

**International Workshop on
NEW PARTIAL WAVE ANALYSIS TOOLS
FOR NEXT GENERATION HADRON SPECTROSCOPY EXPERIMENTS
June 20-22, 2012 Camogli, Italy**

PWA approach for j/ψ decays at BES

-----Automatic Generation of the Partial Wave Analysis Program For Physics Processes

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1. Brief Introduction to FDC
2. The Rules to Construct the Effective Lagrangian
3. FDC-PWA application
4. Summary

1. Brief Introduction

Feynman Diagram Calculation(FDC), The project was started from 1993.

PROGRESS IN FDC PROJECT. Nucl.Instrum.Meth.A534:241-245,2004

FDC Homepage:

<http://v-www.ihep.ac.cn/~wjx>

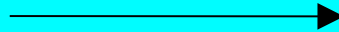
FDC-SM-and-Many-Extensions

FDC-NRQCD

FDC-MSSM

FDC-PWA

FDC-LOOP



There is a common kernel. The Source is written in REDUCE, RLISP.

FDC-PWA was started from 1998 and constructed for
BES partial wave analysis.

PWA: to decide the J^{PC} , mass, width and branch ratio of a resonant.

FDC-PWA: Powerful Tool

To work with high spin states (0, 1/2, 1, 3/2, 2, 5/2, 3, 7/2, 4, 9/2) and construct effective Lagrangians.

The expression of the effective interaction vertices and the propagators for the high spin states are quite lengthy.

The related amplitudes and amplitude squares are complicated.

There are many free parameters in the effective Lagrangian and these parameters will be fixed when the generated program is used to do Likelihood fitting of experimental data.

To generate a complete set of the Fortran sources to do the partial wave analysis on experimental data.

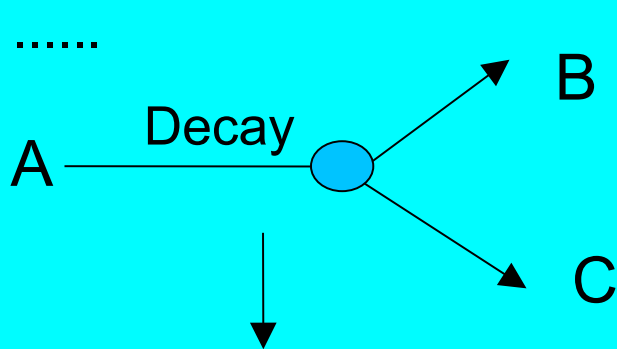
2. The Rule to Construct Effective Lagrangian For PWA

- Lorentz Invariance
- C-parity conservation
- P-parity conservation
- CP conservation
- $H = H^+$
-

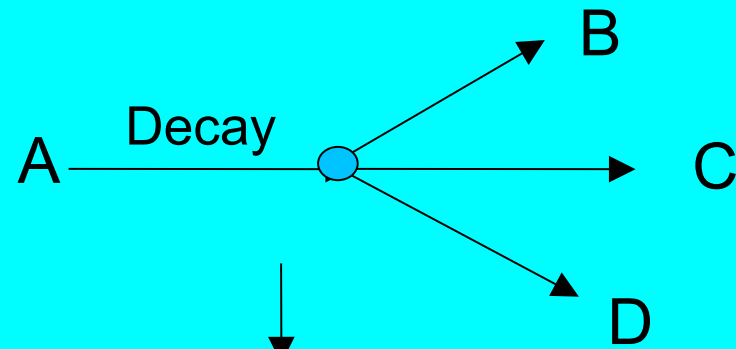


The Input is a list of all related particles.

The output is all interaction vertices



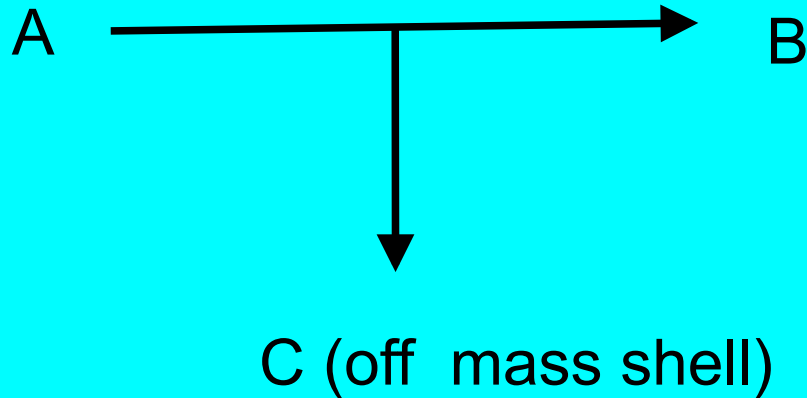
The coefficients of all the independent terms are constant



The coefficients of all the independent terms depend on two variables

Each Coefficient has independent phase factor
Each Propagator has suppression factor

For NN scattering, T-channel vertices must be considered:



The Coefficients of independent terms depend on the:

$$t = (P_A - P_B)^2$$

Option to apply Isopin symmetry:

$$\begin{pmatrix} p \\ n \end{pmatrix}, \quad \begin{pmatrix} \pi^+ \\ \pi^0 \\ \pi^- \end{pmatrix}, \quad \dots\dots\dots$$

- The propagator for resonance:

$$\frac{1}{p^2 - m^2 + im\Gamma}$$

- Suppression Factor for interaction vertices when the resonance is off mass shell:

Barrier, $e^{-|p^2 - m^2|/a}$

There is an option to choose the suppression factor

Physical Process

Input for a physical process: process, physical model,
Many options, histograms, scatter plots.

Generate Feynman Diagram

Manipulate amplitudes for each diagram and generate FORTRAN
source for calculation of amplitudes square

Find and properly treat all the resonance, t-channel
singularities, ...
and generate FORTRAN source for phase space integral and
fitting

Control flag and parameters
files
generated by FDC which can be
changed later by users:
flag.inp, amptable.inp,
fpara.inp, reson.inp

Users should prepare two files:
pdata1.dat –
 experiment events data file
pdata1.mc -
 phase space monte carlo event file

Compile FORTRAN programs and run 'fit' for likelihood fitting

Output: mplot.info, pep.res, mplot.hbook, dplot.hbook

3. FDC-PWA Application:

```
. > gmodel  
. > doall  
. > cd fort  
. > make  
. > fit
```

FDC-PWA: <http://v-www.ihep.ac.cn/~wjx/pwa/index.html>

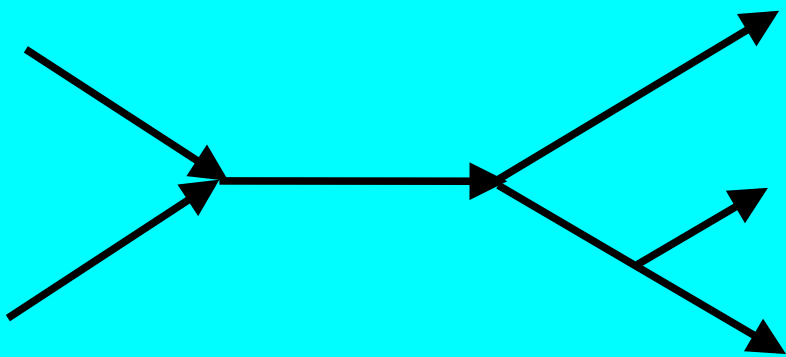
FDC-PWA Application For BEPC physics:

Generated a Effective Lagrangian at BES energy range (J/psi) with about 300 resonant (including high spin state up to spin=7/2)

Generated all the 2, 3, 4, 5, 6 final state decays of J/psi.

Used to do PWA analysis by BES Experimental Group.

Event Generator: There are event generator for each generated physical process, with the free parameters wating for PWA to fix.



