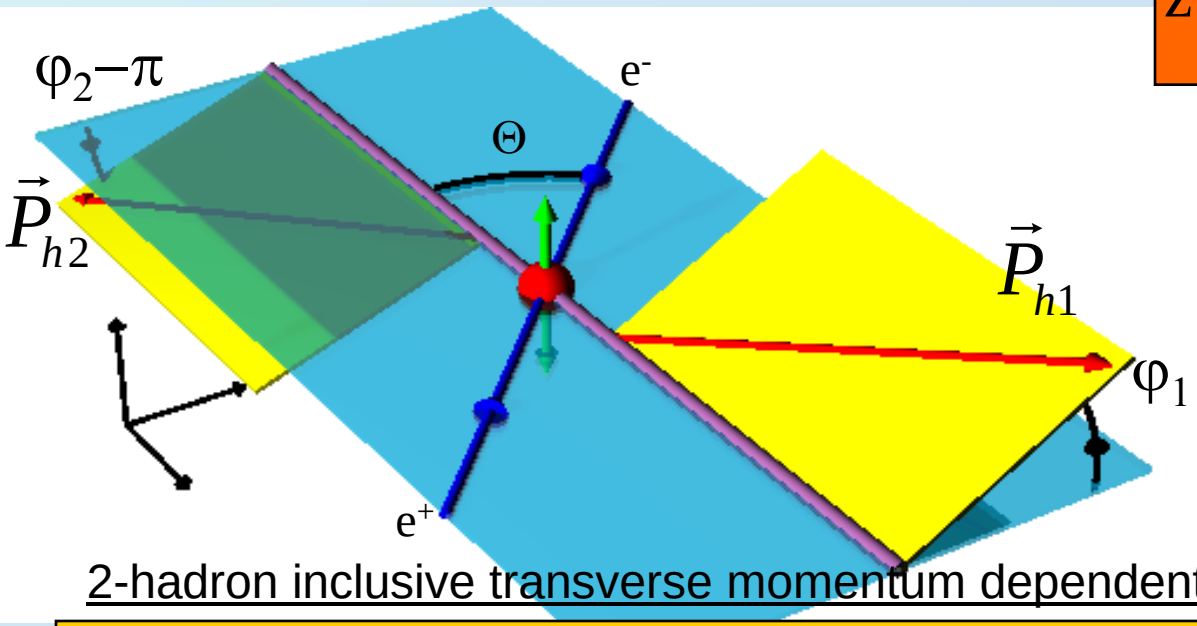
Collins X Collins - finished for charged pion pairs

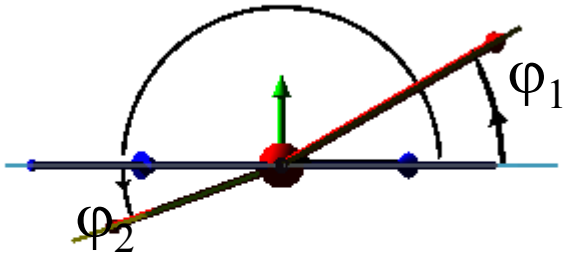
or IFF X IFF – charged pions about to be published

Collins fragmentation in e^+e^- : Angles and Cross section $\cos(\phi_1+\phi_2)$ method

e^+e^- CMS frame:

$$z = \frac{2E_h}{\sqrt{s}}, \quad \sqrt{s} = 10.52\,\textit{GeV}$$





[D.Boer: **PhD thesis(1998)**]

2-hadron inclusive transverse momentum dependent cross section:

