Weak Production of Λ by the $p+n \to p+\Lambda$ reaction

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1.Introduction

- ΔS=1 Weak Baryon-Baryon Interaction
  - Weak nonmesonic decay of Λ hypernuclei ($p\Lambda \rightarrow pn$, $n\Lambda \rightarrow nn$)

    Total decay width: Γ_{nm}

    Decay branch: $\Gamma_{p\,(p\Lambda \rightarrow pn)} / \Gamma_{n\,(n\Lambda \rightarrow nn)}$

    Decay asymmetry: α_p
  - Inverse reaction: $p+n \rightarrow p+\Lambda$

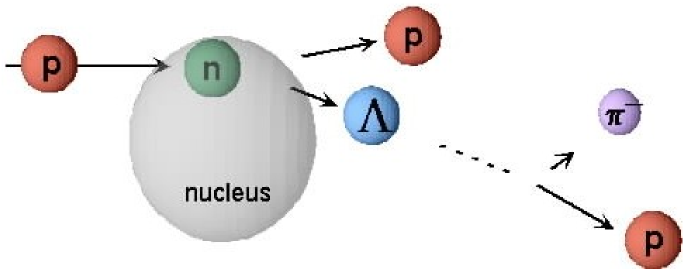
    Free from FSI and mult. nucleon process

    Energy dependence

    Spin dependent observables (pol. p beam, Λ $a_{\Lambda \rightarrow p\pi^-} = 0.64$)

H. Nabetani et al. Phys. Rev. C60 (1999) p017001

- $p+n \rightarrow p+\Lambda$ @ RCNP
  - Beam proton 400MeV (E_{th}= 370MeV)
  - Target nucleus
  - Signal $\Lambda \rightarrow p+ \pi^-$ ~ 64%
    - Decay vertex $\beta\gamma c\tau$ ~ 4cm
    - Invariant mass ~1116MeV



- Observables
  - Cross section $\sigma_{pn\rightarrow p\Lambda}$ (0.1- 1) x 10^{-39}cm^2

    T. Kishimoto, Proc. IV Int Symp. on `‘’WEIN‘95, World Scientific, (1995) 514
    J.Haidenbauer it et al.,Phys. Rev. C52 (1995) p3496
    A.Parreno it et al., Phys. Rev. C59 (1999) p2122
    T.Inoue it et al. Nucl. Phys. A684 (2001) p478
    H.Nabetani Ph.D. thesis Osaka university (2001)
  - Analyzing power $$A_p = \frac{\sigma(h_p = 1) - \sigma(h_p = -1)}{\sigma(h_p = 1) + \sigma(h_p = -1)} \qquad h_p = \sigma_p \cdot \hat{p}$$
- Background
  - Λ by strong interaction : p+n$\rightarrow$ n+K$^+$+Λ E_{th}= 1.6GeV
  - Weak Σ production : p+n$\rightarrow$ n+Σ E_{th}= 540MeV
  - Strong interaction : p+n$\rightarrow$p+p+π^- $\sigma\sim$ 50μb