4. Summary

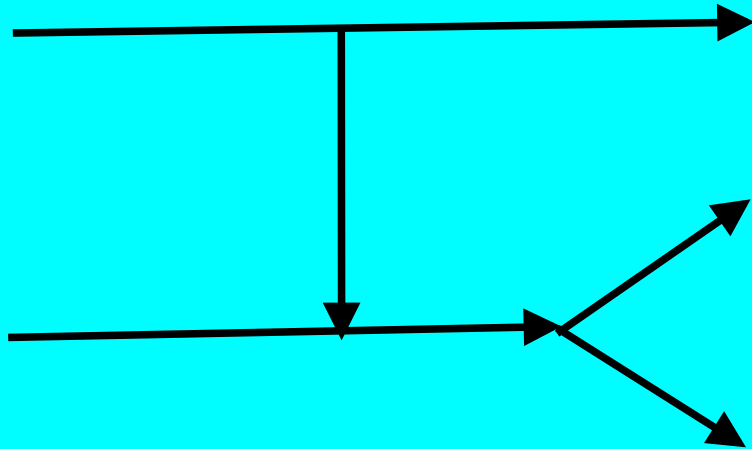
We supply a powerful tool: FDC-PWA

<http://v-www.ihep.ac.cn/~wjx/pwa/index.html>

- **To constructe the effective Lagrangian.**
- **To generate the complete set of Fortran source for PWA analysis.**
- **To generate an event generator.**
- **be used in BES PWA analysis since 1999.**
- **Could be used for any possible experiment.**

Thanks!

FDC-PWA Application on CSR Physics:



Example:

$$p+p \text{----} \rightarrow p+p$$

$$p+p \text{----} \rightarrow p+n+\pi$$

$$p+p \text{----} \rightarrow p+p+\pi$$

$p+p \rightarrow p+p$

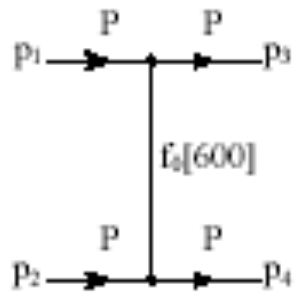


Diagram 1

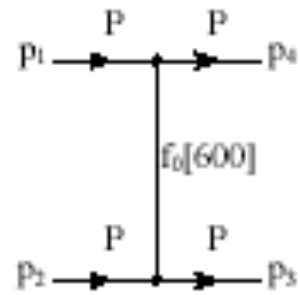


Diagram 2

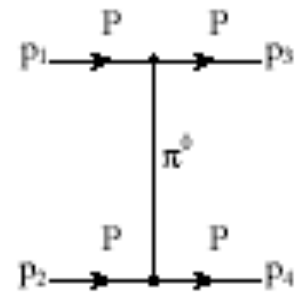


Diagram 3

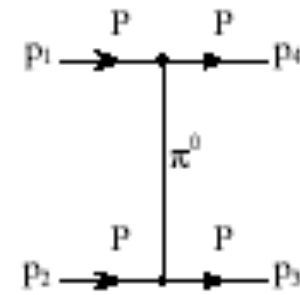


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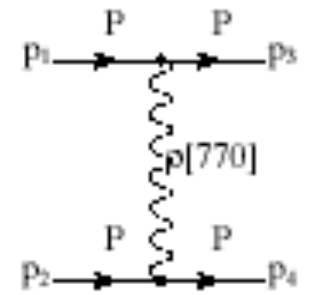


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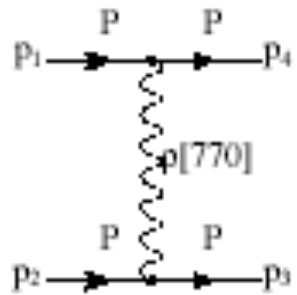
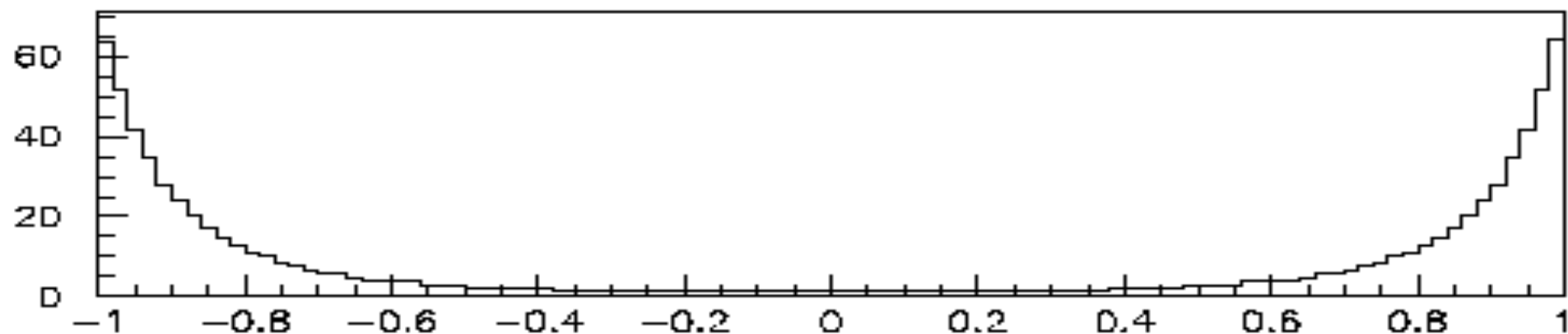
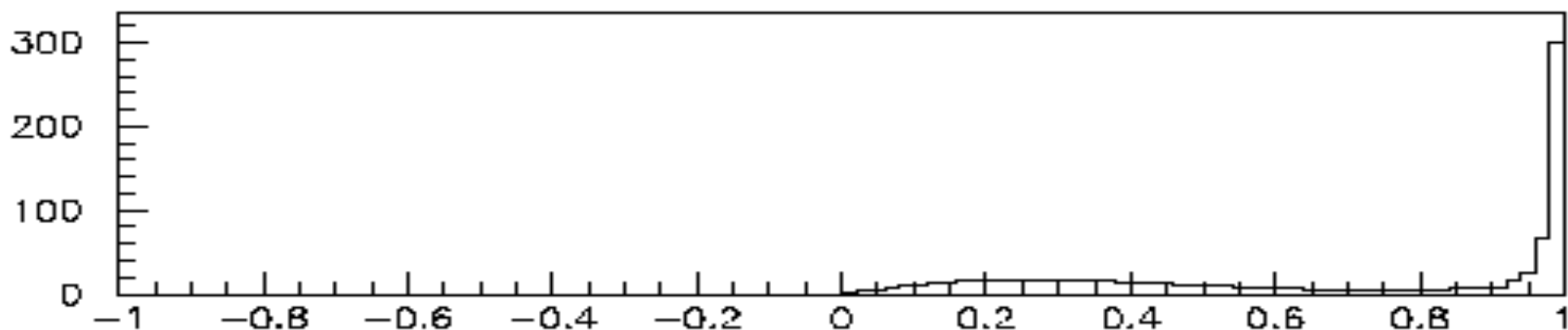


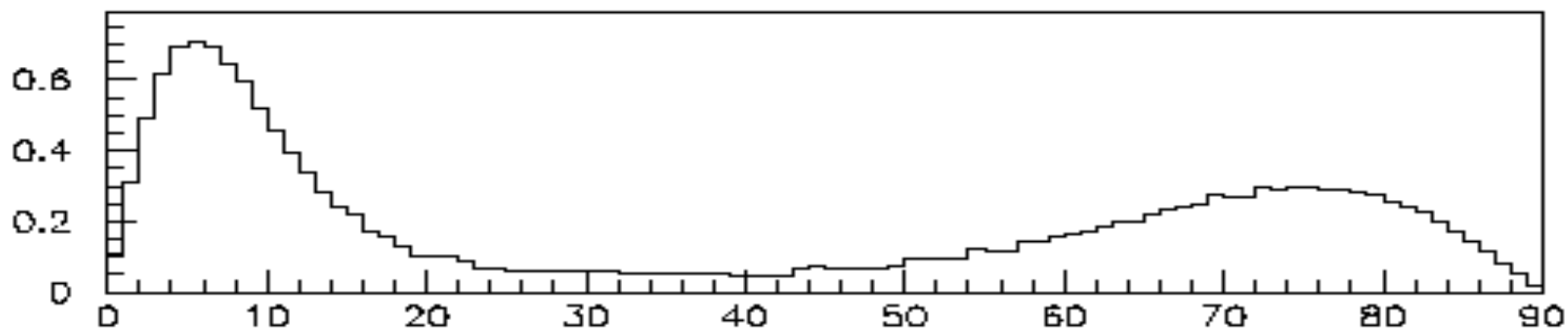
Diagram 6



cos of proton and beam in cm



cos of proton and beam in lab



θ of proton and beam in lab

$p+p \rightarrow p+n+\pi$

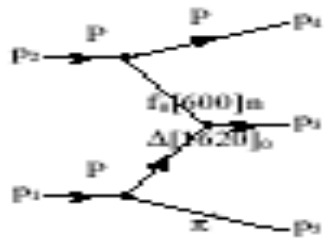


Diagram 1

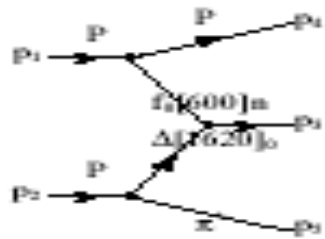


Diagram 2



Diagram 3

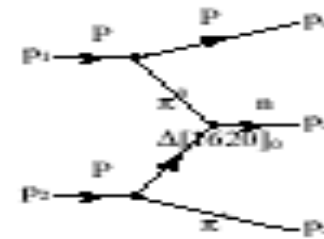


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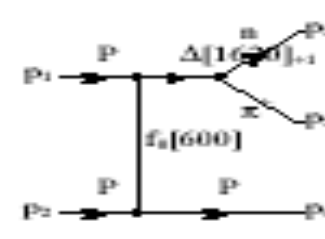


