Two identical π interferometry

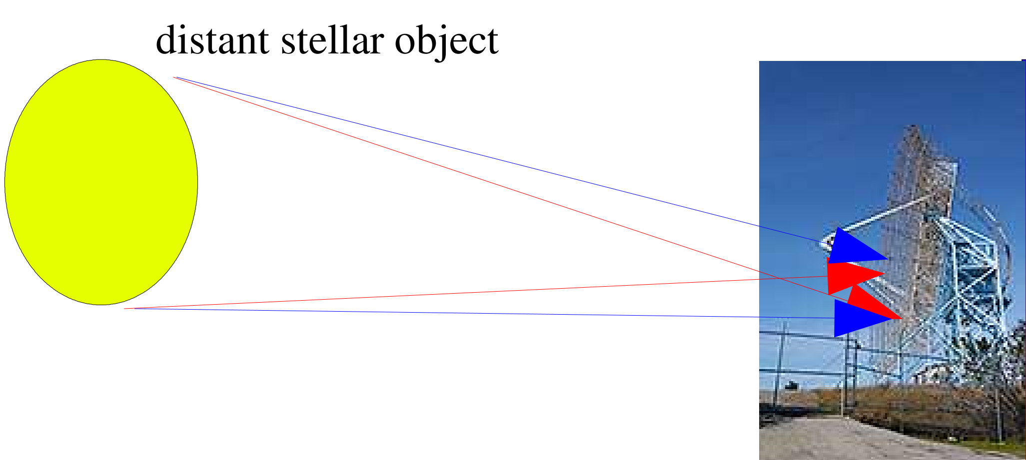
Nick Solomey

Outline:

- What is the quantum mechanics behind it
- Physics that MIPP can do which is uniquely interesting

Two identical boson interferometry

- Origin is in Astronomy, and is called the Hanbury-Brown and Twiss effect, Philosophy Magazine v54 1954.
- Two identical photons must obey Bose-Einstein statistics and are more likely to be found with identical momentum than with differing momentum.



The 2 possible paths of detecting 2 simultaneous photons is shown as blue and red paths, which interfere.

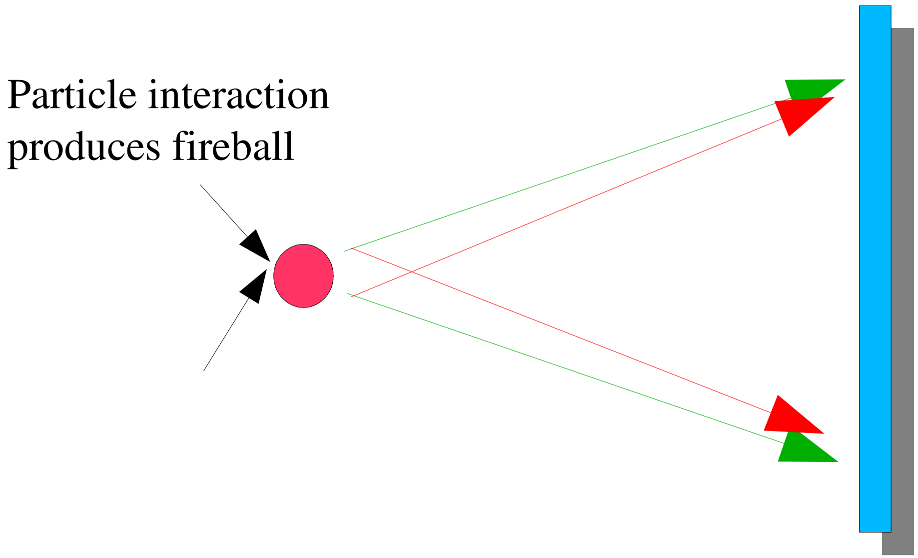
What can and cannot interfere:

- Must be bosons, integer spin particles
- Must be identical, same particle with the same charge
- Must be simultaneous
- Wavefunction must overlap in space

- Cannot be coherent, so $\pi^0 \rightarrow \gamma\gamma$ the two gammas are not able to interfere. The two particles must have no knowledge of each other at creation.

