Further study of narrow baryon resonance decaying into pK^0_s in pA-interactions at 70 GeV/c with SVD-2 setup

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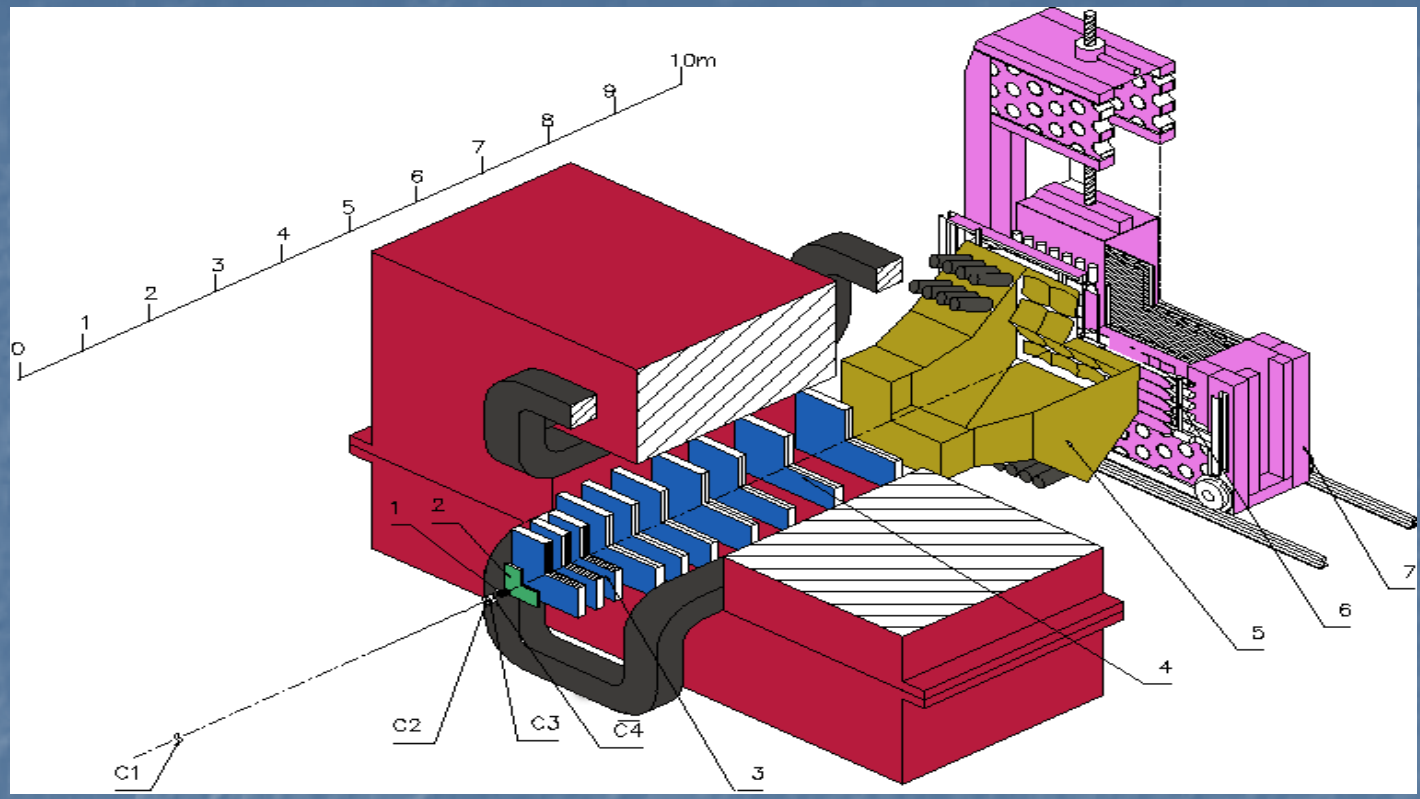
(on behalf of SVD Collaboration)

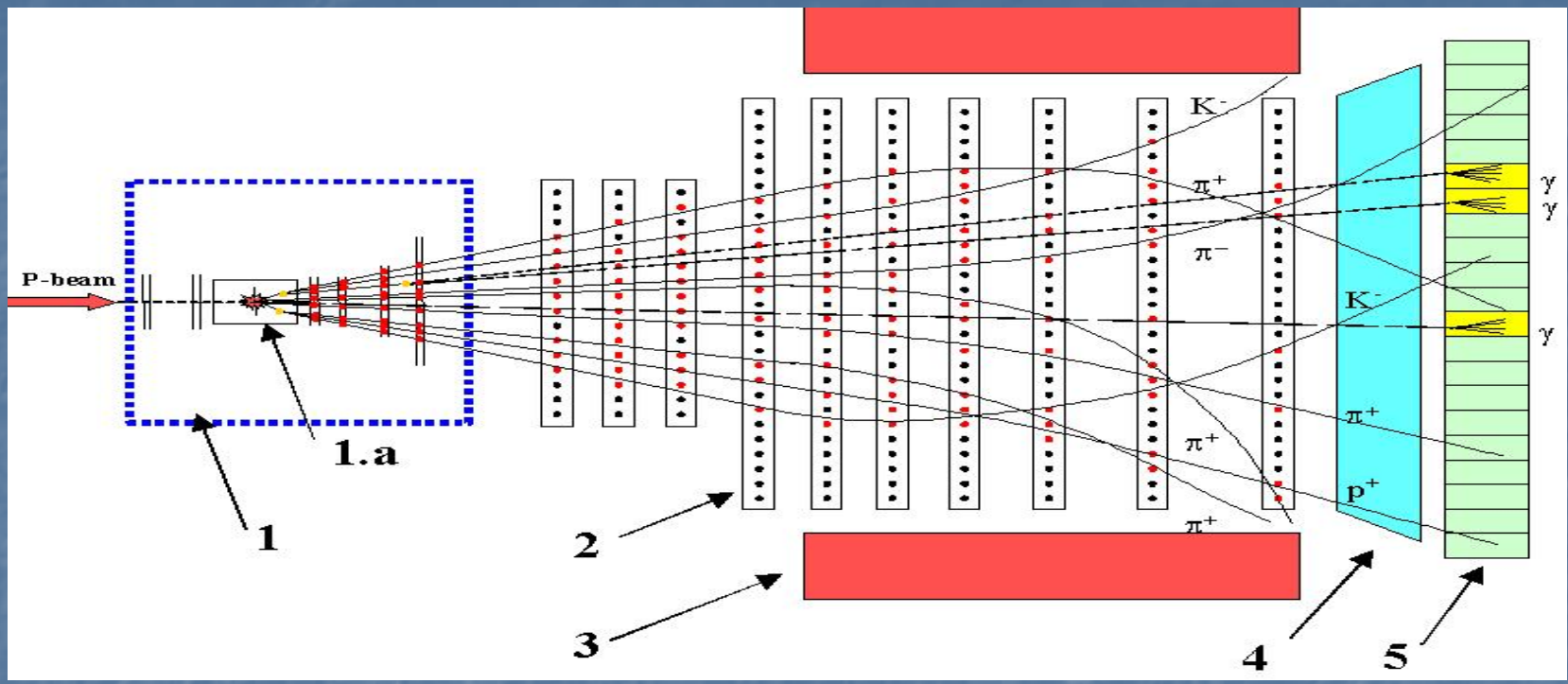
Presented by Mikhail Kubantsev (ITEP and Northwestern University)

SVD-2 detector



- In a development from an older SVD experiment, as a bubble chamber was replaced by a microstrip silicon vertex detector and Cerenkov and gamma detectors were installed. First physics run was in April 2002