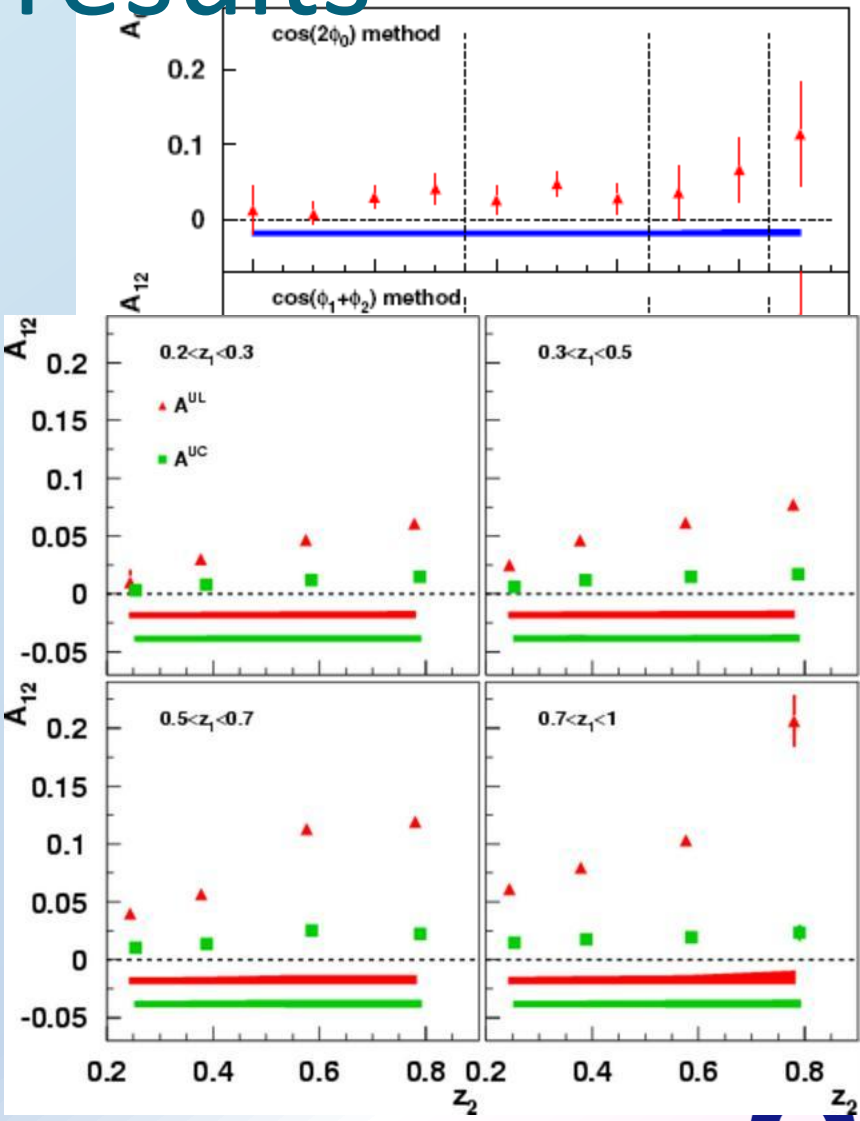
$$\frac{d\sigma(e^+e^- \to h_1h_2X)}{d\Omega dz_1 dz_2 d^2\boldsymbol{q}_T} = \cdots B(y)\,\textit{cos}(\varphi_1+\varphi_2)H_1^{\perp[1]}(z_1)\overline{H}_1^{\perp[1]}(z_2)$$

$$B(y) = y(1-y) \overset{cm}{=} \frac{1}{4}\,\textit{sin}^2\,\Theta$$

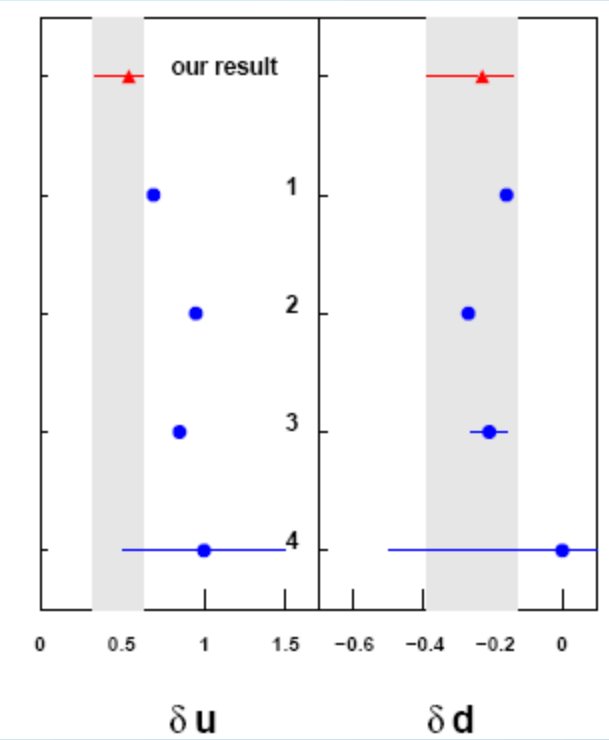
Net (anti-)alignment of transverse quark spins