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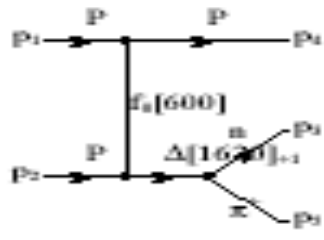


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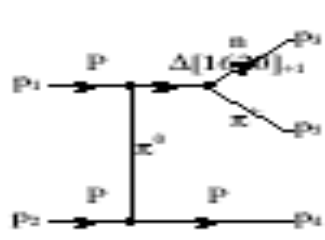


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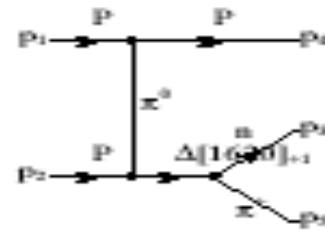


Diagram 8



Diagram 9

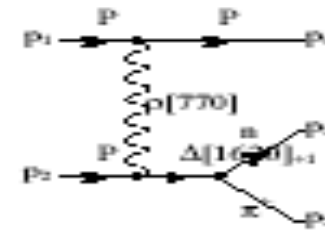


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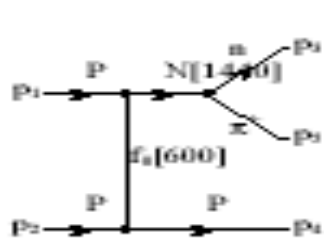


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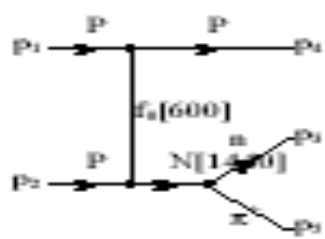


Diagram 12



Diagram 13

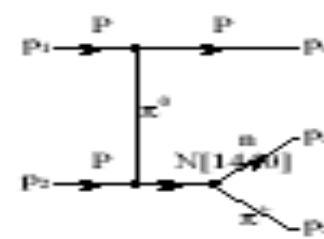


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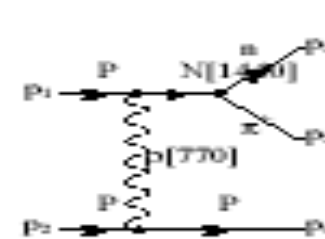


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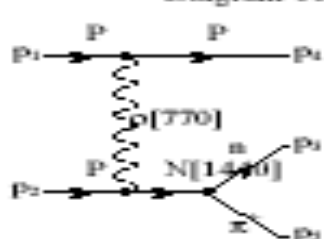


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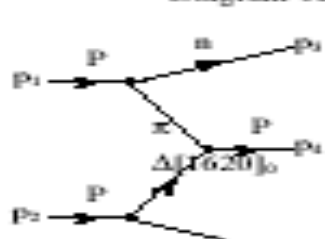


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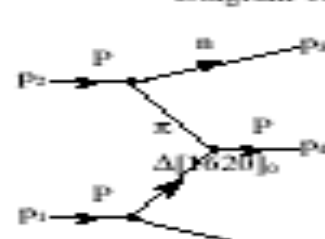


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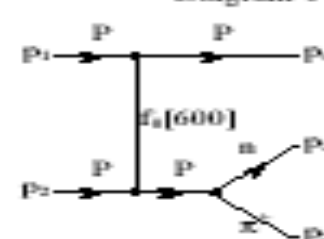


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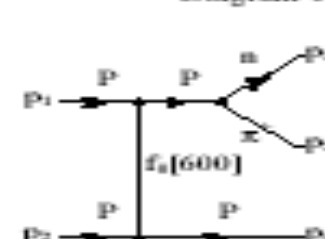


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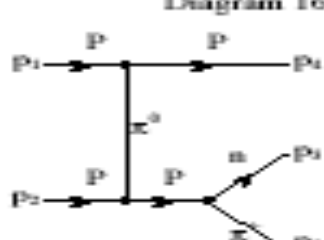


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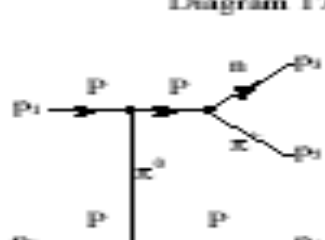


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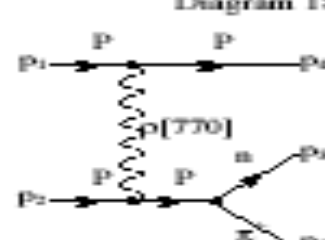


Diagram 23



Diagram 24

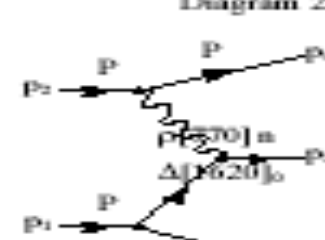


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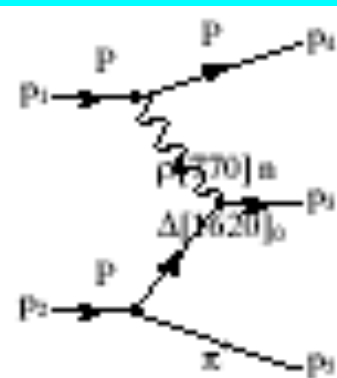


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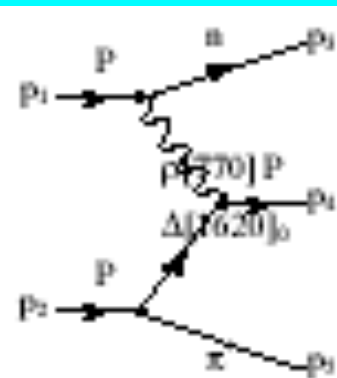


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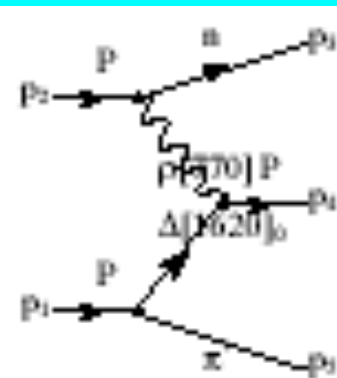


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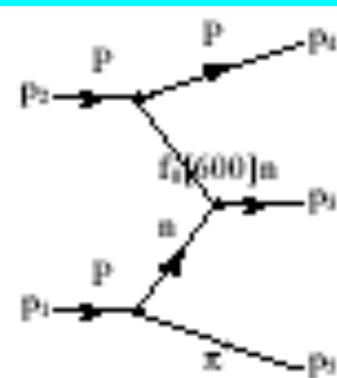


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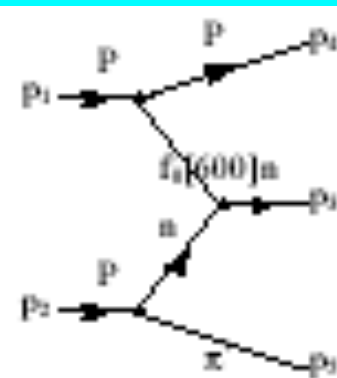


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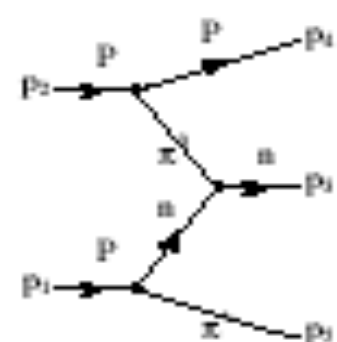