    $\rightarrow$Collimator,Decay vertex
- Difficulty

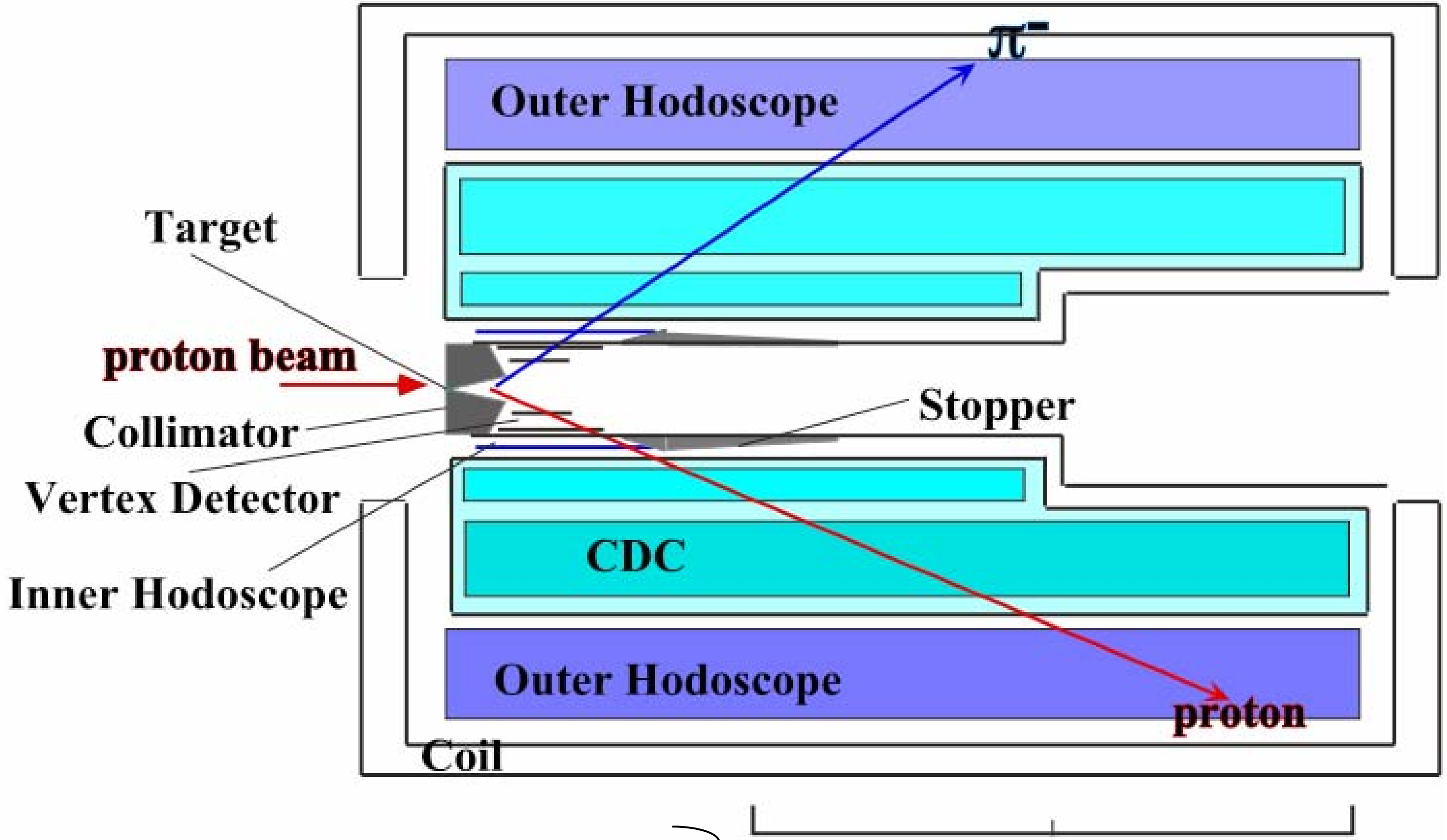
  Operation with Thick target (Beam intensity)

  1. trigger rate $\rightarrow$ negative pion trigger
  2. counting rate of each detector $\rightarrow$ collimator

2. Detector system

Solenoid Magnet 3kG
Cylindrical Drift Chamber (CDC)
Vertex detector

⇨ Momentum
Decay Vertex



Inner Hodoscope
Outer Hodoscope

⇨ Trigger
TOF

- Rough estimation of Yields

$$N_{event} = \sigma \times N_{target} \times N_{beam} \times \epsilon$$

  - Cross section $\sigma \sim 10^{-39} cm^2$
  - Target $N_{target} \sim 10^{24}$ neutron/cm^2 (1cm Cu)
  - Beam intensity

    $N_{beam} \sim 10^{11}$ proton/sec (16nA)
  - Efficiency $\varepsilon \sim 0.026$