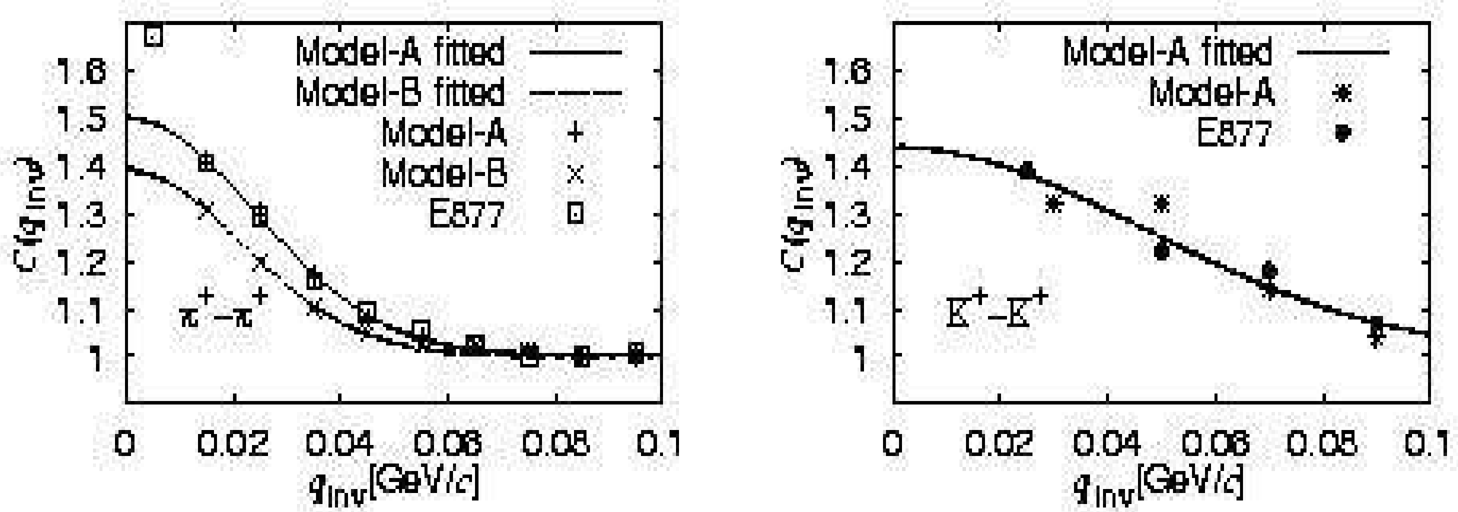
Origin of affect in particle physics:

- It was Goldhaber PRL v3 1959 that first accidentally saw this affect as an angular preference for pions at BNL.
- Independently in 1958 the Russian Physicist Landau has proposed using the HBT effect in particle physics interactions to study the lifetime and size of a ”fireball”.



Particles detected away from fireball and $q = |p_1 - p_2|$

Momentum Observations:



- Take all the π^+ in an event and compute *q* for each pair.

- Take a single π^+ from one event and compute *q* between it and all π^+ from another event to get the background.

- Take the bin-by-bin ratio of these two histograms to see the quantum mechanics HBT affect.

Known problems to avoid:

- Ghost tracks will cause a fake interference peak, often cuts are applied to make sure that the tracks being compared are far enough apart.
- Beam particles when compared to events with other beam particles or particles that have lightly interacted cause a fake interference peak in the background histogram of out of time tracks.

Previous Physics with this affect:

- With large statistics the shape of the constructive interference peak is fitted to give the size and shape of the interaction fireball as well as lifetime.
- It has been used to show the size of the projectile and target particle.
  - proton proton shows ~0.8 fm
  - ^{32}S + Au showed ~5.5 fm
- Using K^+ or K^- projectiles can be very exciting for comparing, plus like in K^0 radius is input to T and CP violation and can be for K^+ and K^-?

Interesting Physics:

T and CP violation sensitive to charged radius of the K^0.