SVD-2 detector schematic view



1. High precision microstrip vertex detector (see next slide).

1a. Active target with Si, C and Pb planes

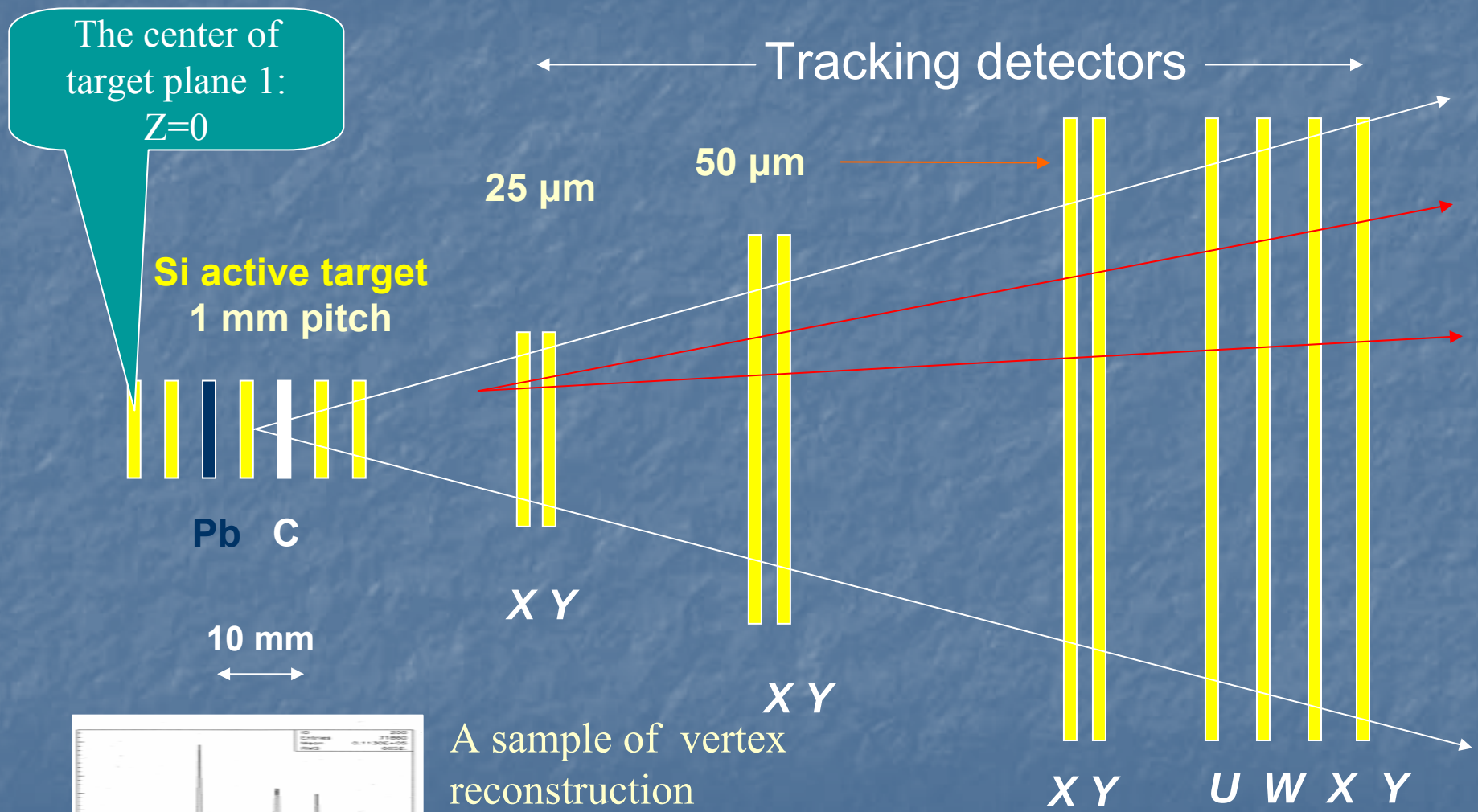
2. Multiwire proportional chambers.

3. Magnet (1.18 T over 3 m region).

4. Multicell threshold Cherenkov counter.

5. Gamma detector.

SVD-2 target / tracking detector



A sample of vertex reconstruction

SVD-2 trigger

Level I:

- Using energy depositions in 5•8 ***Si*** active target strips
- Basic principle is to look for the >2...3 MIPs depositions in consecutive planes
- Decision time: 220 ns
- "Non-usable" events contamination: < 10%. Easily rejected: poor/non-reconstructed primary vertex

Level II:

- Was not implemented at April 2002 run

SVD-2 physics program

- Current projects:
- Measurement of the total charm production cross-sections on Si, C and Pb nuclear targets and study of the cross-section A-dependence.
- Measurement of the differential x_F and p_t spectra and study of the leading effect for the charm mesons and baryons.
- Investigation of the possible influence of the "intrinsic charm" in the proton on the inclusive charm spectra.
- *Searches for new* non-exotic strange baryons and *exotic strange baryons (pentaquarks).*

SVD-2 run I (April '2002)

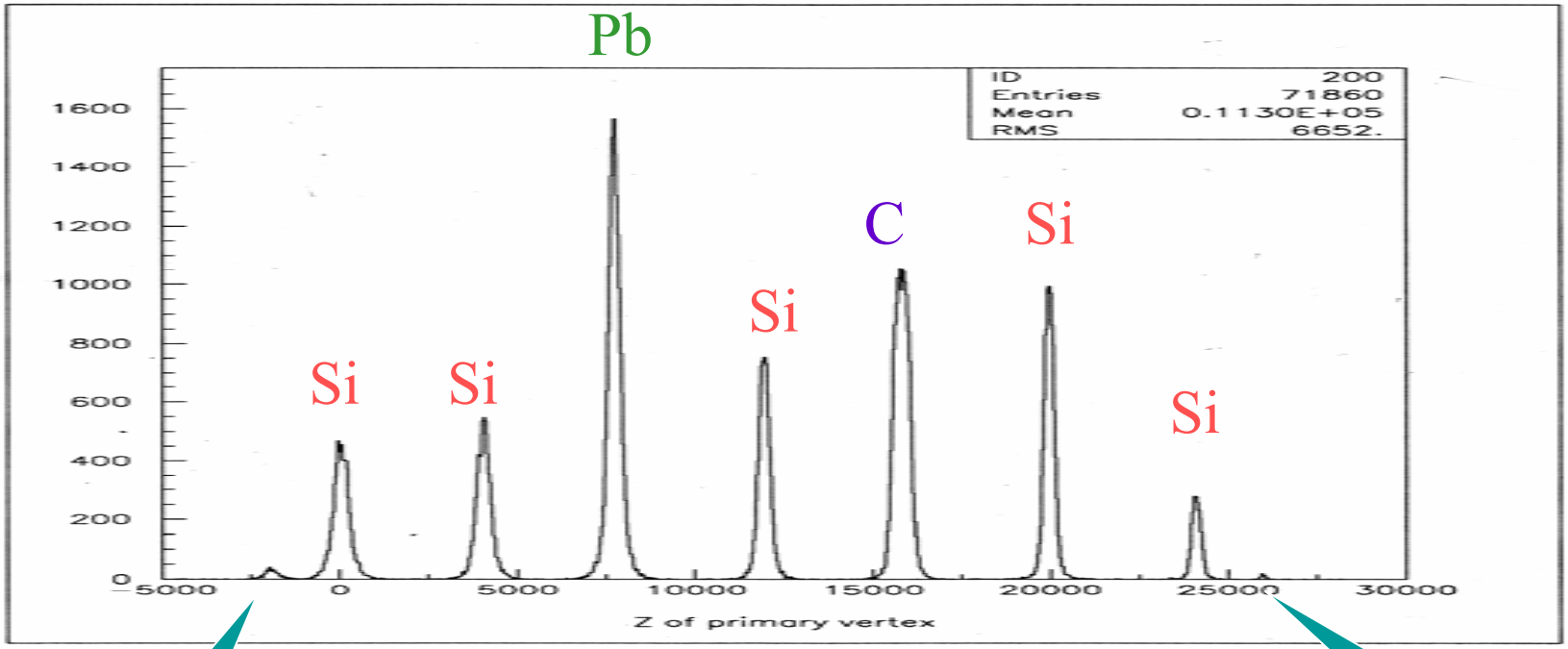
- Proton beam 70 GeV/c from IHEP Protvino U-70 accelerator
- Intensity 5-6×10^5 1/cycle (1.2 sec)
- Total target thickness ~ 0.5% hadronic interaction length
- 400…600 events/cycle registered
- 50,000,000 events recorded