    Branching ratio of $\Lambda \rightarrow p + \pi^-$ ~ 2/3

    Acceptance of detector system ~ 0.05

    DAQ Live time ~ 0.8

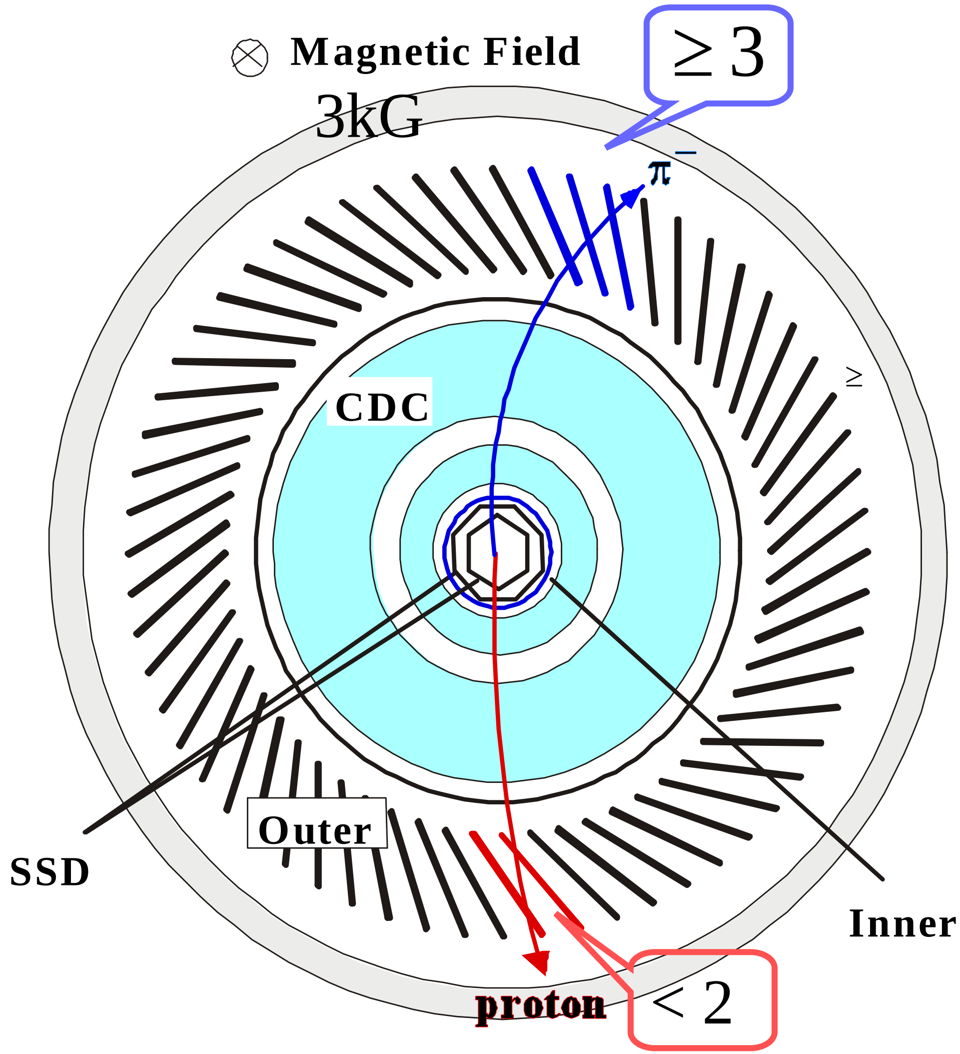
□ $N_{event} \sim$ a few events / week

- Rough estimation of Counting Rate
  - Beam 10^{11}
  - Reaction at Target 10^{10} (1/10)
  - Detector Acceptance 10^{8} (1/100)
  - Collimator 10^{6} (1/100)
  - Single Rate of Counter 2×10^{4} (1/50) -- Trigger Rate 1×10^{3} (1/1000)

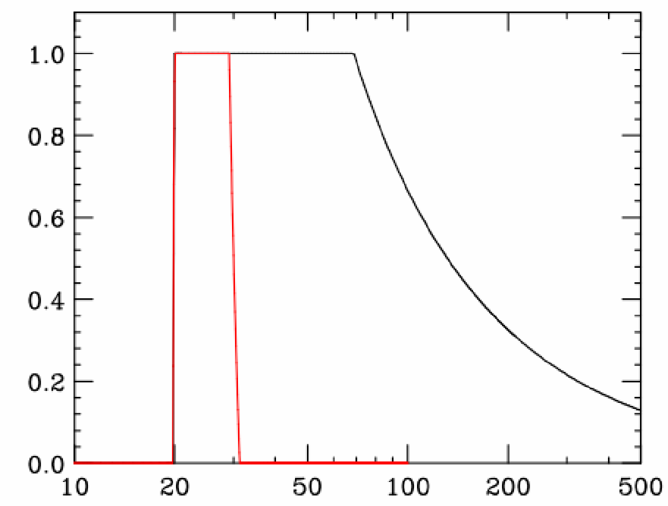
3.Trigger system -- Negative pion trigger --

