K. Long, 4 January 2005

Relativity – Lecture 8

Relativistic collisions – applications III

Lecture 8: Collisions: Appl^{n} III

8.1 Elastic and inelastic collisions

- Relativistic energy: 'two contributions':
  - Rest-mass energy
  - 'Energy of motion'

  } $E = \gamma m_0 c^2$
- If collision causes internal structure of one (or more) objects to change, then rest-mass energy of object changes
- So, relativistic energy 'takes account' of such changes
- Conservation of energy and momentum:
  - Total relativistic energy always conserved
  - Total relativistic momentum always conserved

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- **Elastic collision:**
  - One in which the final state particles are the same as the initial state particles:
    e.g. $a + b \rightarrow a + b$
- **Inelastic collision:**
  - One in which final state particles differ from those in the initial state:
    e.g. $a + b \rightarrow c + d + e$

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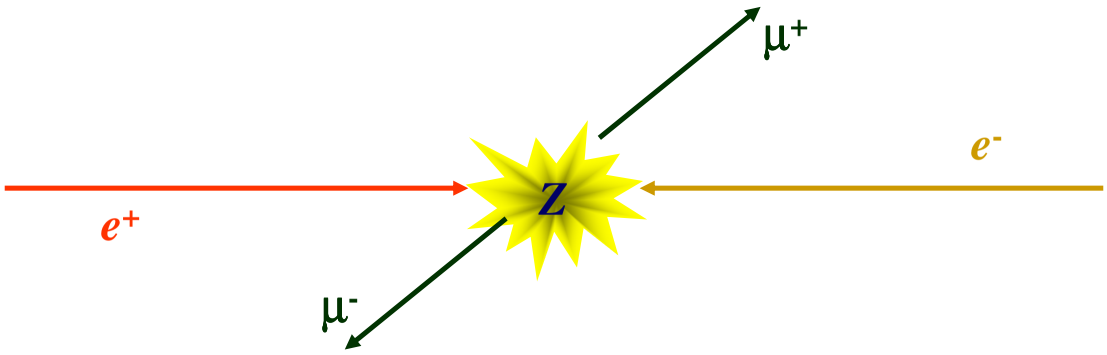
8.2 Annihilation in the centre of mass

- **Example:**



- **Can produce Z^0 at rest only if $E_{cms} \geq m_Z = 90$ GeV**

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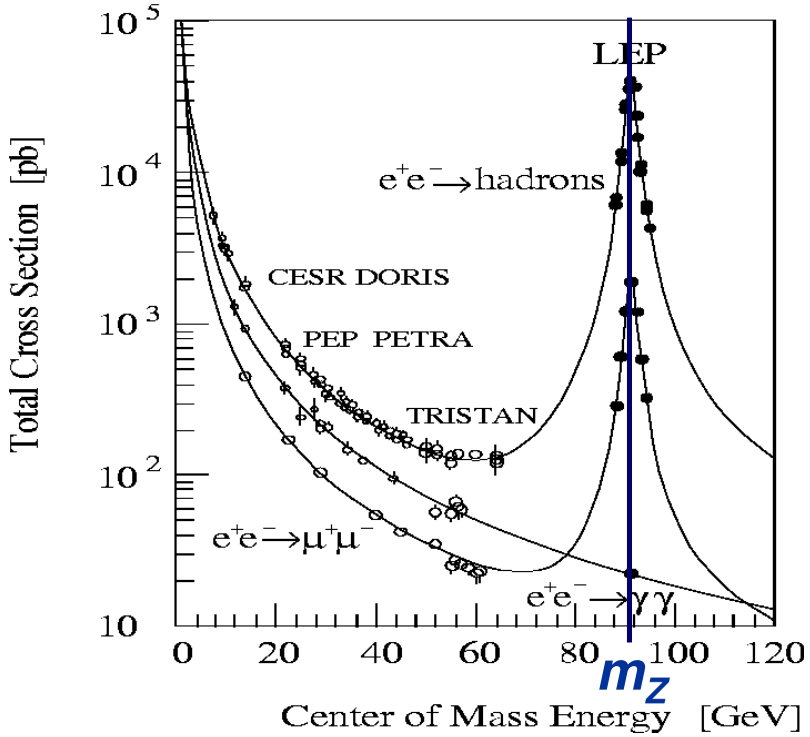
- Rate of reaction $e^+e^- \rightarrow Z^0$ as measured at LEP:



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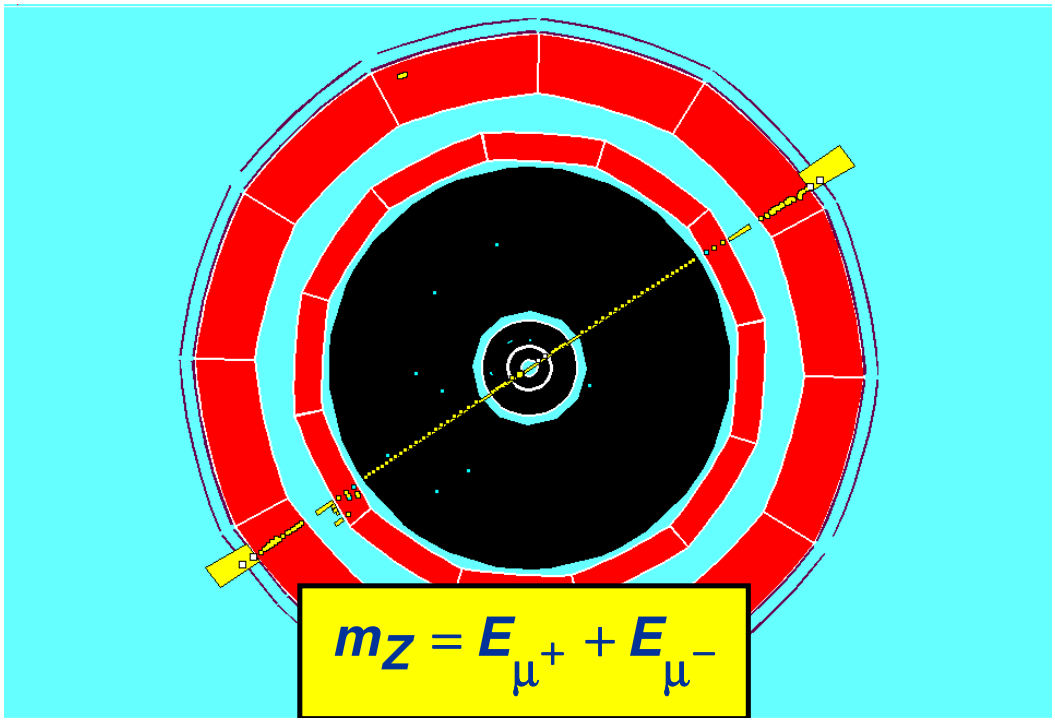
- Reconstruct m_Z from decay products:



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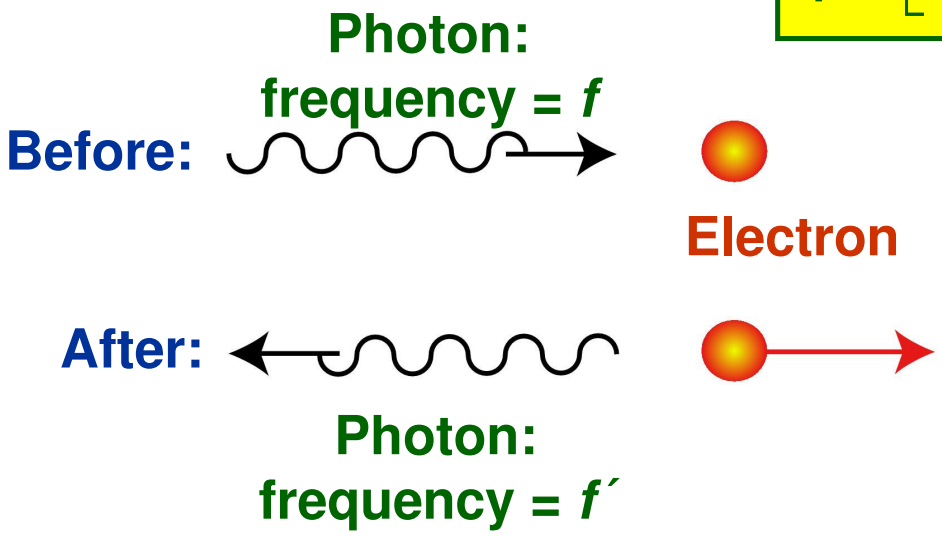
8.3 Scattering