A Measurement of the K^0 Charge Radius and a CP Violating Asymmetry Together with a Search for CP Violating E1 Direct Photon Emission in the Rare Decay $K_L \to \pi^+\pi^-e^+e^-$

E. Abouzaid[4], M. Arenton[11], A.R. Barker[5], L. Bellantoni[7], A. Bellavance[9], E. Blucher[4], G.J. Bock[7], E. Cheu[1], R. Coleman[7], M.D. Corcoran[9], G. Corti[11], B. Cox[11], A.R. Erwin[12], C.O. Escobar[3], A. Glazov[4], A. Golossanov[11,†], R.A. Gomes[4], P. Gouffon[10], K. Hanagaki[8], Y.B. Hsiung[7], H. Huang[5], D.A. Jensen[7], R. Kessler[4], K. Kotera[8], A. Ledovskoy[11], P.L. McBride[7], E. Monnier[4,*], K.S. Nelson[11], H. Nguyen[7], R. Niclasen[5], H. Ping[12], X.R. Qi[7], E.J. Ramberg[7], R.E. Ray[7], M. Ronquest[11], E. Santos[10], J. Shields[11], W. Slater[2], D. Smith[11], N. Solomey[4], E.C. Swallow[4,6], P.A. Toale[5], R. Tschirhart[7], C. Velissaris[12], Y.W. Wah[4], J. Wang[1], H.B. White[7], J. Whitmore[7], M. Wilking[5], B. Winstein[4], R. Winston[4], E.T. Worchester[4], M. Worchester[4], T. Yamanaka[8], E.D. Zimmerman[5], R.F. Zukanovich[10]
(KTeV Collaboration)[1]

K^0 radius ~0.3i fm ! i.e. $\langle r_K \rangle^2 = -0.077\ \mathrm{fm}^2$

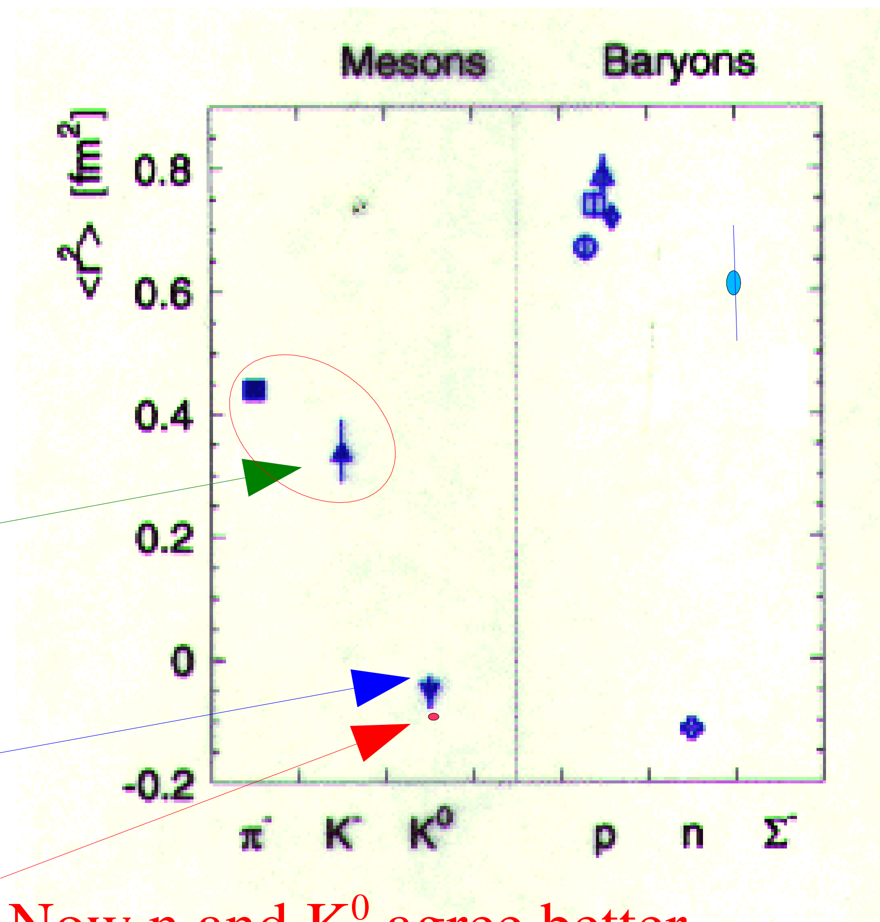
- **Compare K^0 and charged K radius, unequal** but related.
- **Compare K^+ and K^- radius**
- **Compare to affects with other projectile particles: π, p, Hyperons (Σ^+** r=0.6 fm**) and heavy ions on proton**