Experimental resolutions (with a vertex detector)

- X,Y-resolutions for tracks fitted: 7…10 μm
- Z-resolution:
  - primary vertex: 70… 130 μm
  - secondary vertex: 200… 300 μm
- Impact parameter resolution: ~ 14 μm
- Momentum resolution for the 5 GeV tracks is 1%
- Effective mass resolution:
  - K^0 3.8 MeV
  - Λ 1.4 MeV

Primary vertex Z-coordinate in SVD-2 active target

Si – 300μm; Pb – 220 μm; C – 500 μm

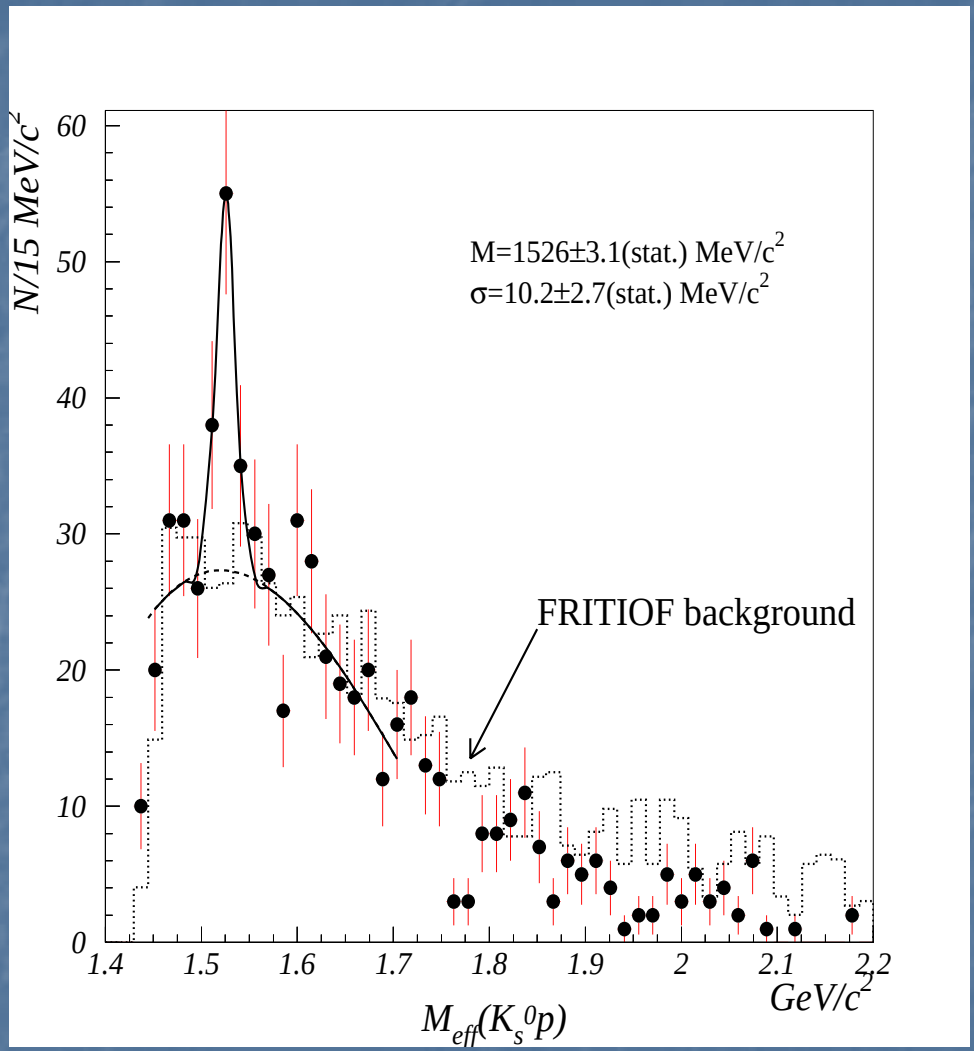


$\sigma_z = 70 \div 130 \mu m$, $\sigma_{x,y} = 7 \div 10 \mu m$

Entrance window (Al 10 μm)

Exit window (Al 10 μm)

SVD result of 02'2004

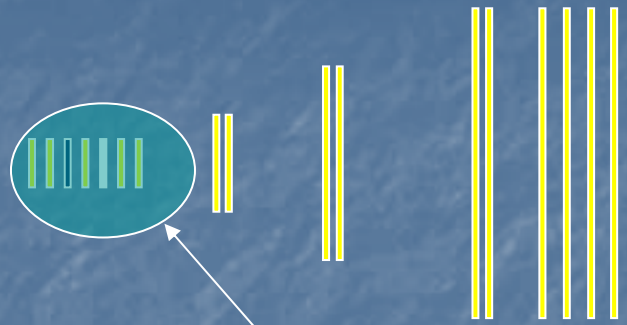


- A by-product of D-mesons search: using neutral particle candidates decaying before silicon tracking planes (5-35 mm region).
- Number of events within a peak: 50 over background of 78.
- Mass: 1526 ± 3(stat.) ± 3(syst.) MeV/c²
- Width Γ < 24 MeV/c²

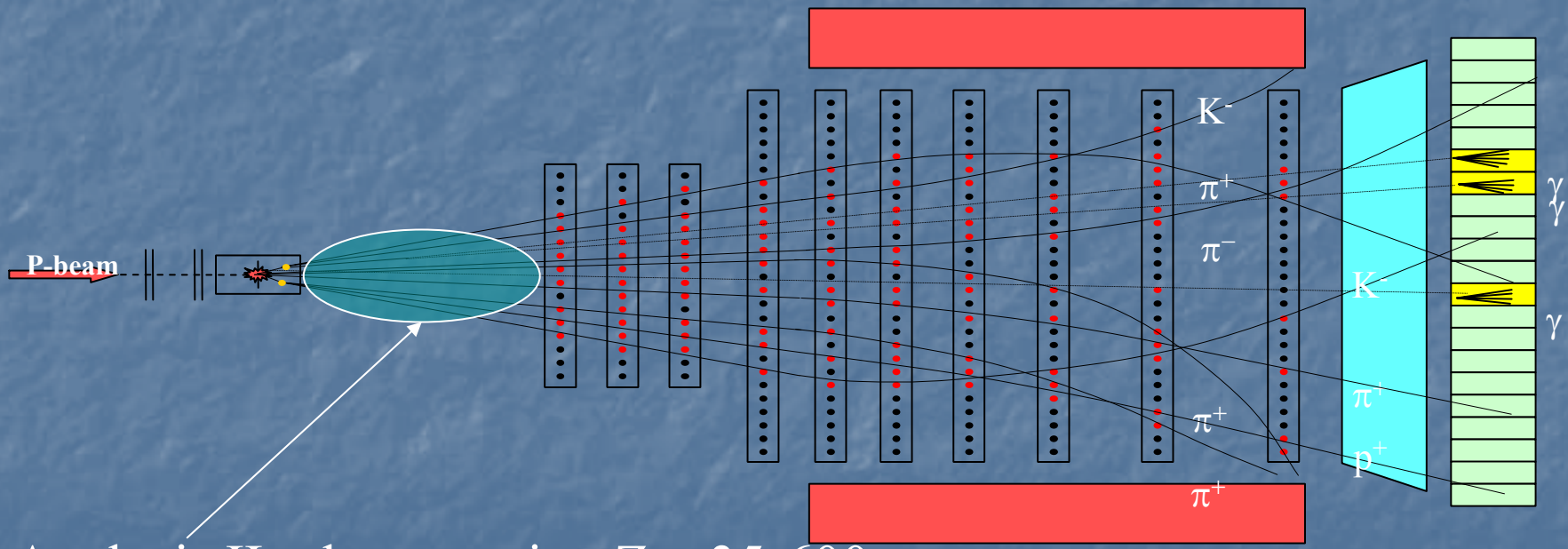
New data analyses

- Analysis I : better reconstruction algorithms for the same 0.5-35 mm region as in `2004 paper
- Analysis II : using spectrometer data to search for the particles decaying ***after*** the tracking detector.