Background - proton, neutron, gamma

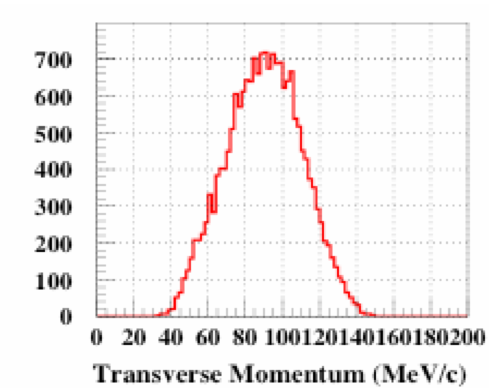
Negative charge - Outer Hodoscope 3hit



Efficiency by 3hit trigger



Transverse momentum MeV/c

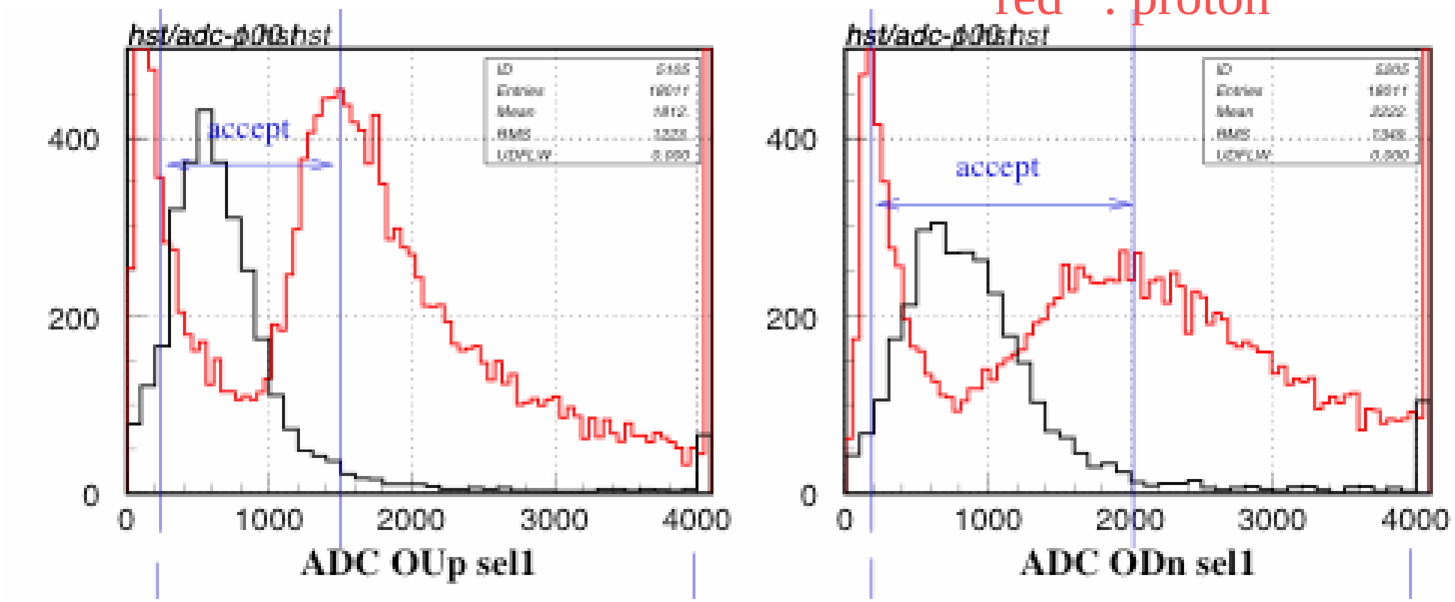


Upper Threshold

Difference of Energy deposit ADC spectra

black: negative pion

red : proton



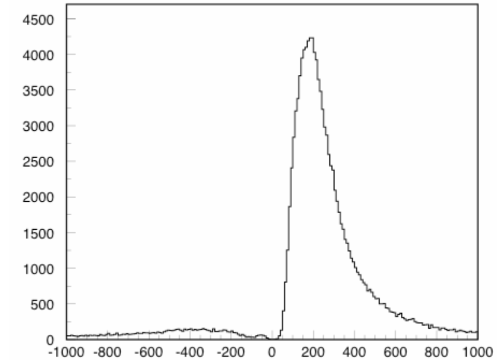
Negative pion trigger = HIT_N & HIT_{N+1} & HIT_{N+2}