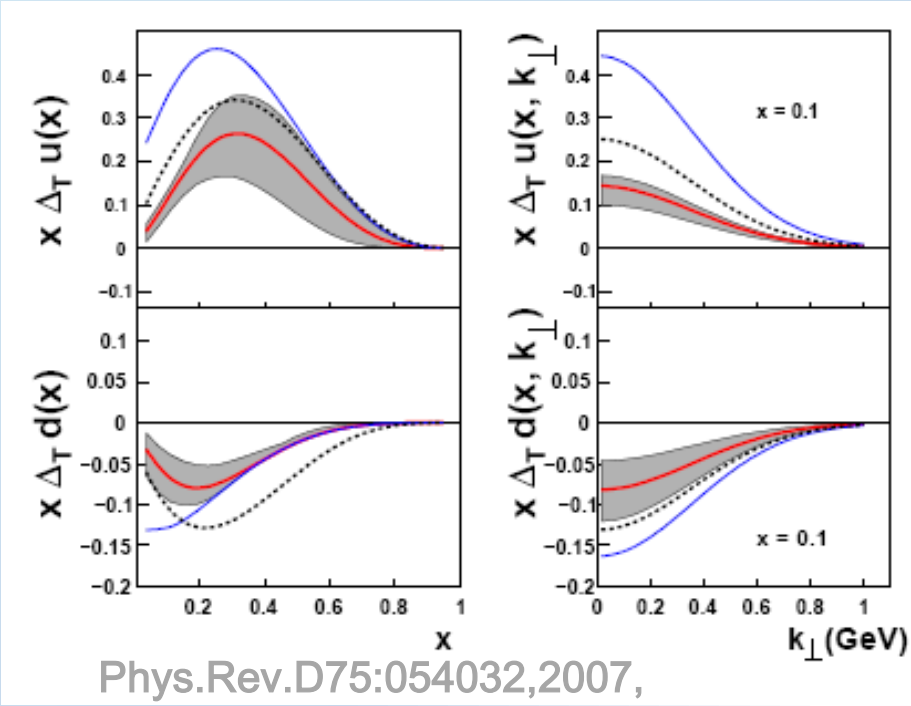
Final Collins results

- First direct measurement of the Collins effect:
  (PRL96: 232002)
- Nonzero asymmetries
- Belle 547 fb^{-1} data set
  (PRD78:032011)



First global analysis from Collins Hermes, Compass d and Belle data





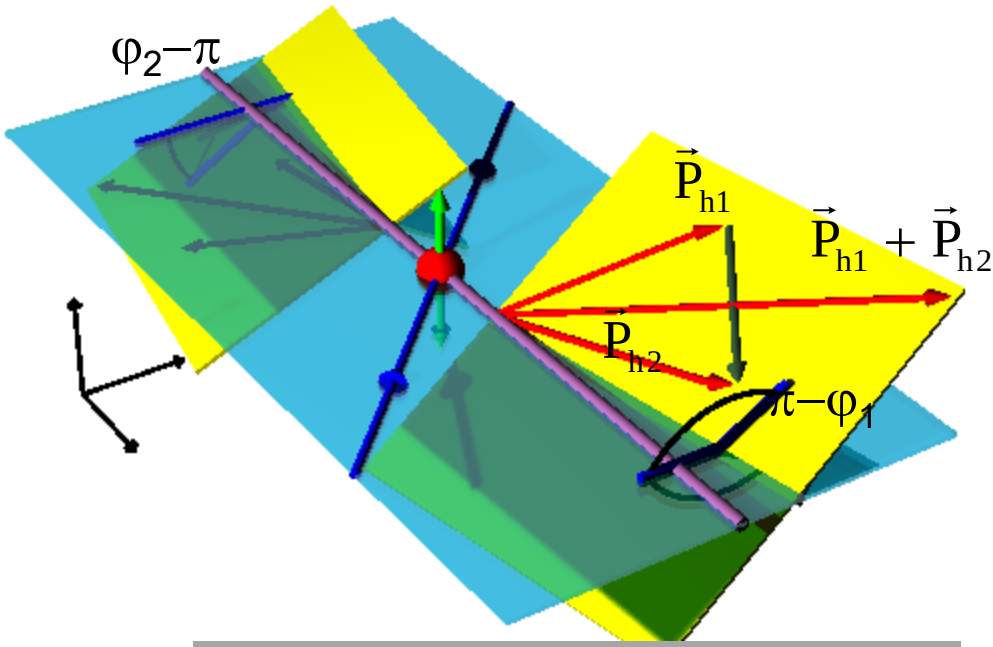
Phys.Rev.D75:054032,2007,
update in Nucl.Phys.Proc.Suppl.1
91:98-107,2009

