Hit-matching in the IST

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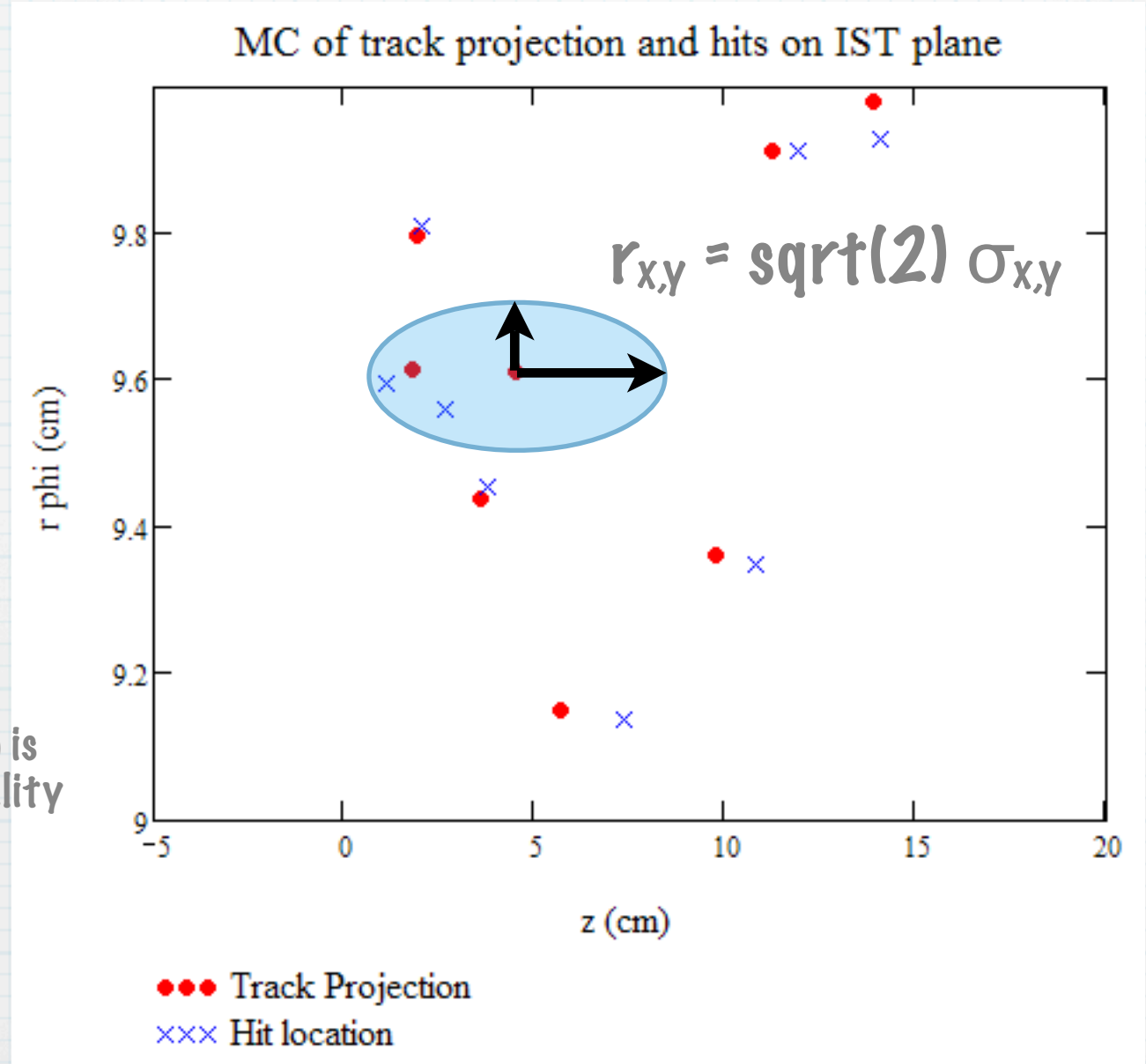
Probability math

- Correct hit-matching:
  P_c = Signal / (Signal + Bgnd)
  - For 1 hit, P_c = 1 / N_{hits} = 1 / (1 + Bgnd)
- N_{hits} = number of hits within an "effective area"
  $A_\sigma = 2\pi\sigma_x\sigma_y$ (Howard did the complete math)
  sigmas are quadratic sum of track projection error and hit position error
  Bgnd = $A_\sigma\rho = 2\pi\sigma_x\sigma_y\rho$ (hit density ~ occupancy)
  P_c = 1 / N_{hits} = 1 / (1 + $A_\sigma\rho$) = 1 / (1 + $2\pi\sigma_x\sigma_y\rho$)

$$N_{hits} = \frac{\sum_{n=1}^{100} n^2 P(n, A_\sigma\rho)}{\sum_{n=1}^{100} nP(n, A_\sigma\rho)} = \frac{\langle n^2 \rangle_{n>0}}{\langle n \rangle_{n>0}} = \frac{\langle n^2 \rangle}{\langle n \rangle} = \frac{(A_\sigma\rho)^2 + A_\sigma\rho}{A_\sigma\rho} = A_\sigma\rho + 1$$