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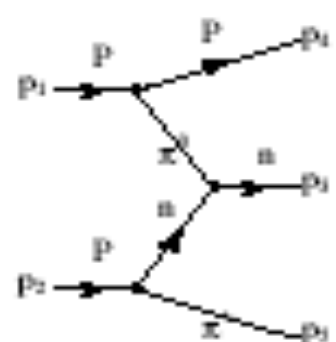


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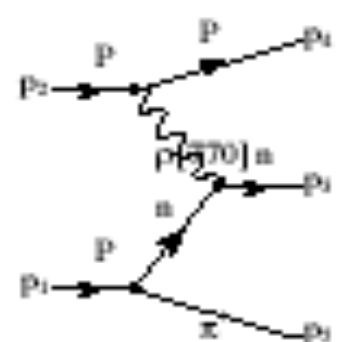


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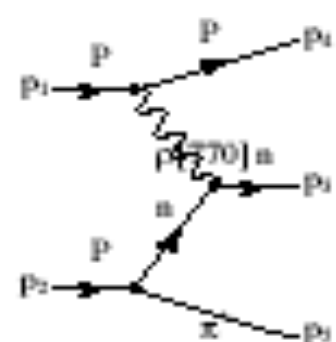


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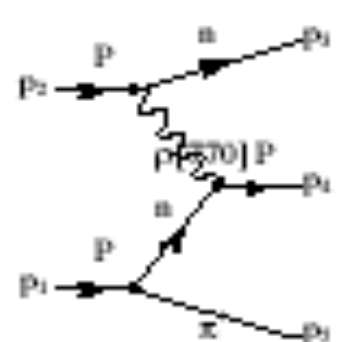


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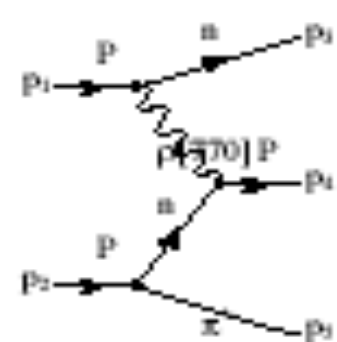


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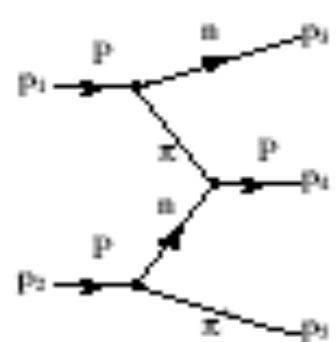


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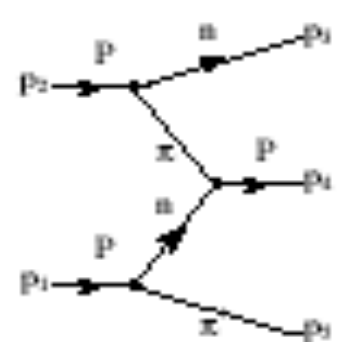
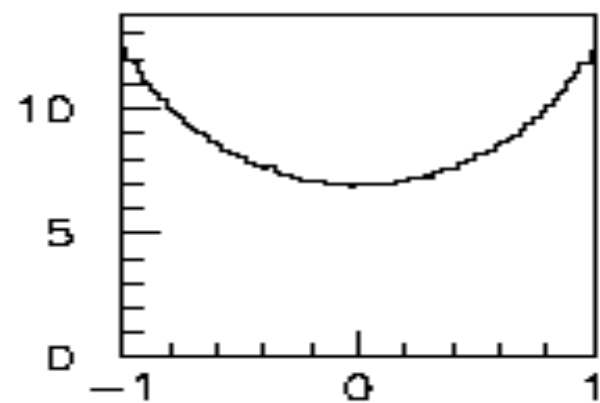
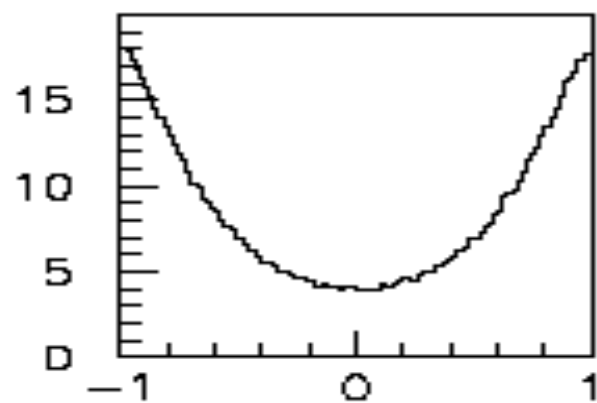