Analyses starting points: K0 candidates. Point of decay selections



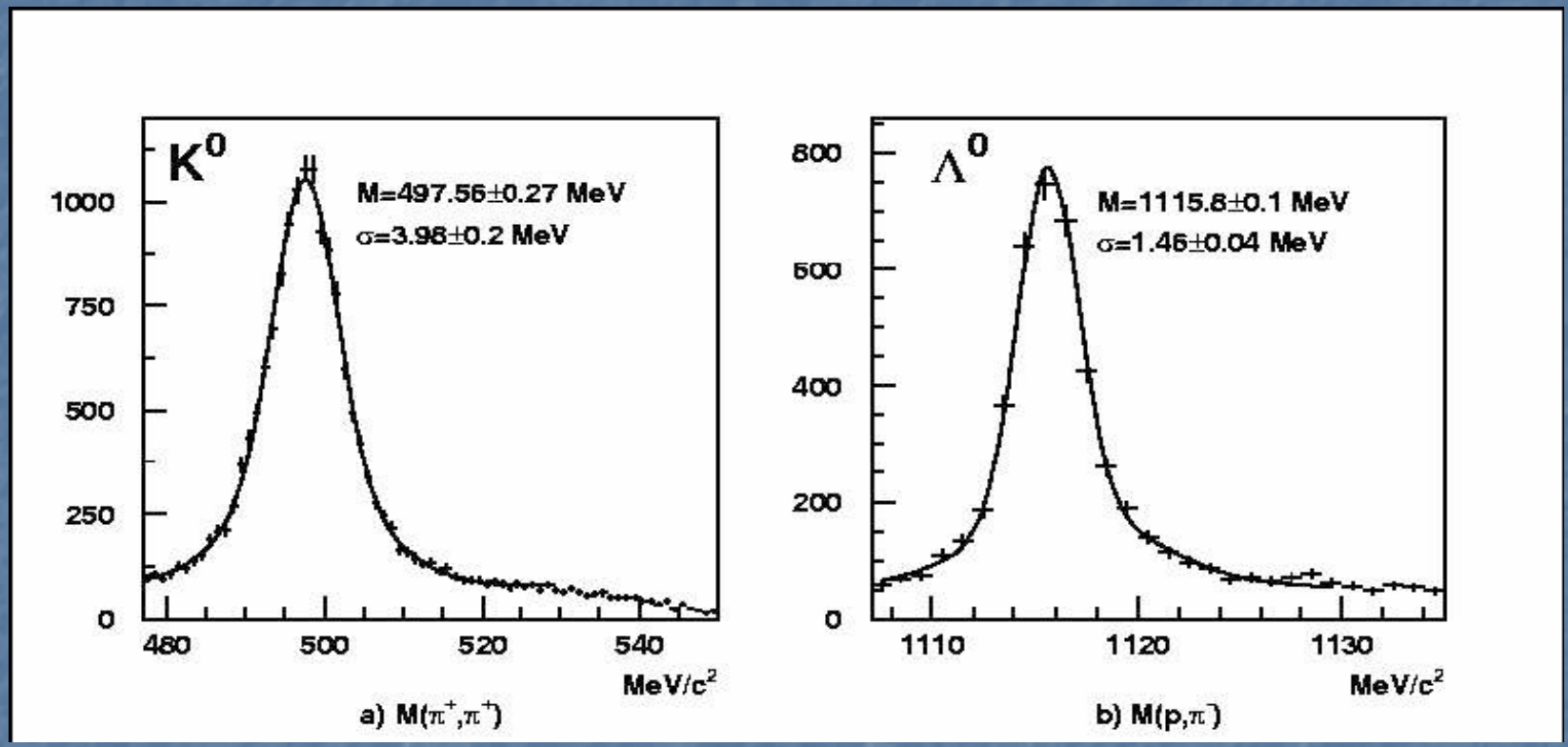
Analysis I : decay region Z = 0.5-35 mm



Analysis II : decay region Z = 35-600 mm

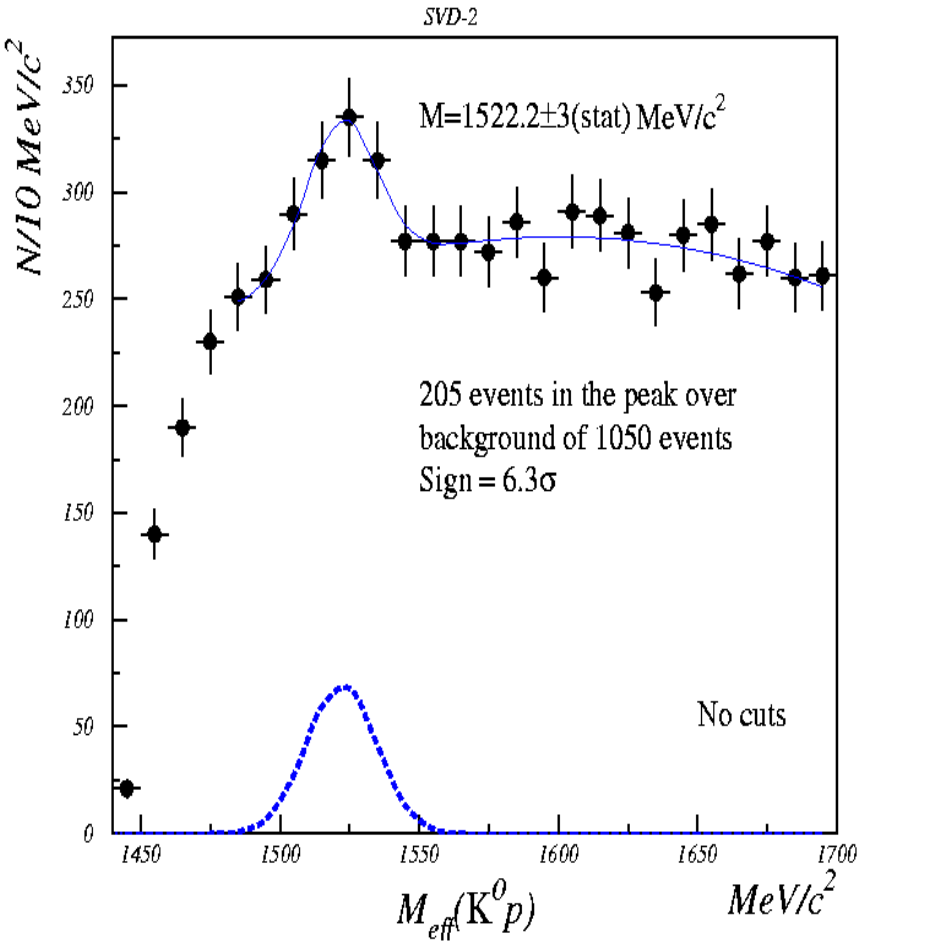
Analysis I initial selection

- events with a number of charged tracks up to 7 selected
- ~30,000 "short" K^0 candidate events found



- Protons are identified as no hits in TCC (P<21 GeV) + any positive track outside TCC aperture