- First results available, still open questions from evolution of Collins FF and transverse momentum dependence

Interference Fragmentation – thrust method

- $e^+e^- \rightarrow (\pi^+\pi^-)_{jet1}(\pi^+\pi^-)_{jet2}X$
- Stay in the mass region around ρ-mass
- Find pion pairs in opposite hemispheres
- Observe angles $\varphi_1+\varphi_2$ between the event-plane (beam, jet-axis) and the two two-pion planes.
- Transverse momentum is integrated (universal function, evolution easy → directly applicable to semi-inclusive DIS and pp)
- Theoretical guidance by papers of Boer,Jakob,Radici[PRD 67,(2003)] and Artru,Collins[ZPhysC69(1996)]
- Early work by Collins, Heppelmann, Ladinsky [NPB420(1994)]

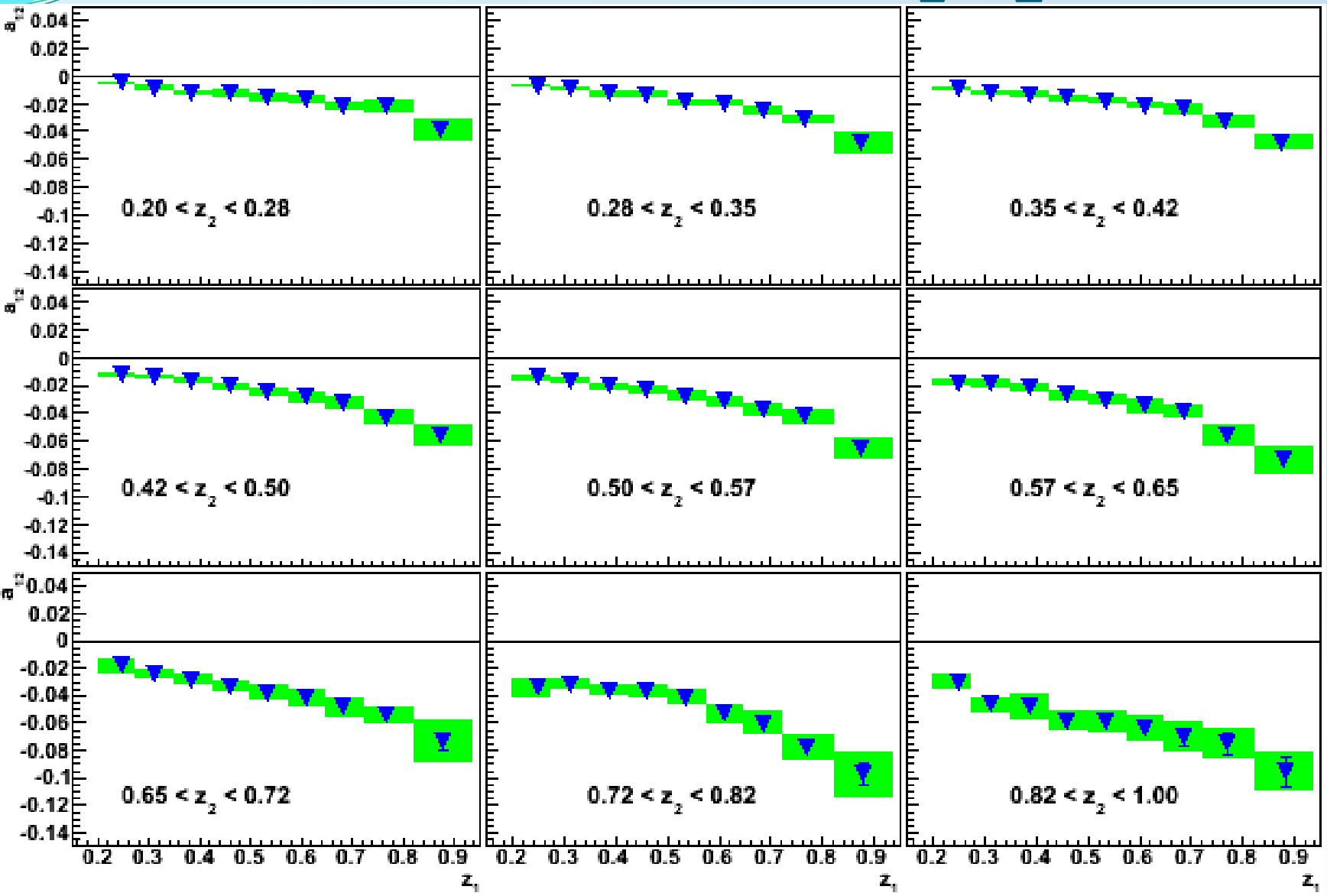
$$A \propto H_1^{\sphericalangle}(z_1, m_1)\overline{H}_1^{\sphericalangle}(z_2, m_2)\cos(\varphi_1 + \varphi_2)$$