HIT_N = (OUT-LowThres.&. $\overline{\text{OUT-HighThres}}$)$_{\text{UpStream -N}}$ &
(OUT-LowThres.&. $\overline{\text{OUT-HighThres}}$)$_{\text{DownStream-N}}$

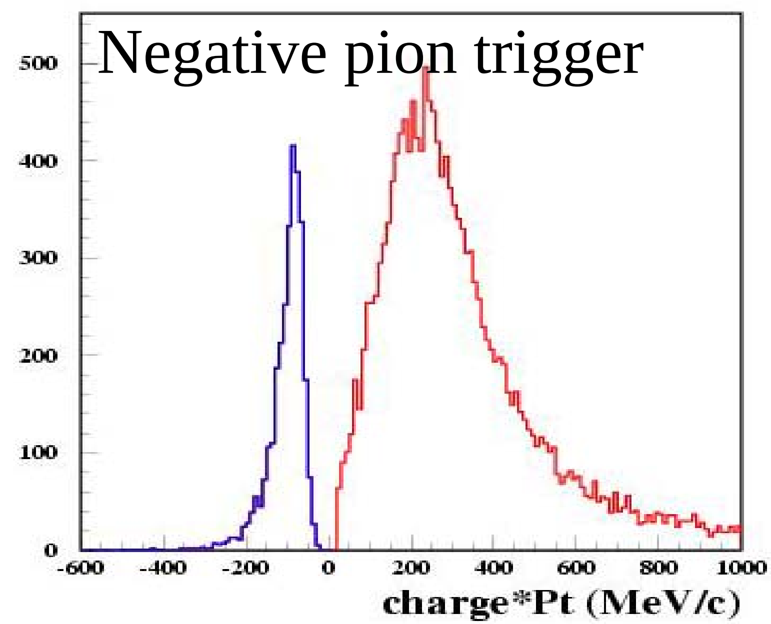
Trigger Rate by negative pion trigger

- $p+n \rightarrow p+p+\pi^-$
- Typical current - 0.2nA
- Target 50 Cu 50 μm
- Solenoid Magnetic field 3kG

IN.and.OUT2coin.