Analysis I : pK^0_s



205 events over the background of 1050

Mass = 1522.2±3±3 MeV

σ_{peak} ~ 12 MeV

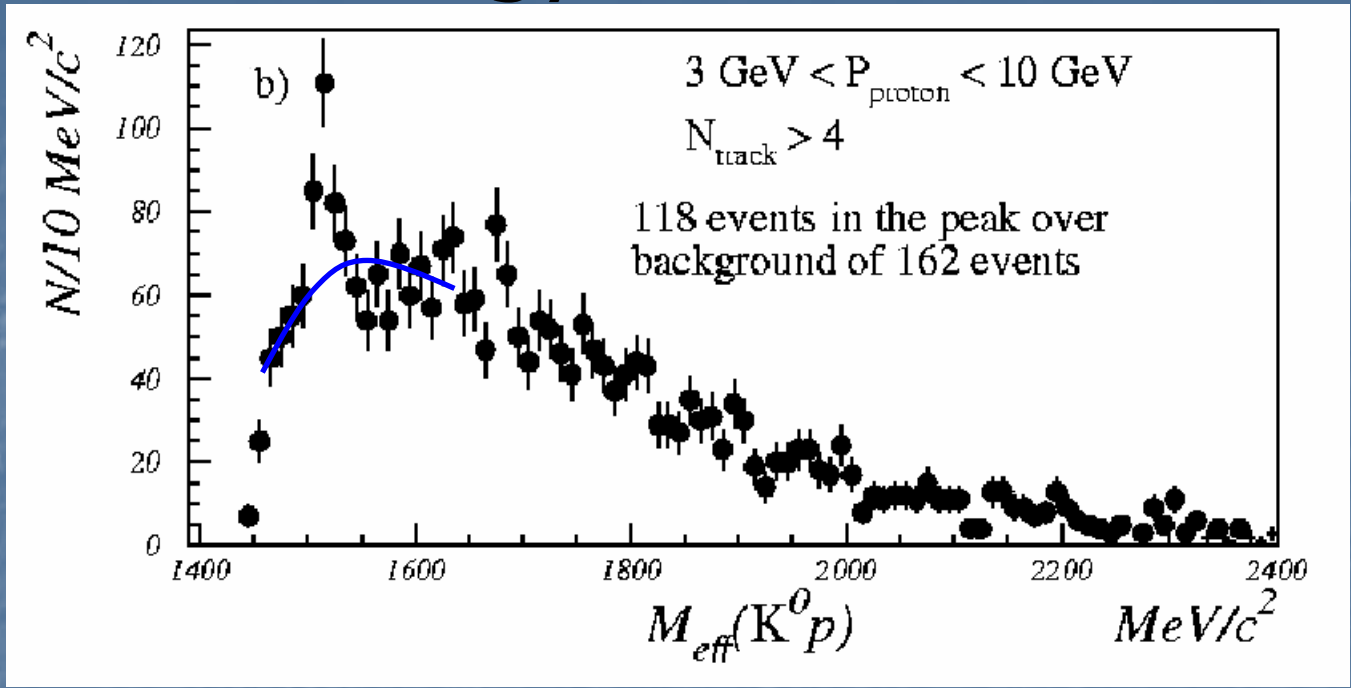
Significance:

$$\frac{S}{\sqrt{B}} = 6.3\sigma$$

$$\frac{S}{\sqrt{S+B}} = 5.8\sigma$$

$$\frac{S}{\sqrt{S+2B}} = 4.2\sigma$$

Proton energy and # of tracks cuts



After the cuts:

- 118 events over the
- background of 162
- σ_{peak} ~ 8 MeV

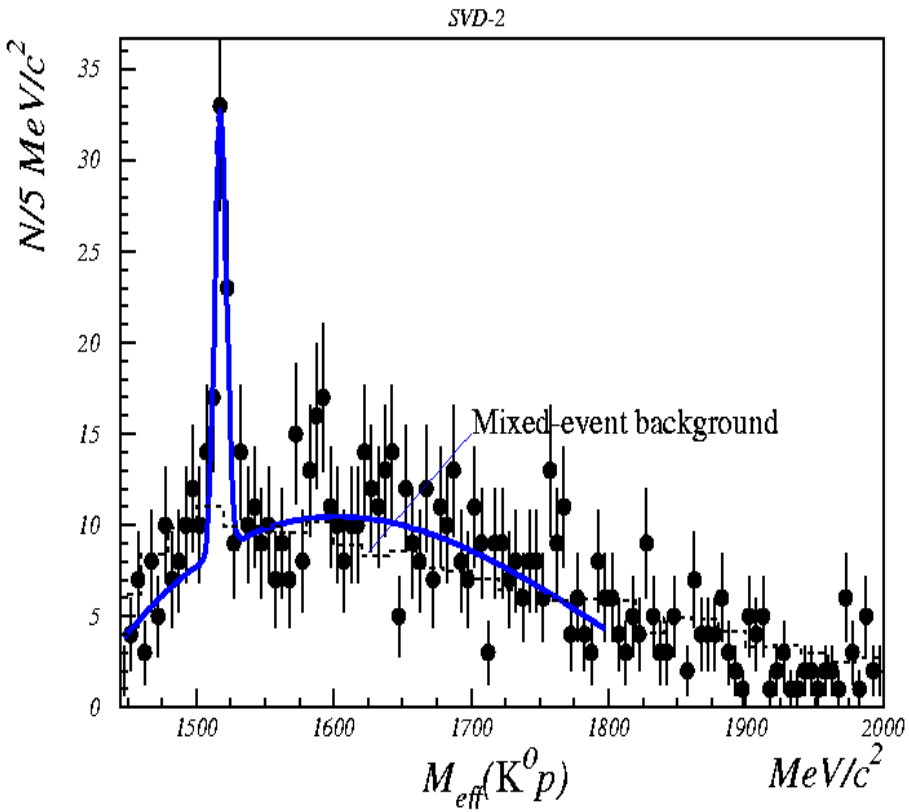
Significance:

$$\frac{S}{\sqrt{B}} = 9.2\sigma$$

$$\frac{S}{\sqrt{S+B}} = 7.2\sigma$$

$$\frac{S}{\sqrt{S+2B}} = 5.6\sigma$$

Applying track *quality* cuts to estimate Γ



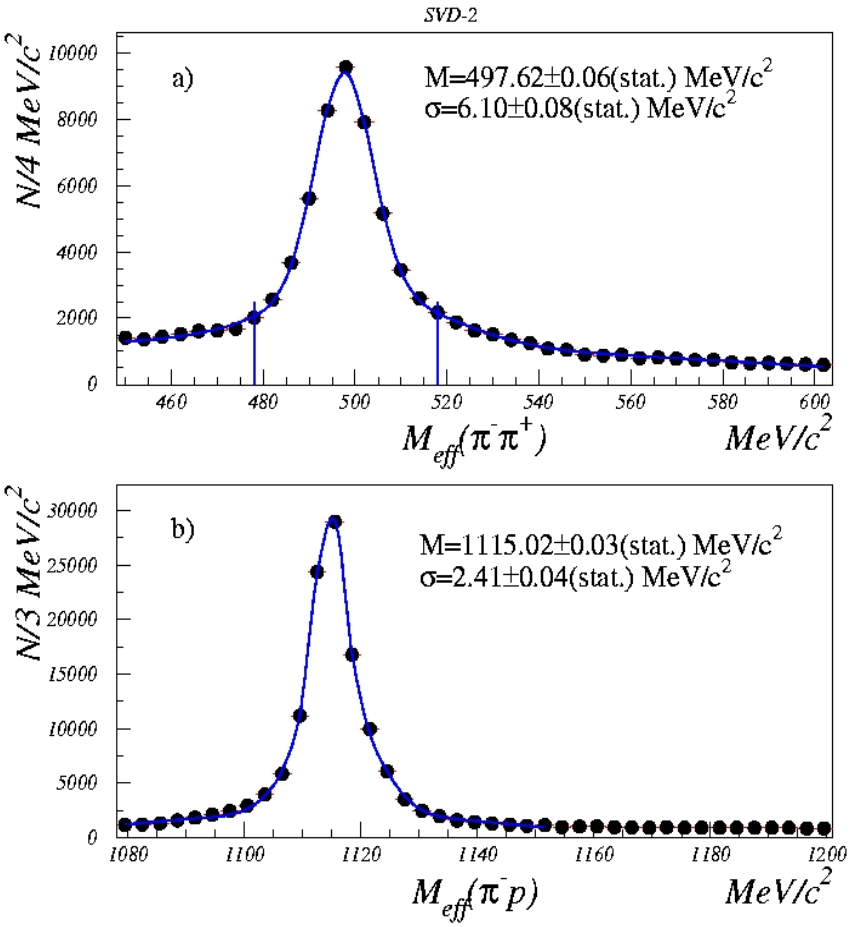
K^0 vertex reconstruction: distance of the closest approach < 3σ

Tracks have >=12 hits in spectrometer

50 signal events over 25 of background

Γ<14 MeV at 95% c.l.