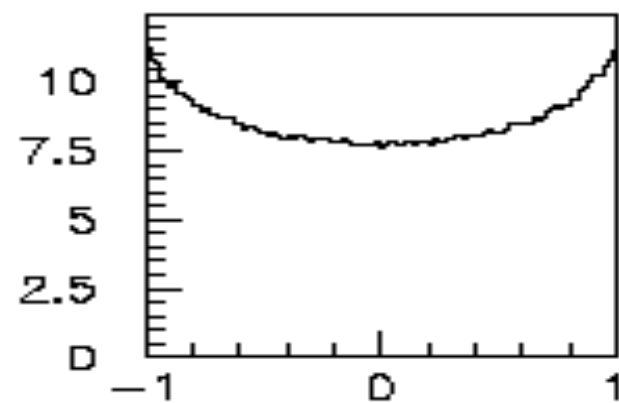
Diagram 38



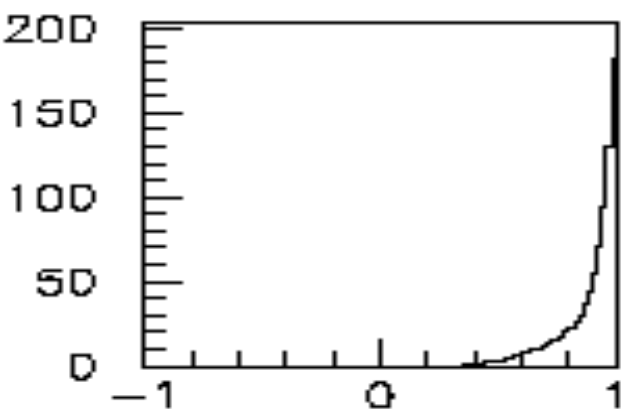
cos of n and beam in cm



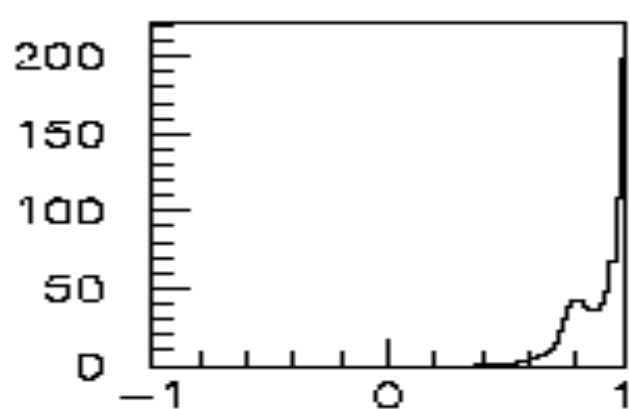
cos of p and beam in cm



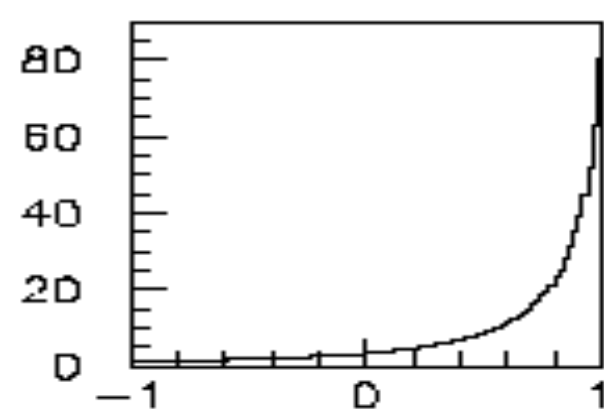
cos of pi and beam in cm



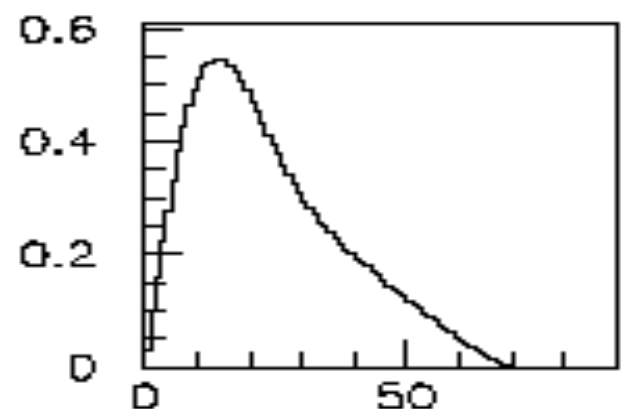
cos of n and beam in lab



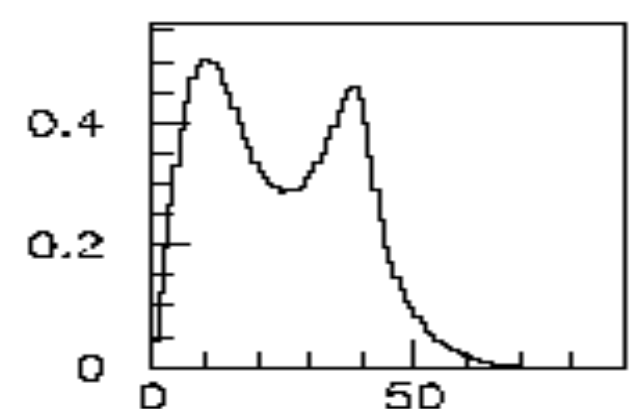
cos of p and beam in lab



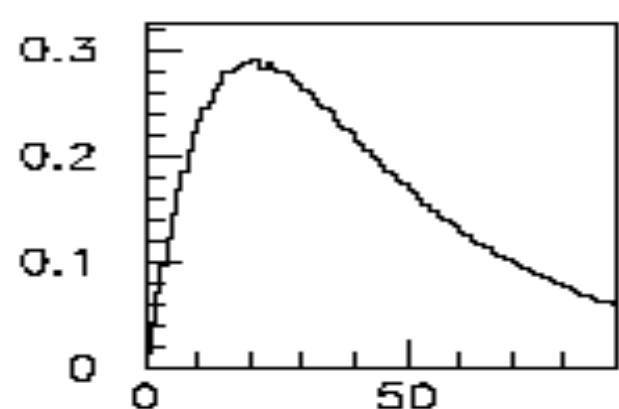
cos of pi and beam in lab



θ of n and beam in lab



θ of p and beam in lab



θ of pi and beam in lab

$p+p \rightarrow p+p+\pi$

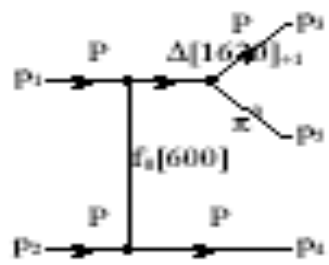


Diagram 1

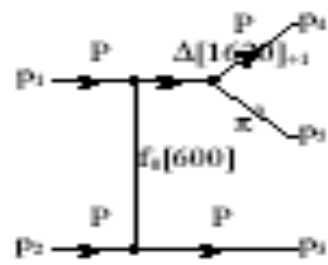


Diagram 2

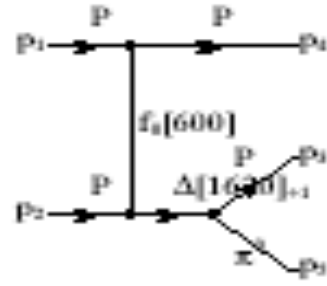


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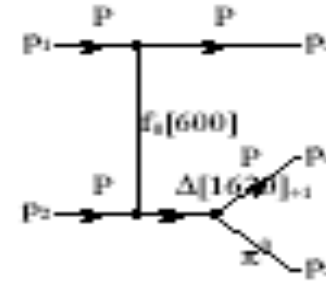


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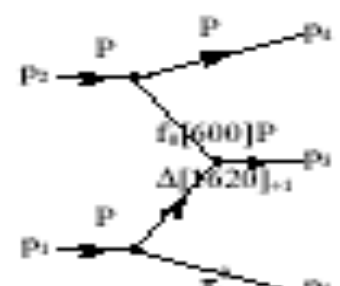


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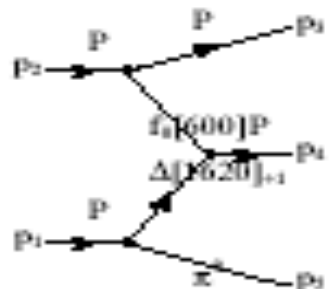


Diagram 6



Diagram 7



Diagram 8



Diagram 9

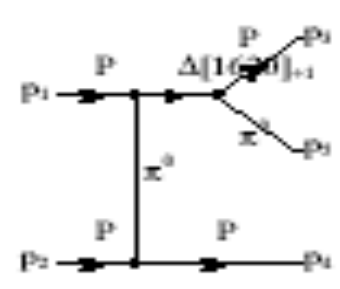


Diagram 10

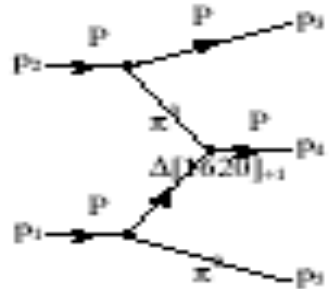


Diagram 11

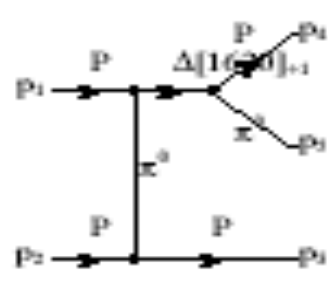


Diagram 12



Diagram 13



Diagram 14

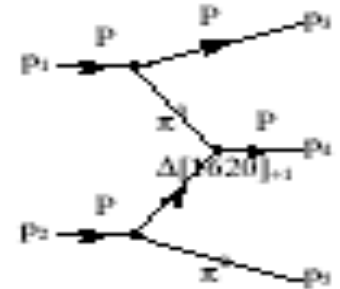


Diagram 15

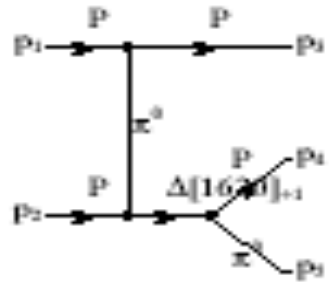


Diagram 16



Diagram 17



Diagram 18

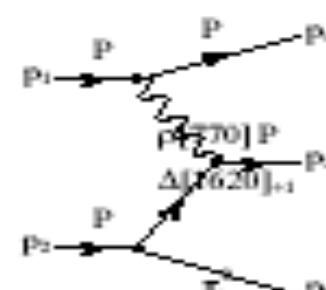


Diagram 19



Diagram 20



Diagram 21



Diagram 22

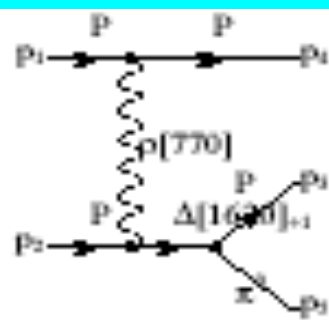


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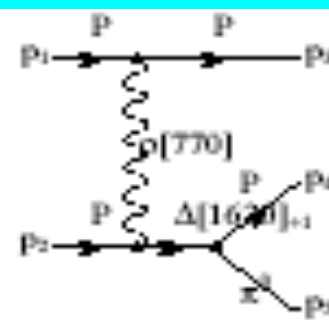


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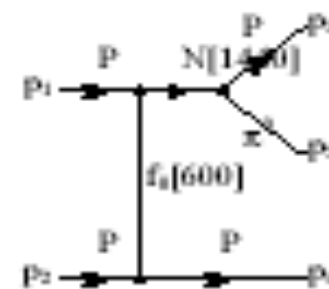


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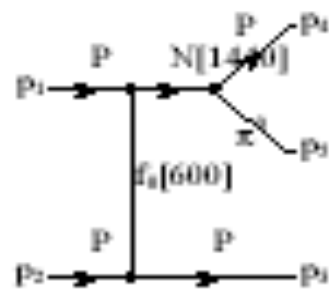