- **Examples I:**
  - $\gamma + e^- \rightarrow \gamma + e^-$

$$\frac{f}{f'} = \left[1 + \frac{2hf}{m_e}\right]$$



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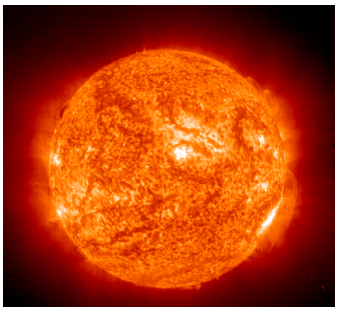
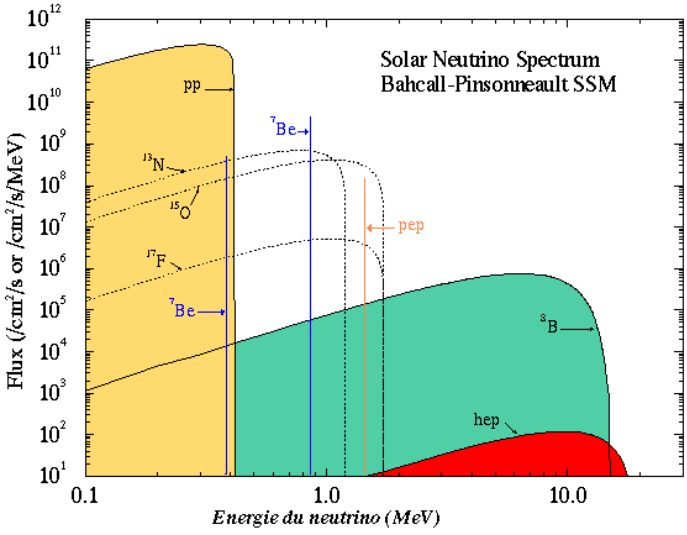
- **Examples II:**
  - $\nu_e + e^- \rightarrow \nu_e + e^-$ – tool for particle physicists



$pp \rightarrow {}^2H + e^+ + \nu_e$		
${}^2H + p \rightarrow {}^3He + \gamma$		
${}^3He + {}^3He \rightarrow {}^4He + 2p$		85%
${}^3He + {}^4He \rightarrow {}^7Be + \gamma$		15%
$e^- + {}^7Be \rightarrow {}^7Li + \nu_e$		
${}^7Li + p \rightarrow 2\,{}^4He$		
$p + {}^7Be \rightarrow {}^8B + \gamma$		0.02%
${}^8B \rightarrow {}^8Be^* + e^+ + \nu_e$		
${}^8Be^* \rightarrow 2\,{}^4He$		