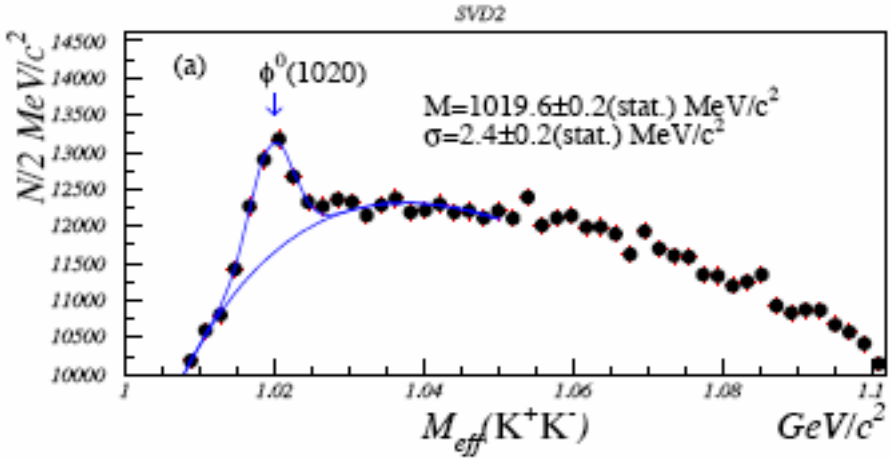
Analysis II: starting point

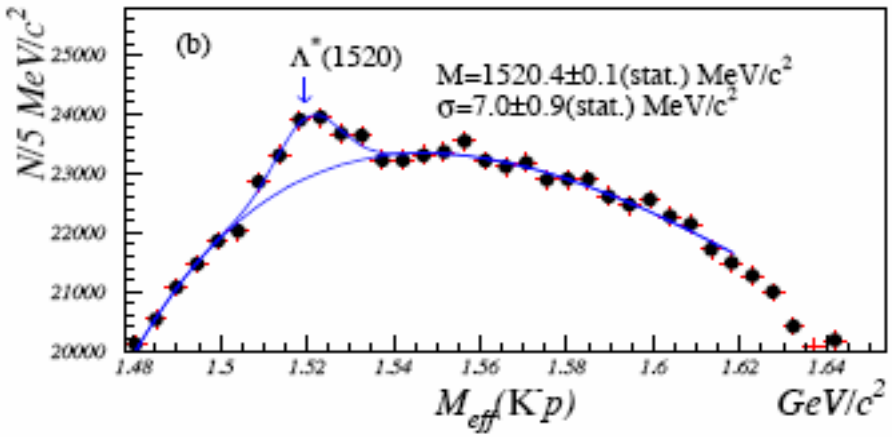


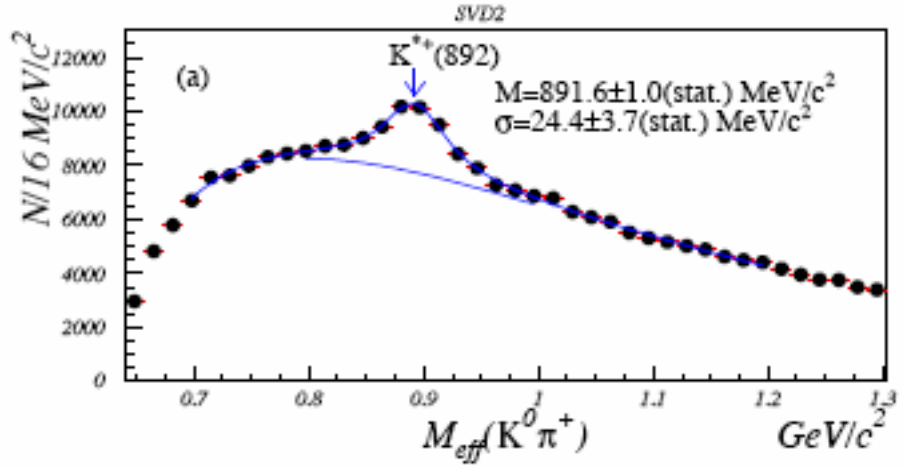
- Only spectrometer wire chamber information is used for the secondary tracks reconstruction
- Effective mass resolution:
  - K^0 6.1 MeV
  - Λ 2.4 MeV

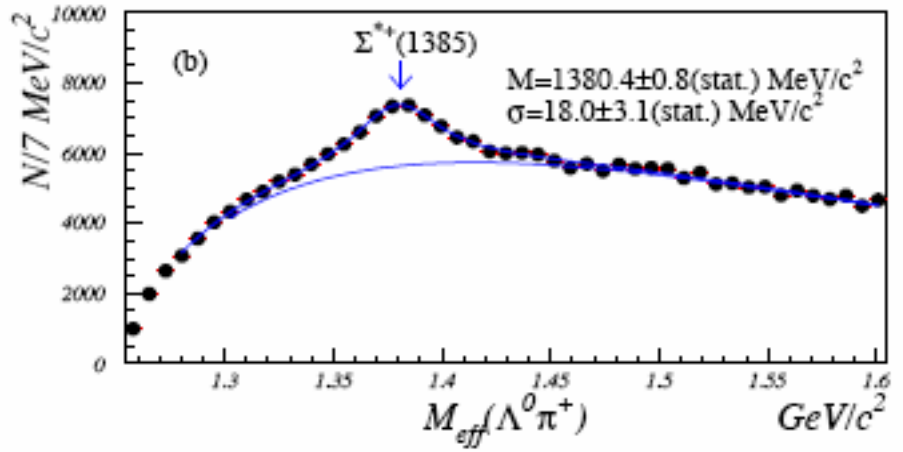
Well-established resonances

Data fit by Gauss + threshold background (Preliminary analysis)