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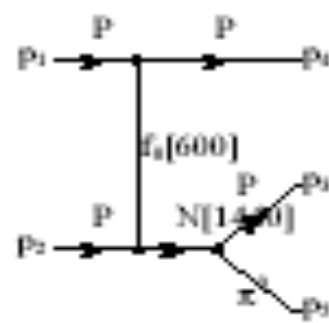


Diagram 27

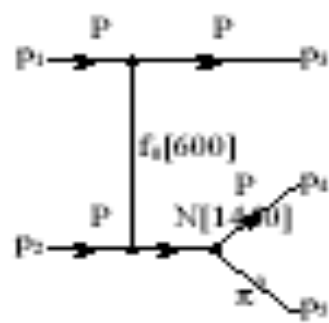


Diagram 28

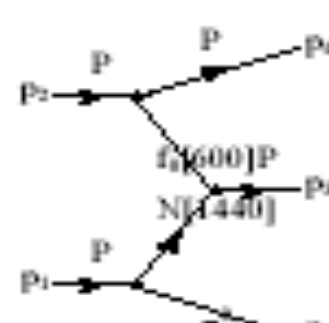


Diagram 29

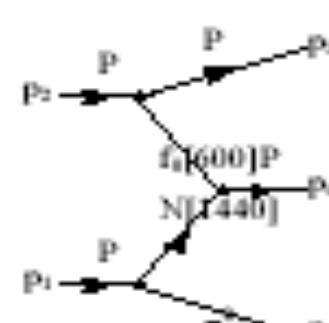


Diagram 30

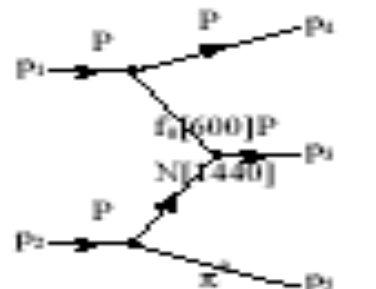


Diagram 31



Diagram 32



Diagram 33

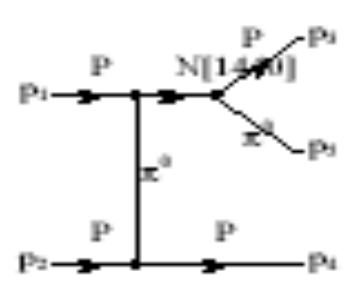


Diagram 34

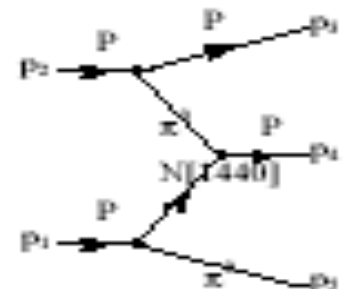


Diagram 35

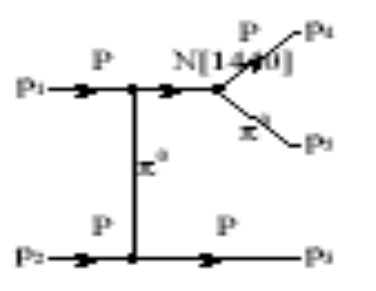


Diagram 36

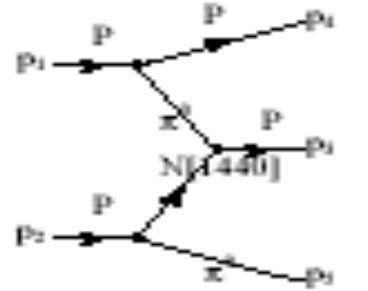


Diagram 37



Diagram 38

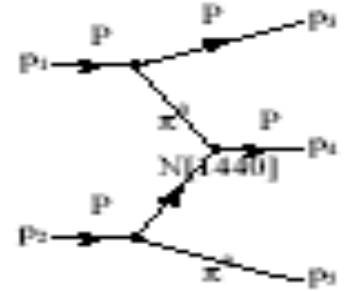


Diagram 39

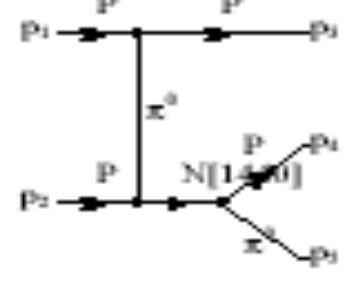


Diagram 40

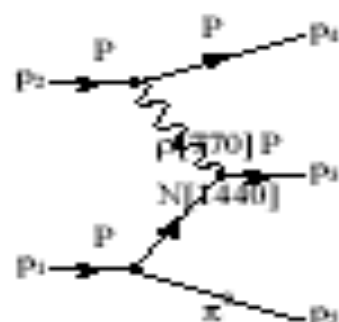


Diagram 41

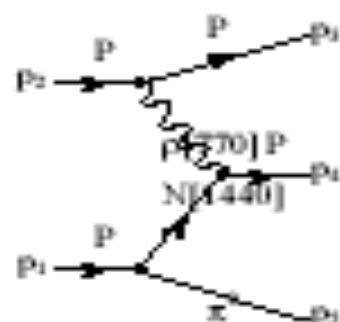


Diagram 42

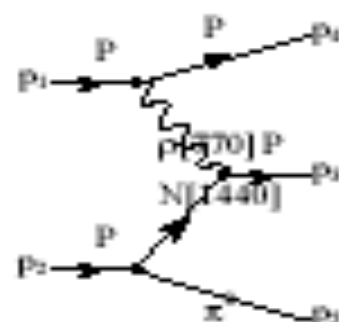


Diagram 43

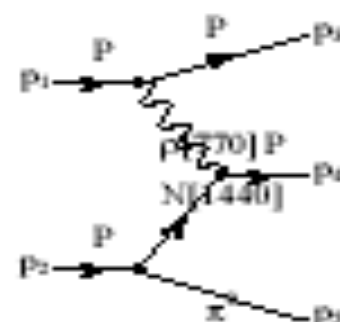


Diagram 44

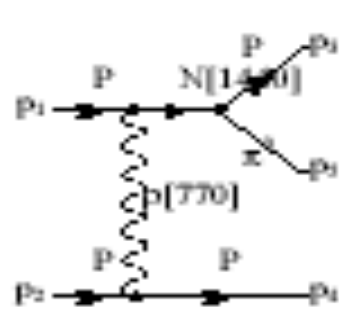