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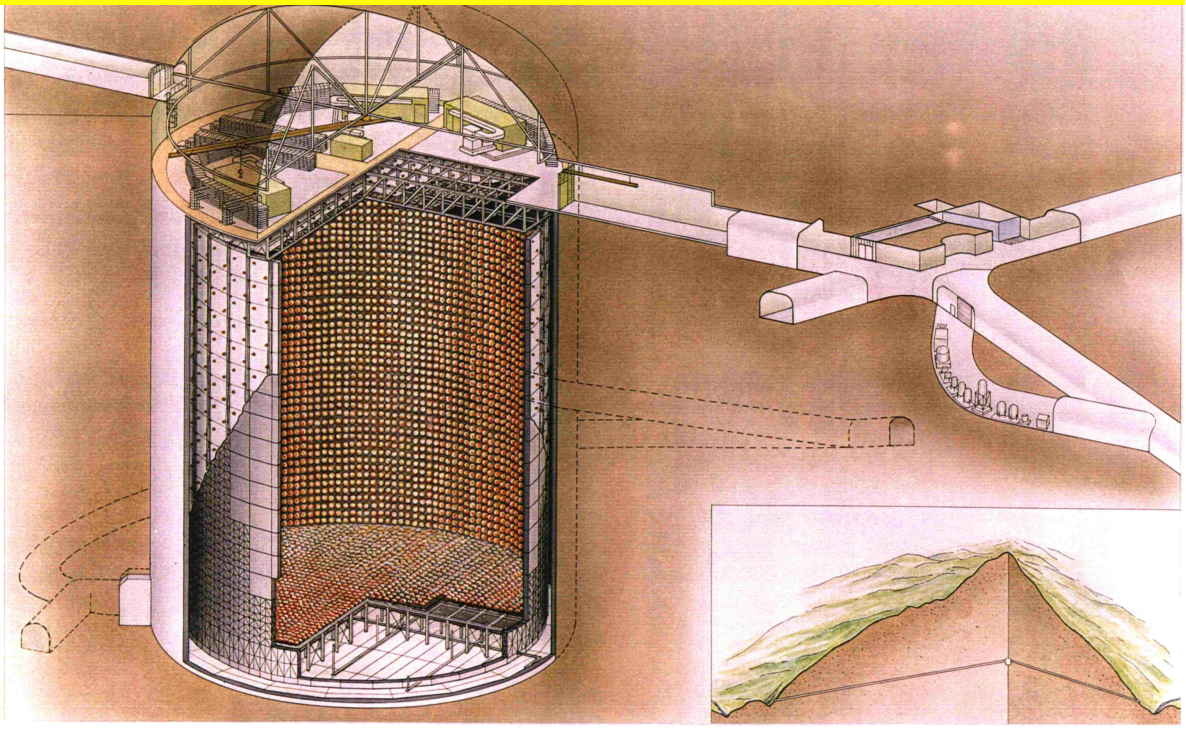