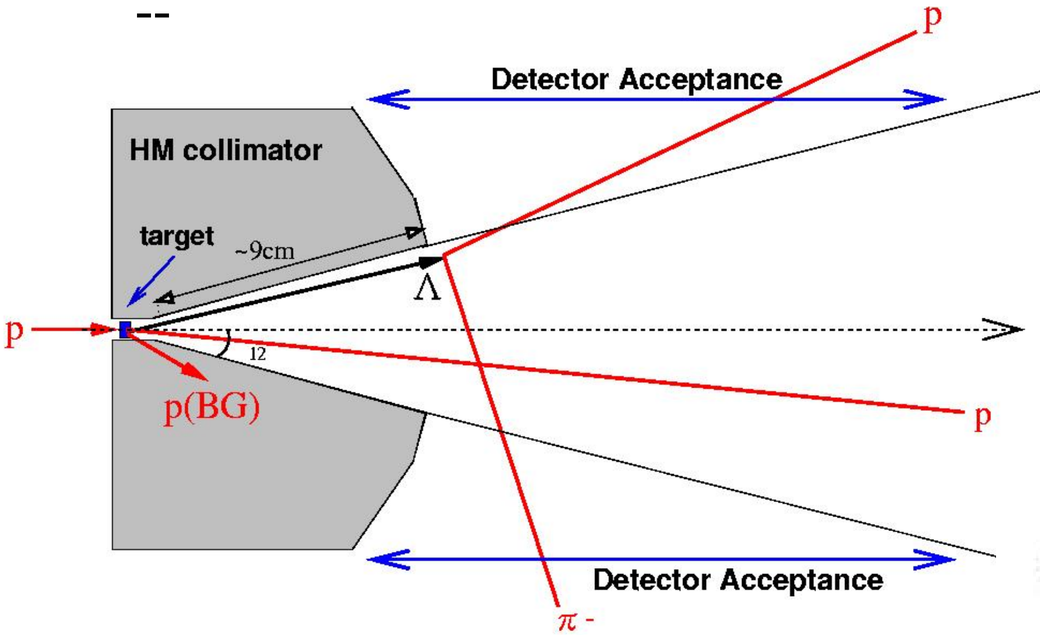


Trigger	Trig/0.1nQ	
IN.and.OUT	110k	100%
IN.and.OUT2coin.	38k	35%
IN.and.OUT3coin	1.5k	2%
Negative pion trigger	450	0.4%



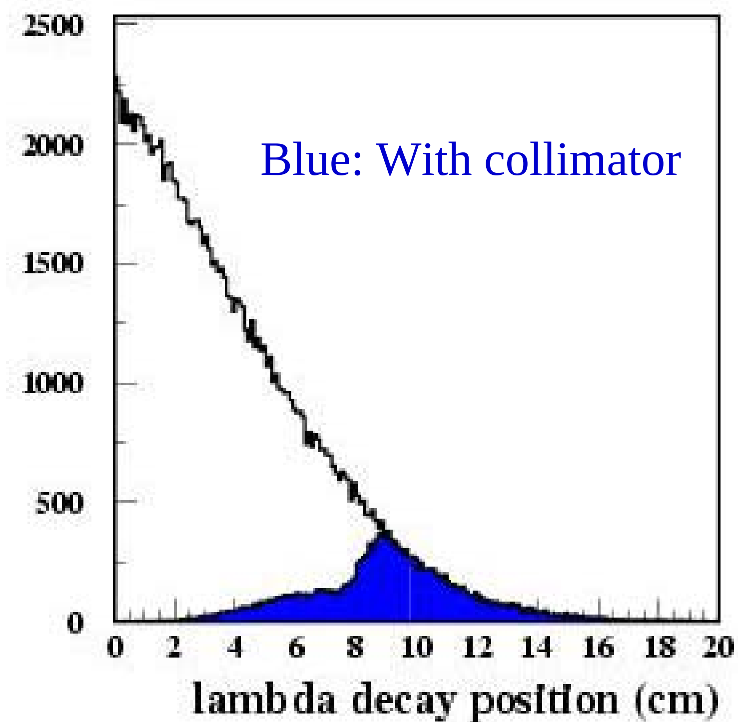
π^- / Triggered events ~8%

4. Collimator--to reduce counting rate of detectors --



Heavy metal (Tungsten95%)
400MeV/c proton
→<1/1000

Hodoscopes < 50MHz
CDC < 500kHz



Λ detection efficiency

w/o collimator / w collimator ~ 13%

Single rate with and without collimator

Single rate – counts/0.1nC

	Outer Hod	Inner Hod	CDC	Trigger
Target only (Cu 0.05mm)	78k	37k	245k	350
Collimator & Target (Cu 3mm)	199k	164k	362k	320

Single rate – counts/0.1nC / Cu 1cm

	Outer Hod	Inner Hod	CDC	Trigger
Target only	15520k	7460k	49000k	70k
Collimator & Target	360k	330k	820k	1.1k
ratio	2.3%	4.4%	1.7%	1.5%

Goal 16nA

- operation with 160 times higher beam intensity

Outer and inner hodosopes will be several 10s MHz → O.K.

4. Summary

- Experimental study of the $p + n \rightarrow p + \Lambda$ reaction
- cross section - a few event/ weak
- Reduction of Trigger Rate by negative pion trigger

    Estimation: 1/1000 Experiment : 0.4%

  Reduction of single rate by collimator

    Estimation: 1/100 Experiment: 1.7% - 4.4%

  We got very close value to requirement.

What we have to do before physics run

- Further adjustment of detector system
- Study of background

    π^- produced by strong interaction (under analysis)
- Vertex detector - construction, test, etc.