Diagram 45

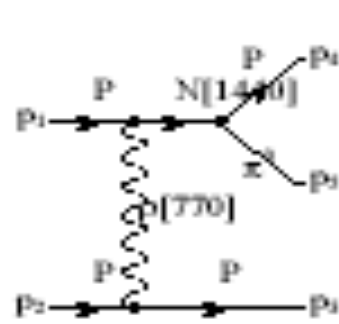


Diagram 46

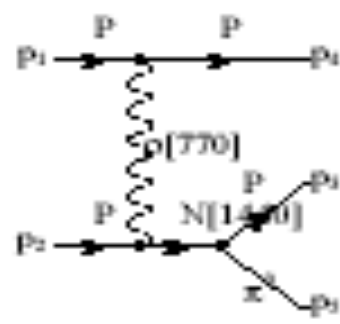


Diagram 47

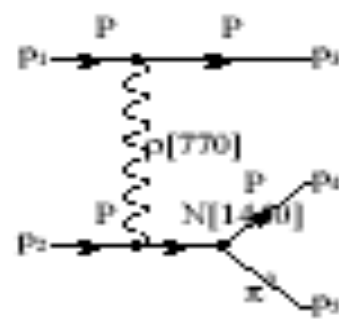


Diagram 48

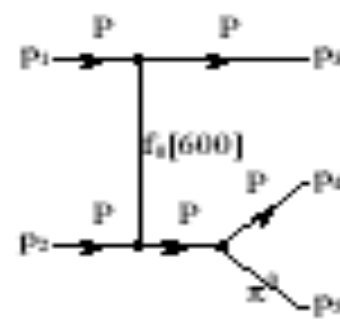


Diagram 49

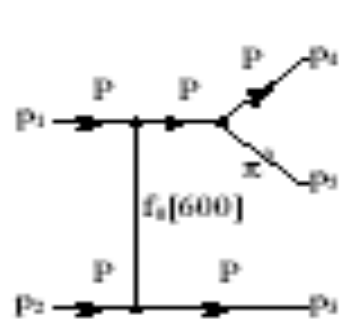


Diagram 50

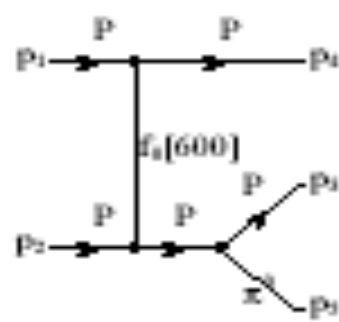


Diagram 51

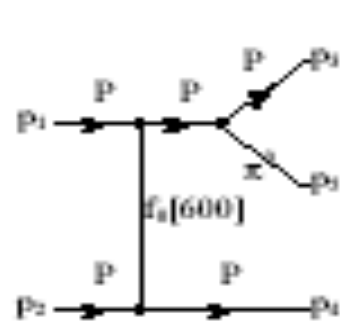


Diagram 52

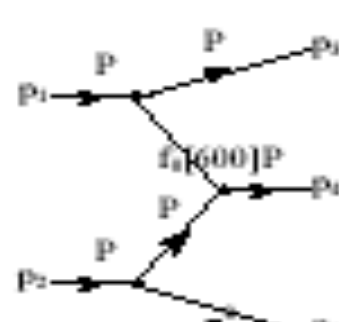


Diagram 53

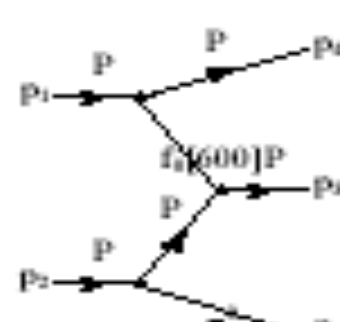


Diagram 54

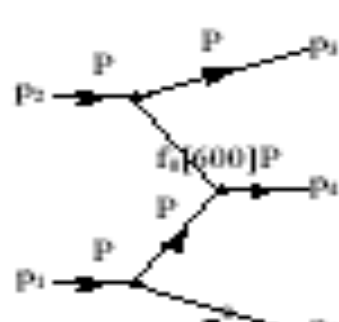


Diagram 55

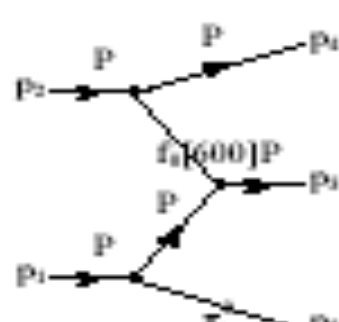


Diagram 56

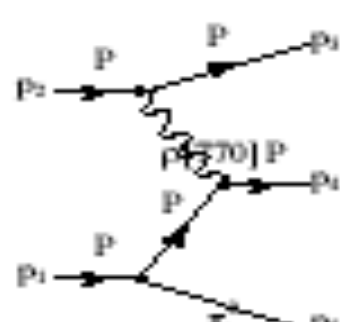


Diagram 57

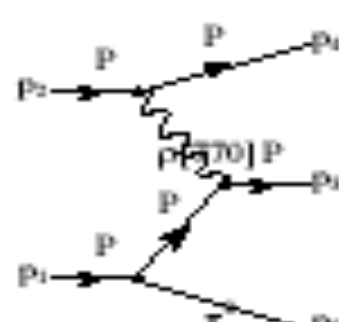


Diagram 58

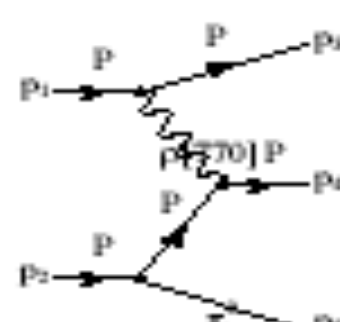


Diagram 59

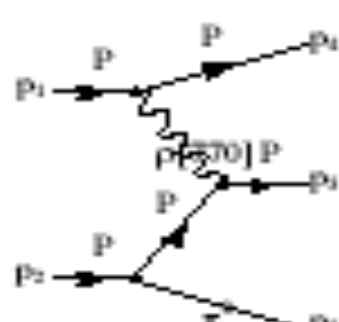


Diagram 60

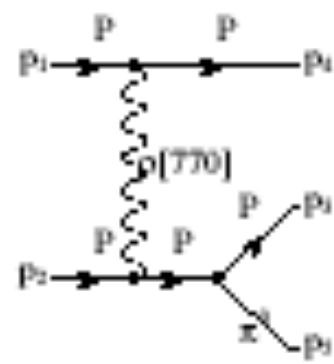


Diagram 61

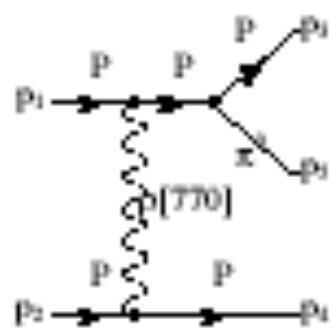


Diagram 62