Current knowledge of radius:

These come from both HBT fireball, electron back scattering and decay asymmetry parameters:

Can improve charged Kaon and compare K^+ and K^-, which would be a first. Plus no reason π and K meson should be different.

Old ε'/ε before KTeV and NA48



New KTeV radius with error bar! Now n and K^0 agree better. See hep-ex/0508010. K^0 is measured differently than p, π^+ or K^+.

Strange particle production with p-LH2

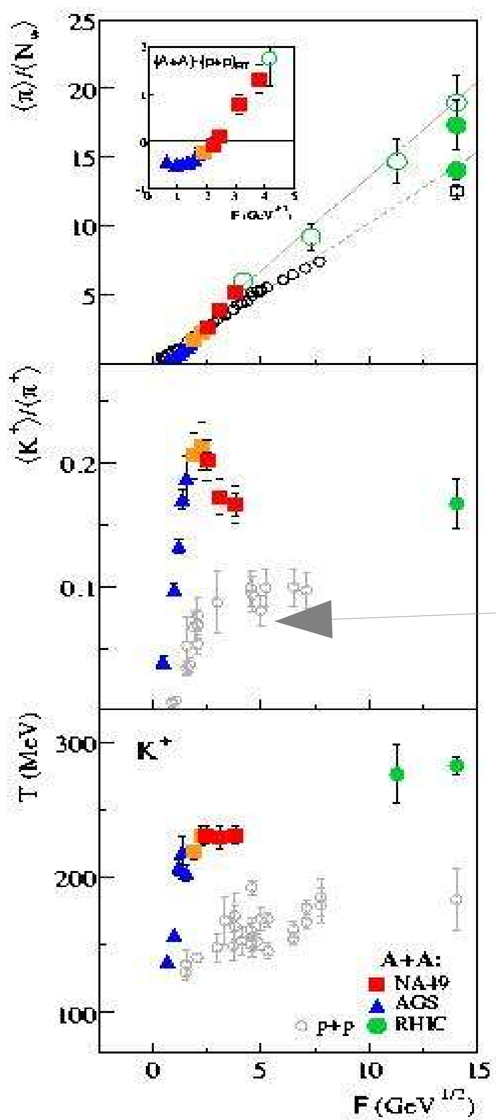


FIG. 2: Energy dependence of the mean pion multiplicity per wounded nucleon, the $\langle K^+\rangle/\langle\pi^+\rangle$ ratio and the inverse slope parameter T of the transverse mass spectra of K^+ mesons measured in central Pb+Pb (Au+Au) collisions (solid symbols) compared to results from p+p($\bar{p}$) reactions (open dots). The changes in the SPS energy range (solid squares) suggest the onset of the deconfinement phase transition.

- Low momentum p-p references for heavy ion physics searches for quark-gluon plasma used old LH2 bubble chamber data as a <u>reference</u>.
- These could use a new improved measurement.
- Study ratio of yields:

$\langle K^+\rangle/\langle\pi^+\rangle$

$\langle\Lambda\rangle/\langle N\rangle$

$\langle K^0\rangle/\langle\pi^+\rangle$

Checkered flag at the finish line

Conclusion:

- **MIPP can use the HBT 2 π interferometry to produce uniquely interesting physics.** Advantage of not needing a lot of the detector working.
  - It would only need the TPC with momentum and vertexing, but without particle ID since most of the particles are pions.
  - A detailed Monte-Carlo is not needed because reference comes from pions out of time with each other.
- Could be a very good analysis for a person who has been on MIPP from the beginning who wants to get out a few physics papers quickly.