Model predictions by:

- Jaffe et al. [PRL **80,**(1998)]
- Radici et al. [PR**D 65,**(2002)]

Results for 9x9 z_1 z_2 binning

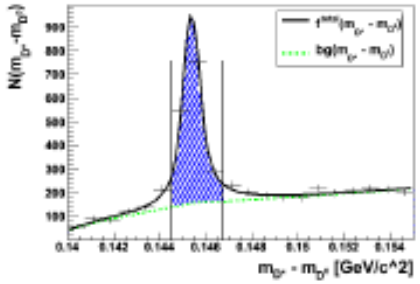


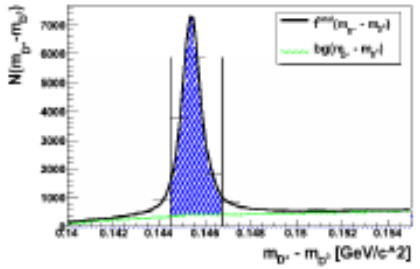
2. Unpolarized Fragmentation Functions- New precision measurement at Q^2 = 100 GeV^2 in progress at Belle

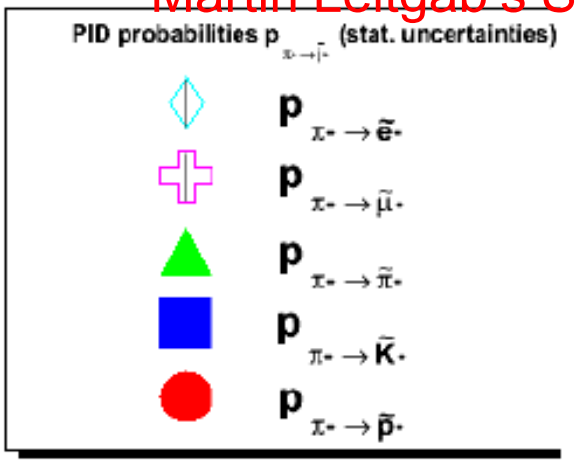
Martin Leitgab's Spin 2010 talk

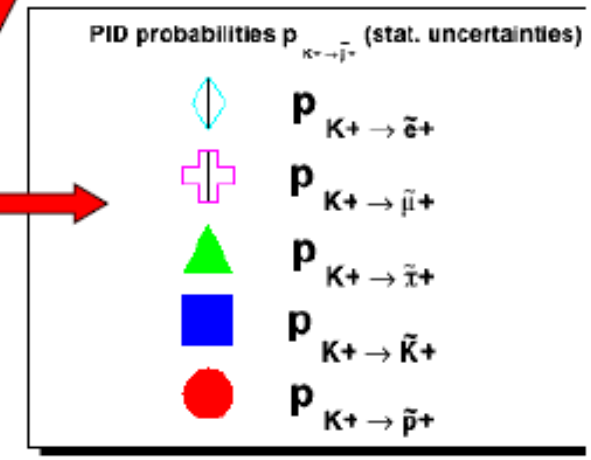
Extensive PID studies PID probabilities extracted from real data over wide kinematic range:

