

ANTI-NEUTRON MEASUREMENT WITH THE TOP SUBDETECTOR AT BELLE II

 INFNTo Belle II Meeting Tuesday 25th February 19:30 ACDT / 10:00 CET ,

Shanette De La Motte INFN Sezione di Torino

• shanette.delamotte@belle2.org

*Generated using "main" (last commit: Sat Nov 2 18:37:56 2024 +0100, globaltag: main_2024-07-19), Default run-independent phase III conditions (i.e. expNum is 0)

DESIGN OF MC STUDY

- Studying simulated **TOP response to 100 000 MC events** generated (via Particle Gun/EvtGen packages)
 - \bar{n}^0 begin at origin and travelling radially outwards with |p|=1 GeV, $\theta=92$ and uniformly distributed $\phi \in [-\pi, \pi]$
 - Also place μ^+ at origin with same dynamics (i.e. also $\theta=92$ with random ϕ), to "tag" the event start time for the TOP.
- Use `*TOPRingPlotter*` module to save MC TOP digits attributed to "tagging" muon, as well as other event info.
 - *Then* use new `*dumpOtherSlots*` option with `*TOPRingPlotter*` to access **all TOP signal** **not** **associated with the tagging muon i.e. from the annihilation**
 - Useful as charged productions produced in \overline{n}^{0} event might not reach tracking detectors!

Statistics

100 000 events generated

42 257 events contain a TOP signal *not* associated with tagging muon (i.e. from \bar{n} annihilation)

38 628 of \bar{n} annihilations occur "just before" TOP, in TOP, or in ECL (i.e. between 110cm and 162cm)

Proportion of annihilation events with TOP signal and in region of interest ≈ 38.6%

`dumpOtherSlots` now merged to `*main*` as of 12/02/25 at commit `*cf9de52*` ! * tagged in light-2501-betelgeuse!



Transverse distance: nbar slot 118cm - 125cm from origin adjacent slot (after, slot-1) **NO. OF TOP DIGITS PER** adjacent slot (after.slot+1) 500 tagging mu **7** 638 / 100 000 of \overline{n}^0 with p = |1| GeV with $\theta = 92$ annihilate EVENT, ACCORDING TO in TOP (~7.7%) WHERE \bar{n}^0 ANNIHILATION 5 981 of them leave signal in same TOP module as the annihilation TAKES PLACE 30 40 50 60 70 Before TOP FCI Transverse distance: nbar slot Transverse distance: nbar slot adjacent slot (after.s 125cm - 162cm from origin adjacent slot (after,slot-1) adjacent slot (after,s 110cm – 118cm from origin adjacent slot (after.slot+1) tagging mu **54** 146 / 100 000 of \overline{n}^0 with p = |1| GeV with $\theta = 92$ annihilate **876** / 100 000 of \bar{n}^0 with p = |1| GeV with $\theta = 92$ Events annihilate in "before TOP" region ($\sim 1.9\%$) in ECL (~54.1%) 22 0003 of them leave signal same TOP **449** of them leave signal in TOP module parallel to \bar{n}^0 module the \bar{n}^0 travels through trajectory 20 -20 60 40 50 30 40 60

TOP DIGITS, WHEN \bar{n}^0 **ANNIHILATION OCCURS IN TOP, [118,125)CM**

200

100

0

-100

-200

-200

-100

0





Jacarandas in bloom outside my office! Adelaide, October, 2024

TO DO

- In the process of generating 100,000 events, where θ ∈ {47,92,137} (equal probabilities).
- Write code to perform Gaussian fit of primary peak in digitTime.
 - Determine if there's a correlation with $\bar{n}^0 \theta$ (and *p* in the future!)
- Arrive in Milan on 15/03!



Cheers! Ciao!

shanette.delamotte@belle2.org

(Back-up slides following)

OUR GOAL: Determine a method of measuring the properties of anti-neutrons (\overline{n}^0 or "n-bar"), via the timing signatures of their annihilation in detector volumes.



 \mathbf{Z}

- Our case-study: the **TOP sub-detector** of the Belle II experiment.
- Anti-neutron identification differs from standard neutrons, in that they can be **identified via annihilation** events within detector volumes.
- IF anti-neutron annihilation induces an electromagnetic shower in the ECL, the full \bar{n}^0 energy can be measured.
- IF anti-neutron annihilation instead induces a hadronic shower where charged products escape the ECL, measurements can be incomplete.
- Can improve \bar{n}^0 measurement by studying cases where annihilation products back-scatter into the Time-of-Propagation (TOP) subdetector, a timing-based Cherenkov radiation detector.
- Additionally, can look at cases where anti-neutron annihilation occurs slightly before or within the TOP, where products can be detected before further measurement when entering the ECL.

WHERE ARE ANTI-NEUTRONS ANNIHILATING?





nbar mcDecayVertexZ









LOOKING AT TOP SIGNAL DUE TO ANTI-NEUTRON ANNIHILATION

38 628 annihilations leave TOP signal and occur between 110cm and 162cm **29 433** of them have signal in a TOP module with the same phi as the anti-neutron decayVertexPhi





HOW MANY HITS IN EACH TOP MODULE, PER EVENT, ACCORDING TO *n ANNIHILATION TRANSVERSE RADIUS*



ANNIHILATION NEAR TOP MATERIALS



WHERE ARE ANTI-NEUTRONS ANNIHILATING?





TOP SIGNAL, ACCORDING TO WHERE ANNIHILATION TAKES PLACE



- 38 628/1e6 annihilations leave TOP signal and occur between 110cm and 162cm
- 29 433 of them have signal in a TOP module with the same phi as the anti-neutron decayVertexPhi

HOW MANY HITS IN EACH TOP MODULE, PER EVENT, ACCORDING TO \bar{n} ANNIHILATION TRANSVERSE RADIUS





TOP DIGITS, WHEN \bar{n}^0 **ANNIHILATION OCCURS IN ECL, [125,162)CM**





Slot "before" \bar{n}^0

Slot "after" \bar{n}^0