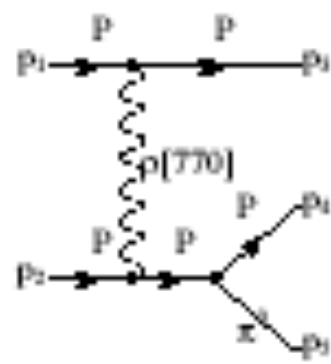


Diagram 63

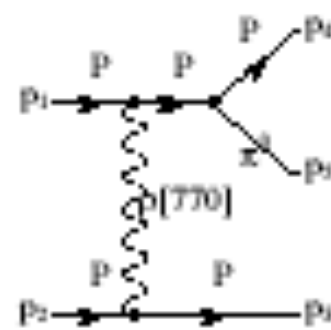


Diagram 64

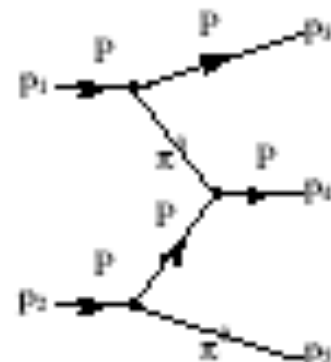


Diagram 65

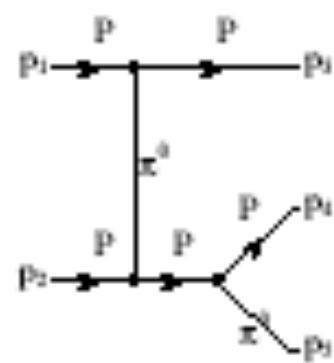


Diagram 66

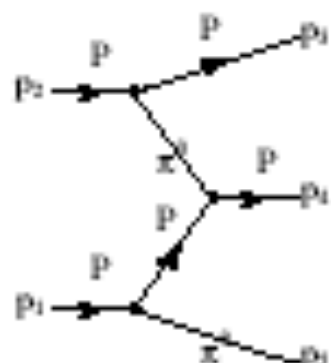


Diagram 67

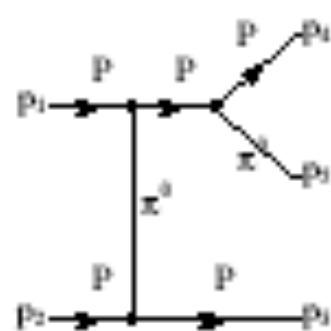


Diagram 68

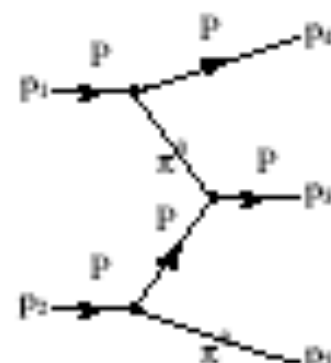


Diagram 69

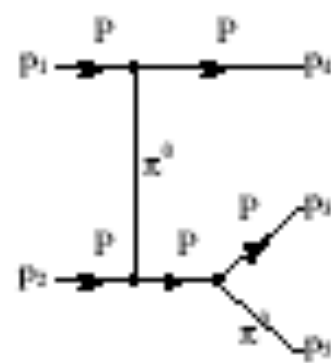


Diagram 70

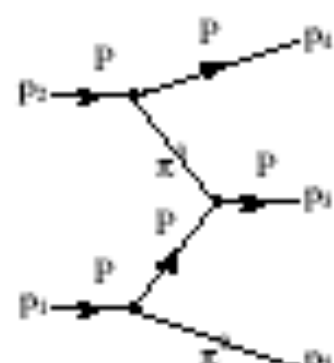


Diagram 71

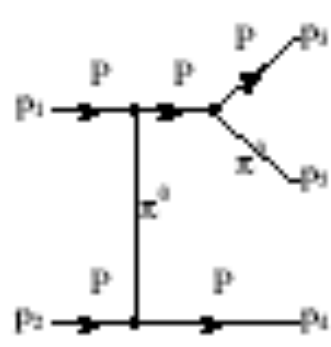
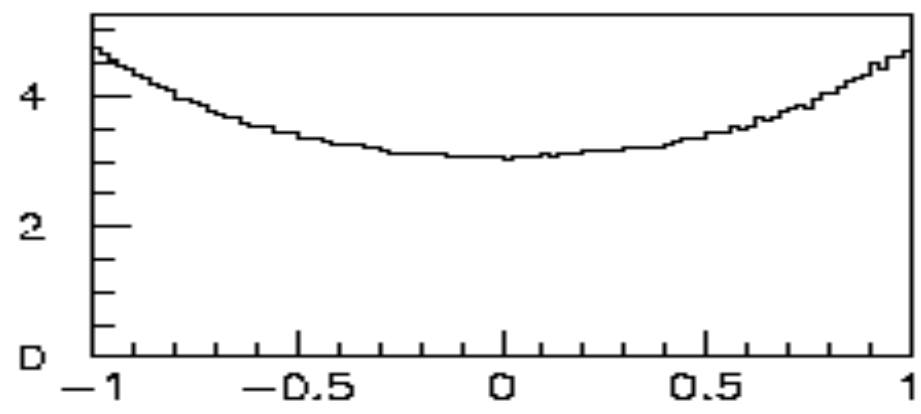
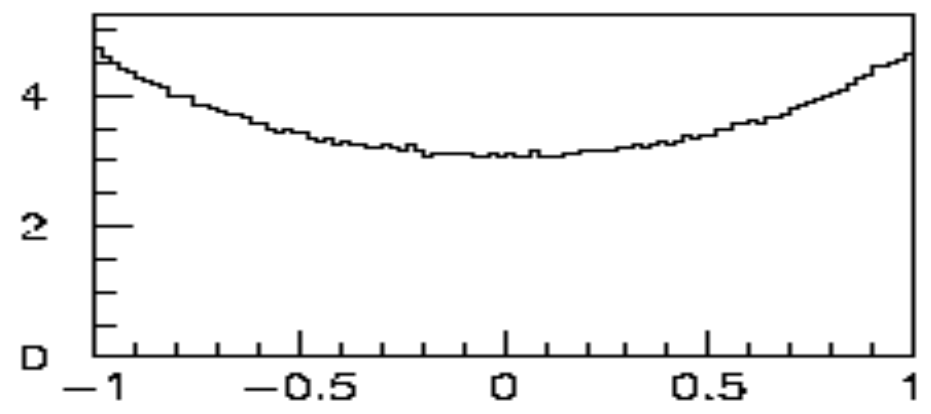


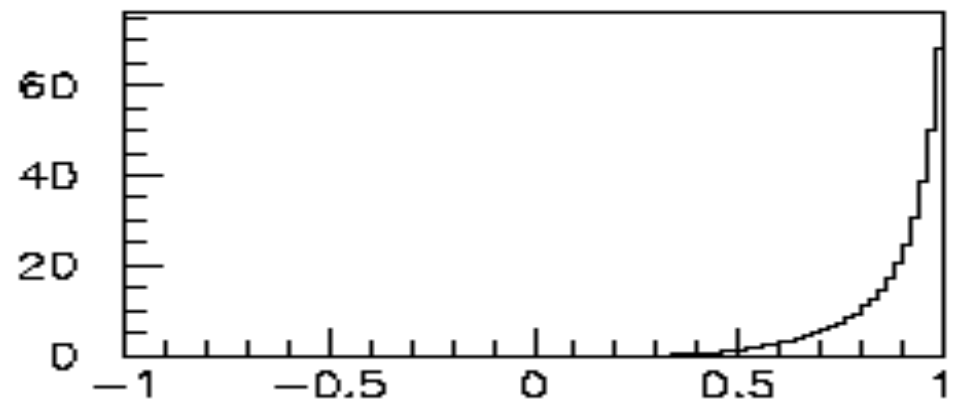
Diagram 72



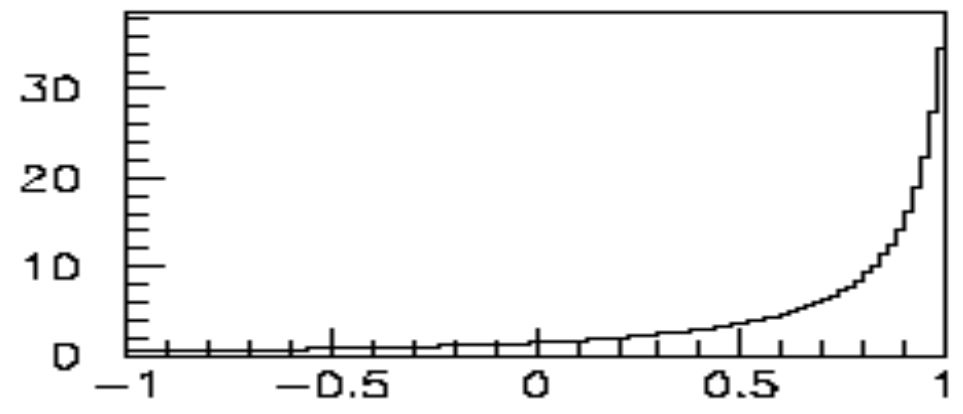
cos of p and beam in cm



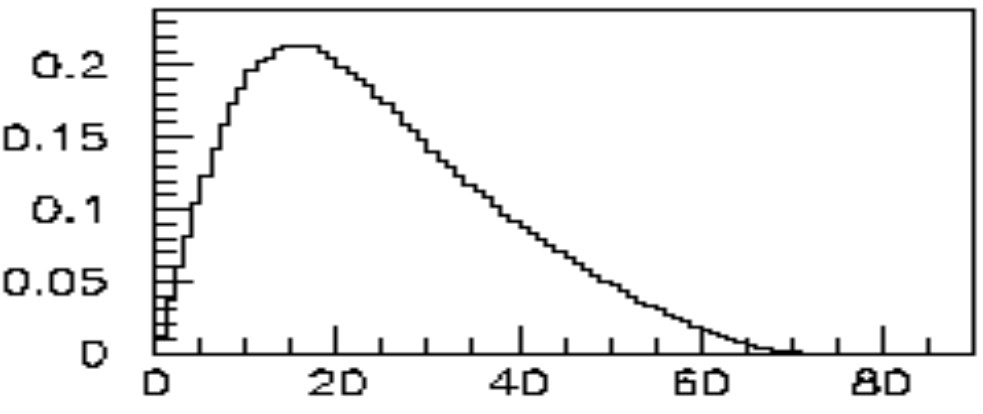
cos of pi and beam in cm



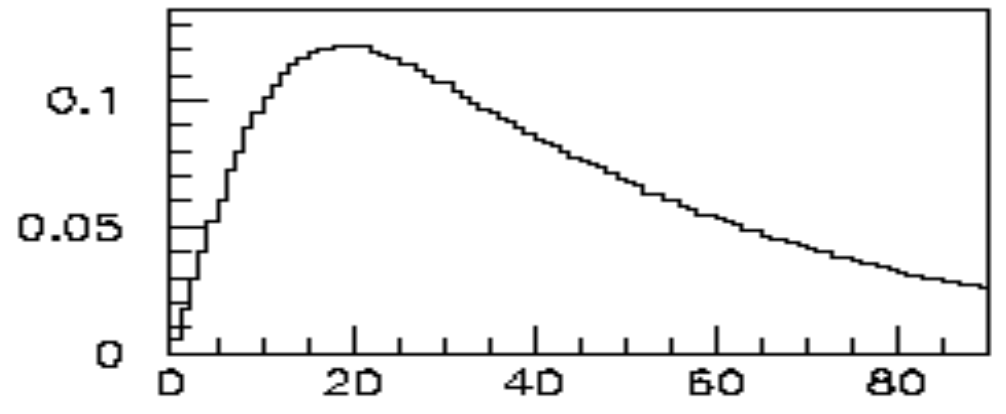
cos of p and beam in lab



cos of pi and beam in lab



θ of p and beam in lab



θ of pi and beam in lab