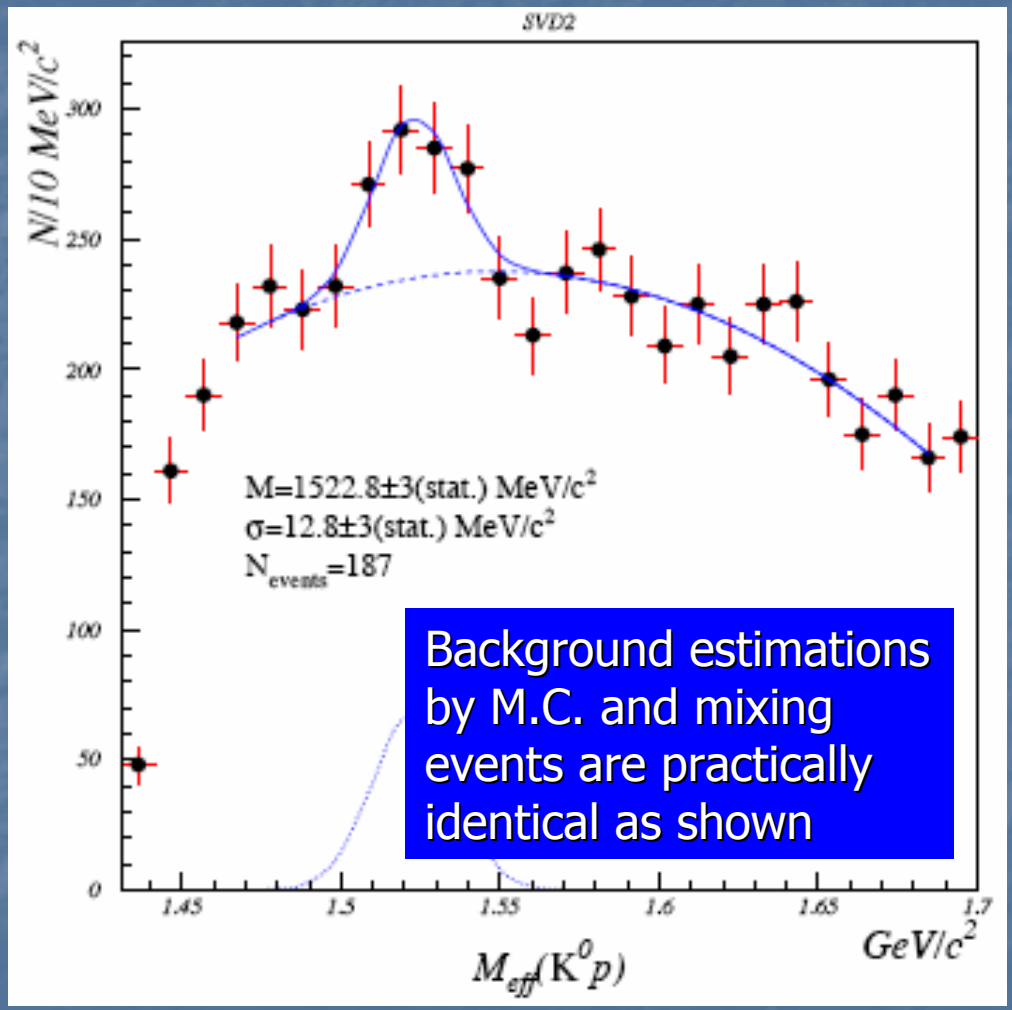
Well-established resonances

Particle	Decay mode	Exp. Mass	PDG mass	Exp. FWHM	PDG Γ	Res. estim.
$\phi^0(1020)$	K^+K^-	1019.6	1019.4	5.7	4.5	1.5
$\Lambda^*(1520)$	K^-p	1520.4	1519.5	16.5	15.6	2.3
$K^*(892)$	$K^0\pi^+$	891.6	891.7	58	51	12
$\Sigma^+(1385)$	$\Lambda^0\pi^+$	1380.4	1382.8	43	36	10

Analysis II: Events selection

- 6 or less primary charged tracks
- K^0 -- not Λ! Cutting off good Λ candidates
- Protons selected as:
  - a positive particle with 8 GeV < p < 15 GeV
  - number of hits >= 12 (in 18 chambers)
  - no Cerenkov hit (not a pion)

Analysis II: K^0p effective mass



187 events over the background of 940

Mass = 1522.8±3±3 MeV

σ_{peak} ~ 12 MeV

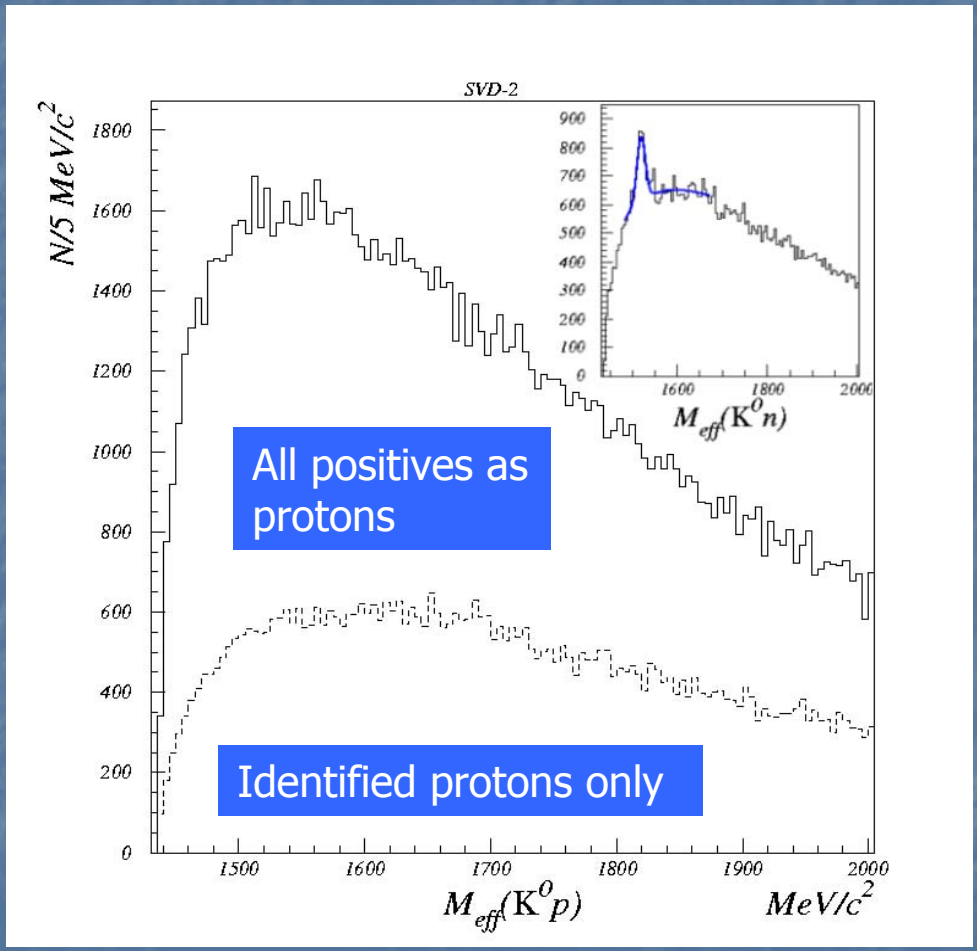
Peak significance:

$$\frac{S}{\sqrt{B}} = 6.1\sigma$$

$$\frac{S}{\sqrt{S+B}} = 5.6\sigma$$

$$\frac{S}{\sqrt{S+2B}} = 4.1\sigma$$

Monte-Carlo simulation



- *p-Si* interactions simulated in the RQMD model to include nuclear effects + GEANT 3.21
- The same analysis cuts
- No peaks in the pK^0_s spectrum
- nK^0_s spectrum shows $\Lambda(1520)$ signal

SVD-2 result

- The inclusive reaction $pA \to pK^0_s + X$ with a 70 GeV proton beam of IHEP accelerator are studied
- Two different statistically independent samples of candidates are analyzed
- A narrow peak with a mass M=1523 ±2(stat.) ±3(syst) *MeV/c²* is observed, with 392 of signal over 1990 of background events in two analyzes combined
- Statistical significance is

$$\frac{S}{\sqrt{B}} = 8.6\sigma \qquad \frac{S}{\sqrt{S+B}} = 8\sigma \qquad \frac{S}{\sqrt{S+2B}} = 5.9\sigma$$

- Preliminary cross-section estimation is $\sigma \cdot \mathrm{Br}(\Theta^+ \to pK^0) \sim 6$ μb (still needs detailed Monte Carlo study).

Work in progress!

Notes about SELEX Hyperon Experiment

600 GeV hyperon Beam at Fermilab: mostly Σ^- beam

1. Very good space and momentum resolution due to silicon strip detectors and wire chambers
2. Good particle ID: RICH counter
3. Study of charmed baryon and meson states
4. Observation some new states (double Charm, Ds(2640))
5. How about hunt for pentaquarks?

Note about SELEX Hyperon Experiment Θ+ search

Mode $\Theta^+ \rightarrow pK^0_s$ (K^0_s are detected) is used for search (no means to detect neutrons), however:

1. **Huge background from beam fragmentation:**

$\Sigma^- \rightarrow \overline{K}^0 (\overline{ds}) + X$ - it produce wrong strangeness for Θ^+ were K^0 ($d\overline{s}$) is a decay particle (still the same K0s are detected)

2. **Comparing with 70 GeV beam with 600 GeV beam multiplicity is higher by ~2, so combinatorics background is higher by ~4. It is already known that Θ^+ production cross section is not significantly rising with energy.**

So in spite great efforts to produce result SELEX collaboration can not give any meaningful answer about existence of the Θ^+.