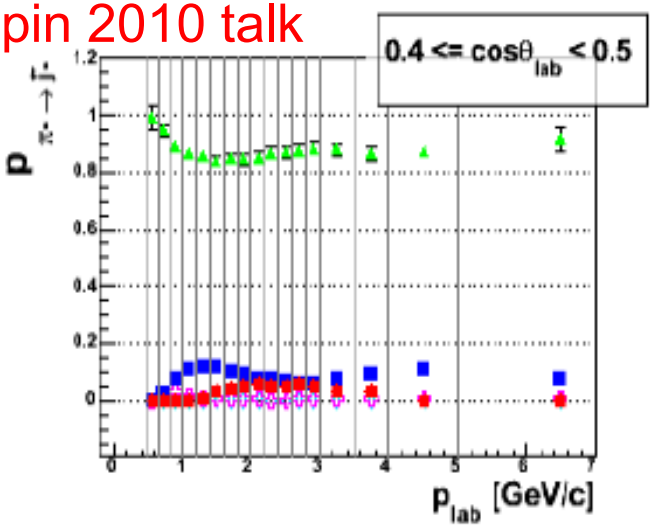
e.g. $D^* \rightarrow \pi_{slow}\,(D^0 \rightarrow \pi_{fast}\, K)$

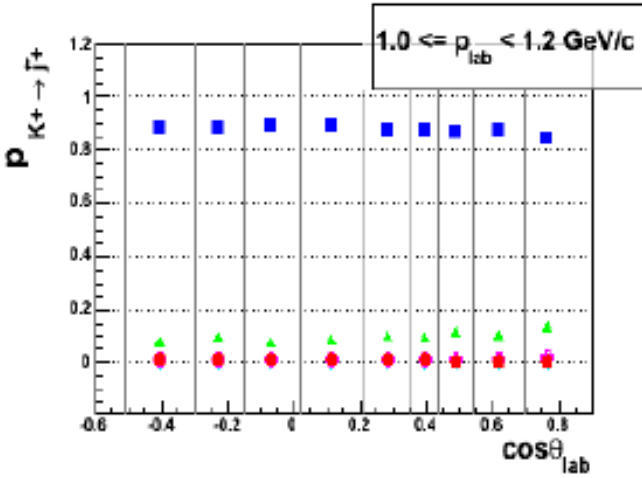










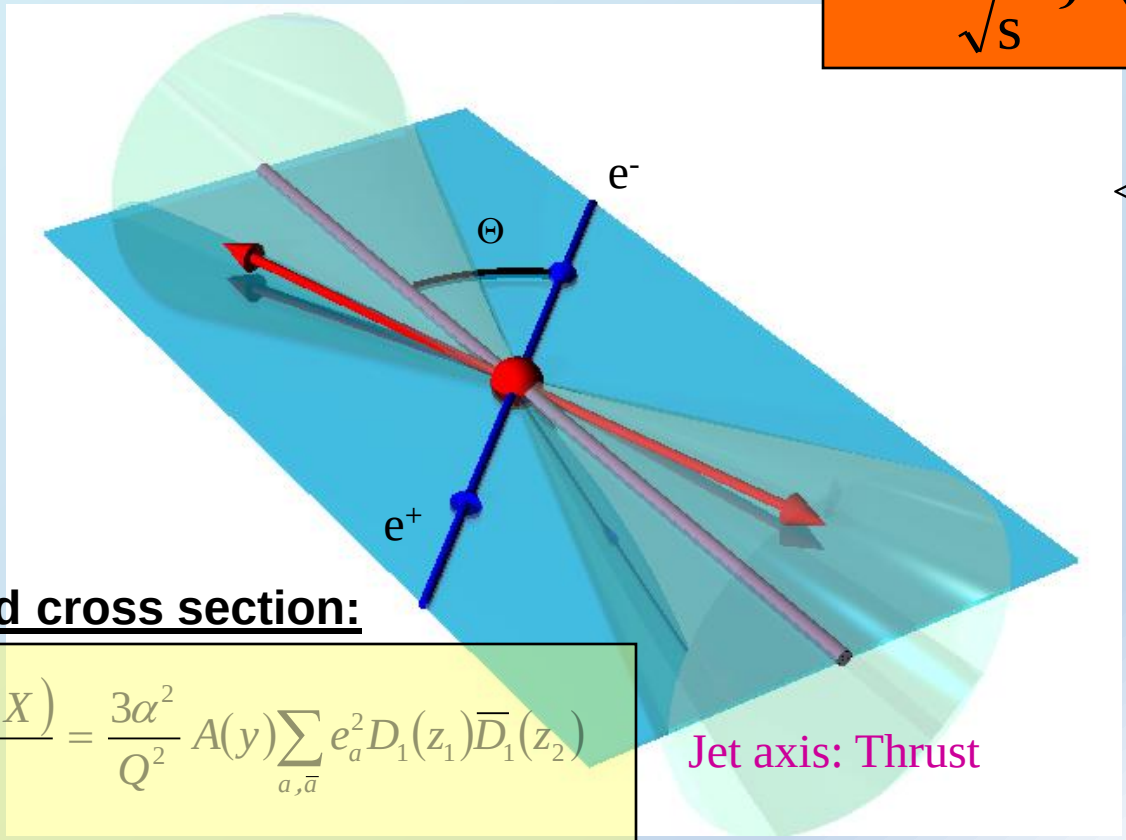


further corrections for momentum smearing, acceptance effects

Event Structure for hadron pairs in e^+e^- annihilation

e^+e^- CMS frame:

$$z = \frac{2E_h}{\sqrt{s}}, \quad \sqrt{s} = 10.52\,GeV$$



$\langle N_{h^+,-} \rangle = 6.4$

Jet axis: Thrust

Spin averaged cross section:

$$\frac{d\sigma(e^+e^- \to h_1 h_2 X)}{d\Omega dz_1 dz_2} = \frac{3\alpha^2}{Q^2} A(y) \sum_{a,\bar{a}} e_a^2 D_1(z_1) \bar{D}_1(z_2)$$

$$A(y) = \left(\frac{1}{2} - y + y^2\right) \overset{(cm)}{=} \frac{1}{4}\left(1 + cos^2\,\Theta\right)$$

Unpolarized 2-hadron fragmentation