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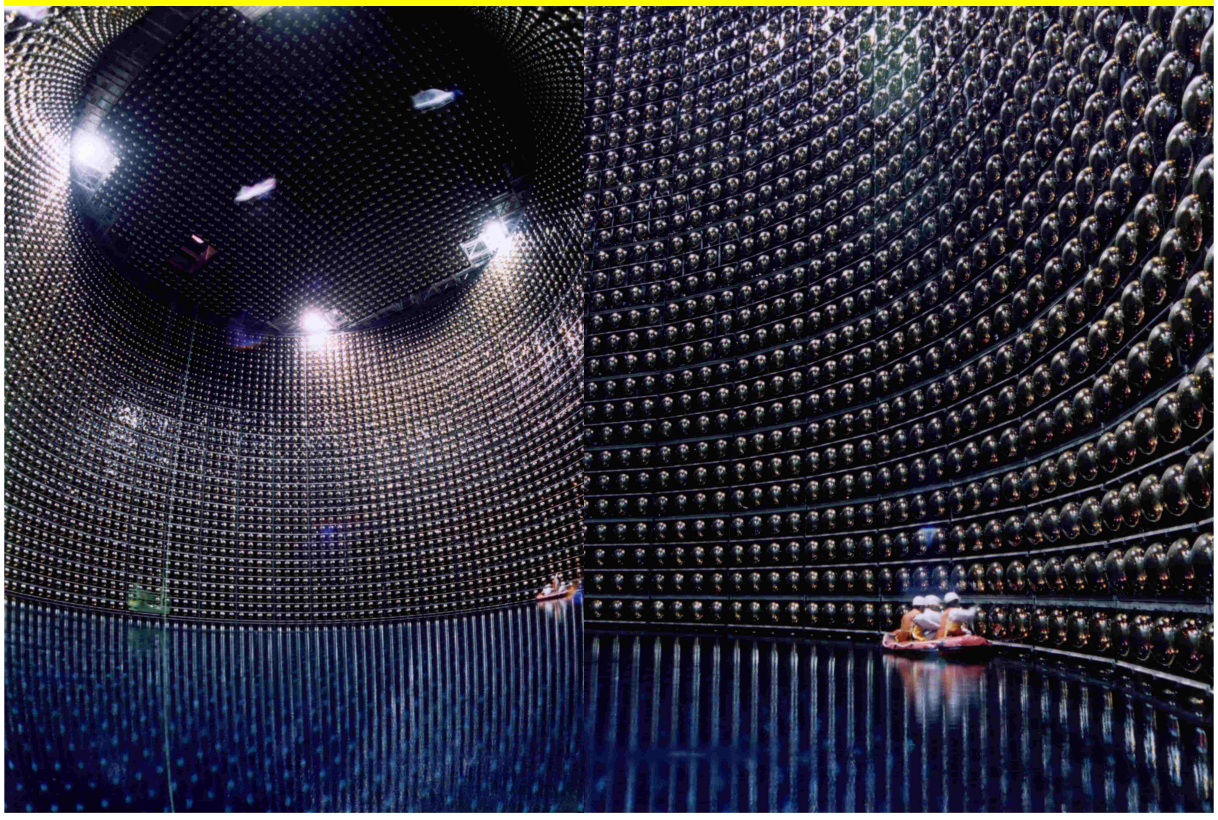

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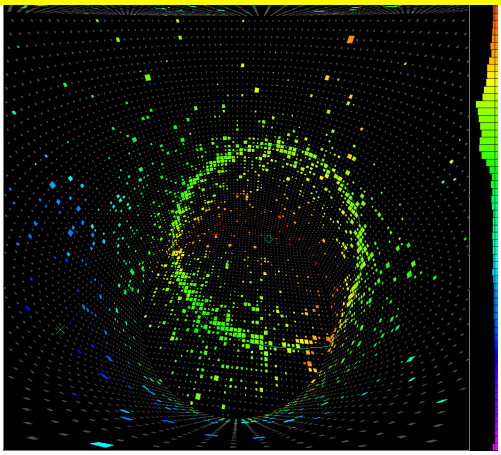
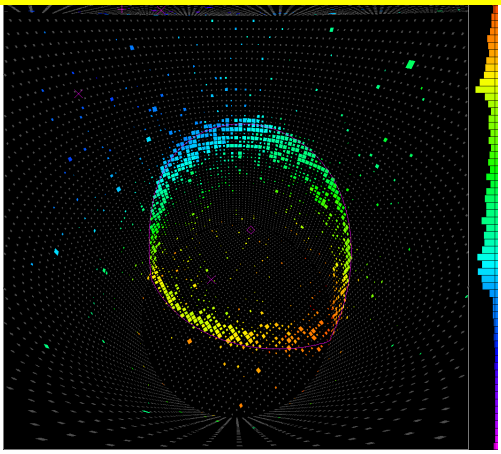
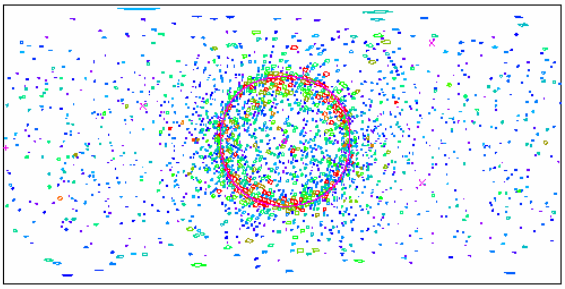
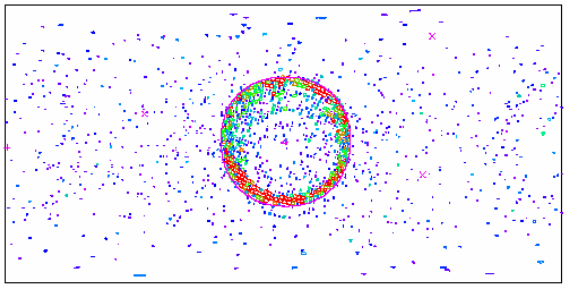