Notes about SELEX Hyperon Experiment Θ^+ search vs SVD-2

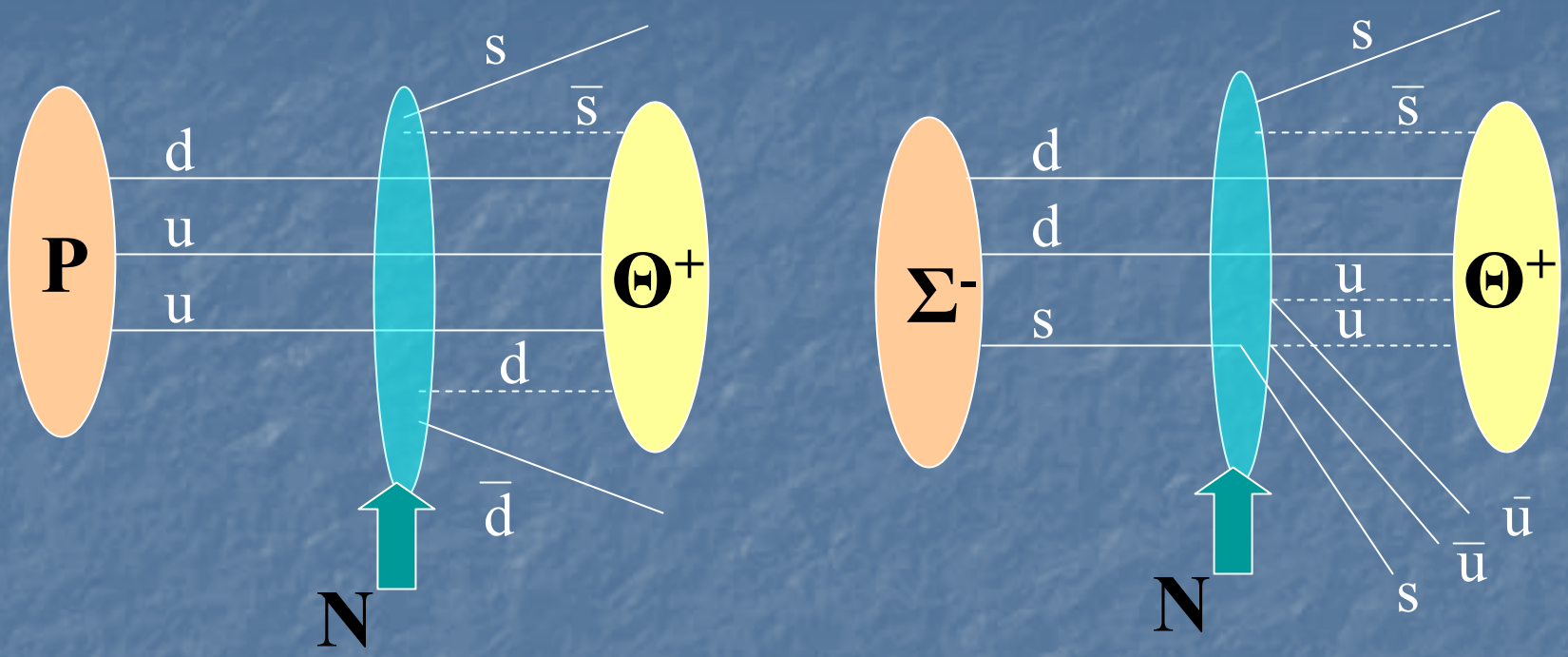
On the contrary, proton beam at 70 GeV has advantages:

- **no big background from $\bar{K}^0$ from beam fragmentation**
- **overall multiplicity is lower**
- **other backgrounds can be lower**
- **cross section in detector acceptance is higher**

Additional comparison with the hyperon beam:

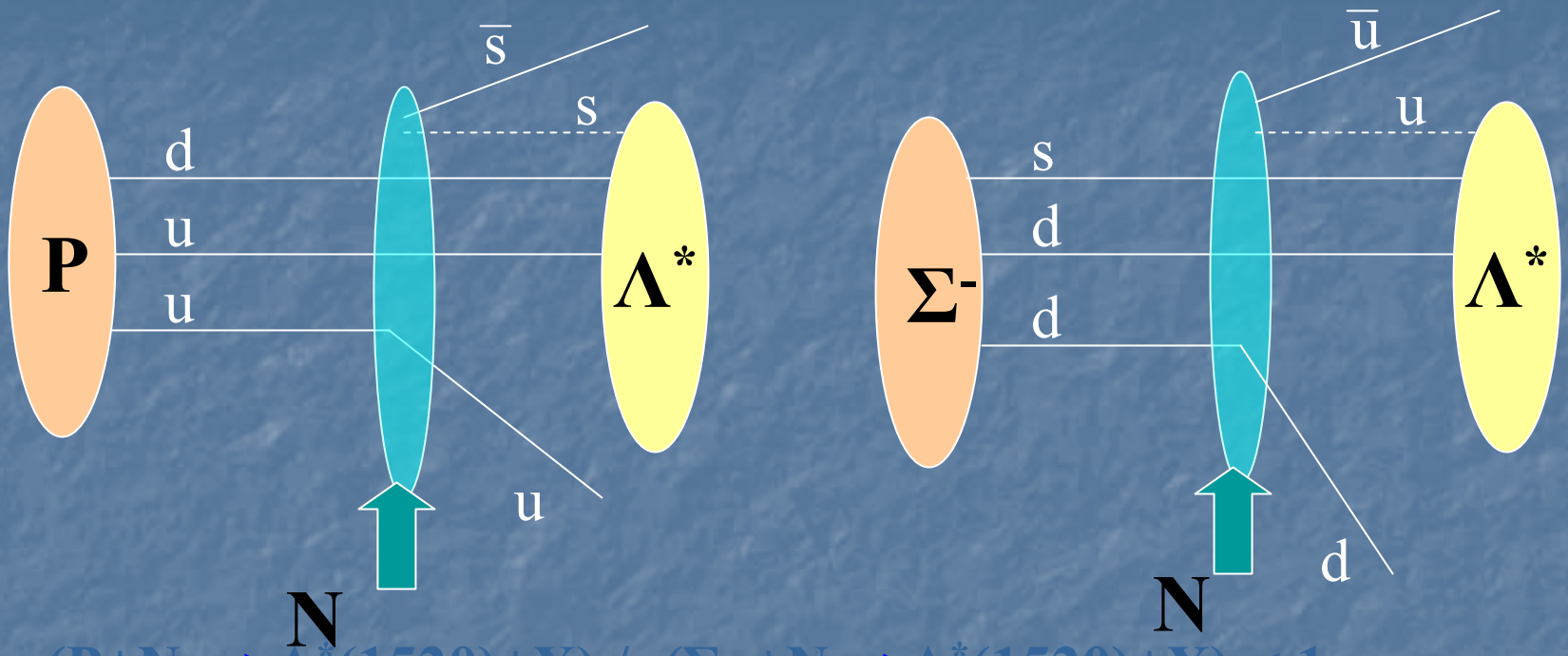
and the reference process of $\Lambda^*(1520)$ production

Pentaquark in fragmentation



$\sigma(P+N \rightarrow \Theta^+ + X) / \sigma(\Sigma^- + N \rightarrow \Theta^+ + X) > 1$

$\Lambda^*(1520)$ in fragmentation



$$\sigma(P+N \rightarrow \Lambda^*(1520)+X) / \sigma(\Sigma^- +N \rightarrow \Lambda^*(1520)+X) < 1$$

So,

$$\frac{\sigma(P+N \rightarrow \Theta^+ +X)}{\sigma(P+N \rightarrow \Lambda^*(1520)+X)} \Big/ \frac{\sigma(\Sigma^- +N \rightarrow \Theta^+ +X)}{\sigma(\Sigma^- +N \rightarrow \Lambda^*(1520)+X)} > 1$$

SVD-2 vs SPHYNX: a statement from Alex Kubarovski:

"About SPHINX: the basic SPHINX idea is to look for exotics in the deep fragmentation area X_f > 0.8.

I'm myself coauthor of some SPHINX papers: always quasi-exclusive reactions are investigated, where exotics may born (for example there is a claim for X(2000) pentaquark).

So I don't think it is possible to compare results - it is completely different experiments, though at the same energy."