Favored	= u→π^+,d→π^-,cc.
Unfavored	= d→π^+,u→π^-,cc.

- Detect two hadrons simultaneously:

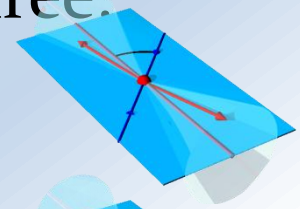
  e^+e^-→hhX
- If two hadrons in opposite hemispheres one obtains sensitivity to favored/ disfavored fragmentation:

- Unlike-sign pion pairs (U):
  (favored x favored + unfavored x unfavored)
- Like-sign pion pairs (L):
  (favored x unfavored + unfavored x favored)
- any charge hadron pairs (C):
  (favored + unfavored) x (favored + unfavored)

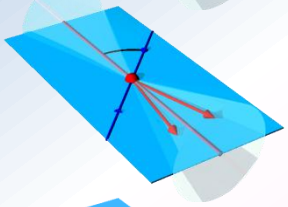
- Difficulty: contribution from one quark fragmentation q→hhX

→measure all three:

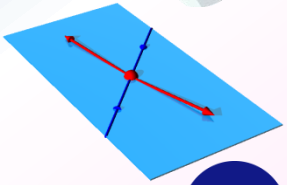
- $(hh)_{jet1}$ X



- $(h)_{jet1}(h)_{jet2}$X



- hhX,



( ) requires thrust cut

RIKEN