Electron-like



Muon-like



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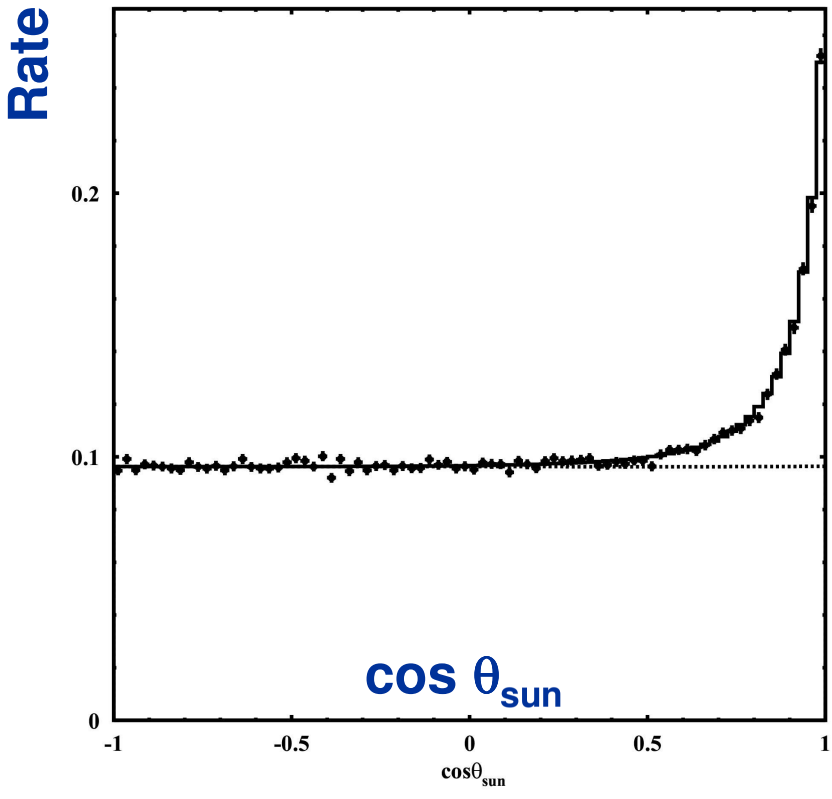

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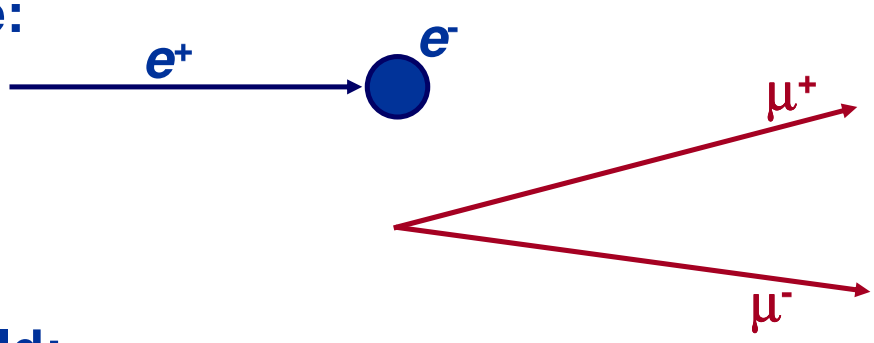
8.4 Annihilation with one particle at rest

- **Example:**
  - **Before:**
  - **After:**



- **Threshold:**
  - **Reaction may only take place if:**

$$E_e > \frac{2m_\mu^2}{m_e}$$