Effective areas

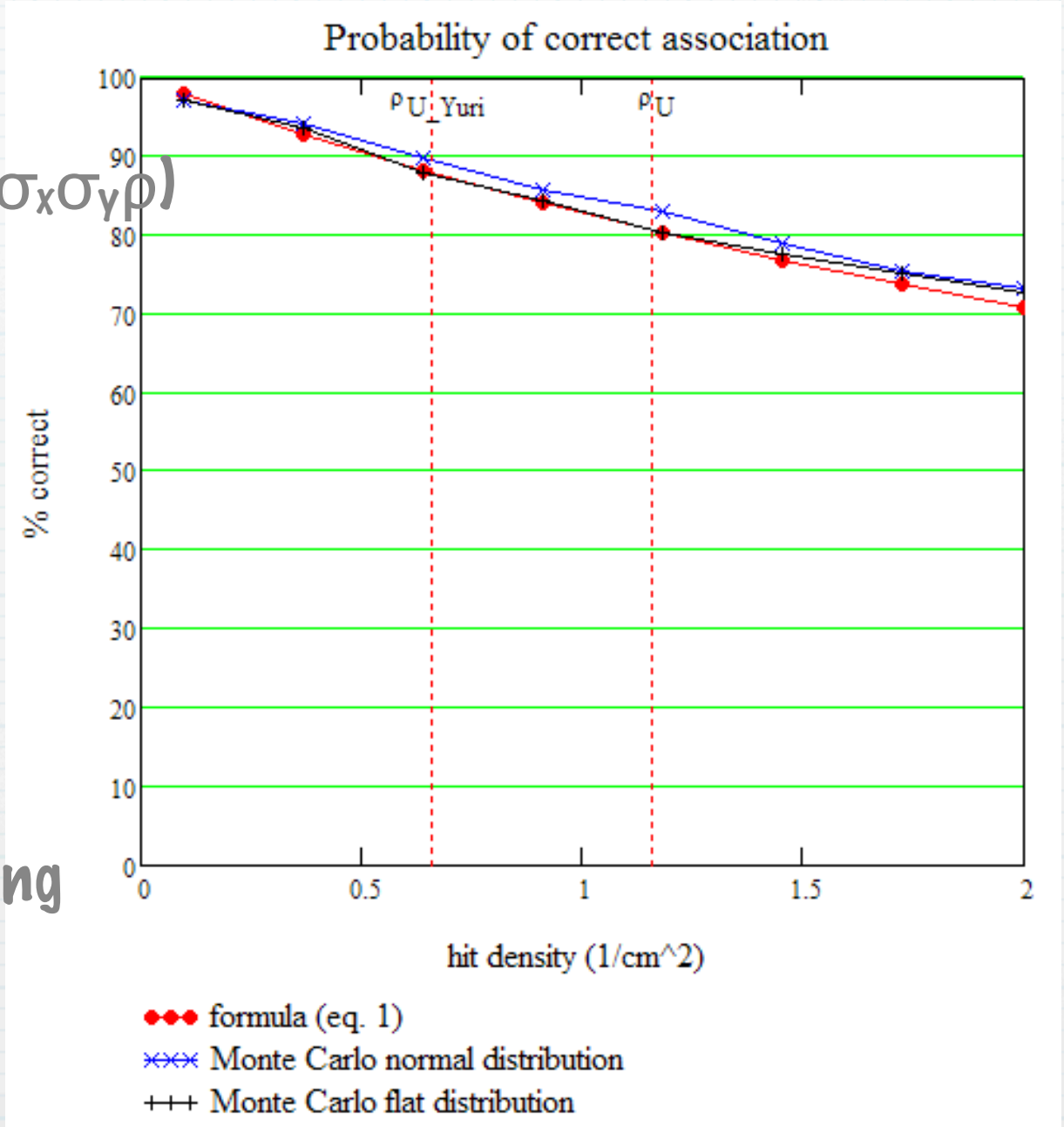


(x , y) in math is
(r phi , z) in reality

(arbitrary ellipse drawn to suit demonstration)

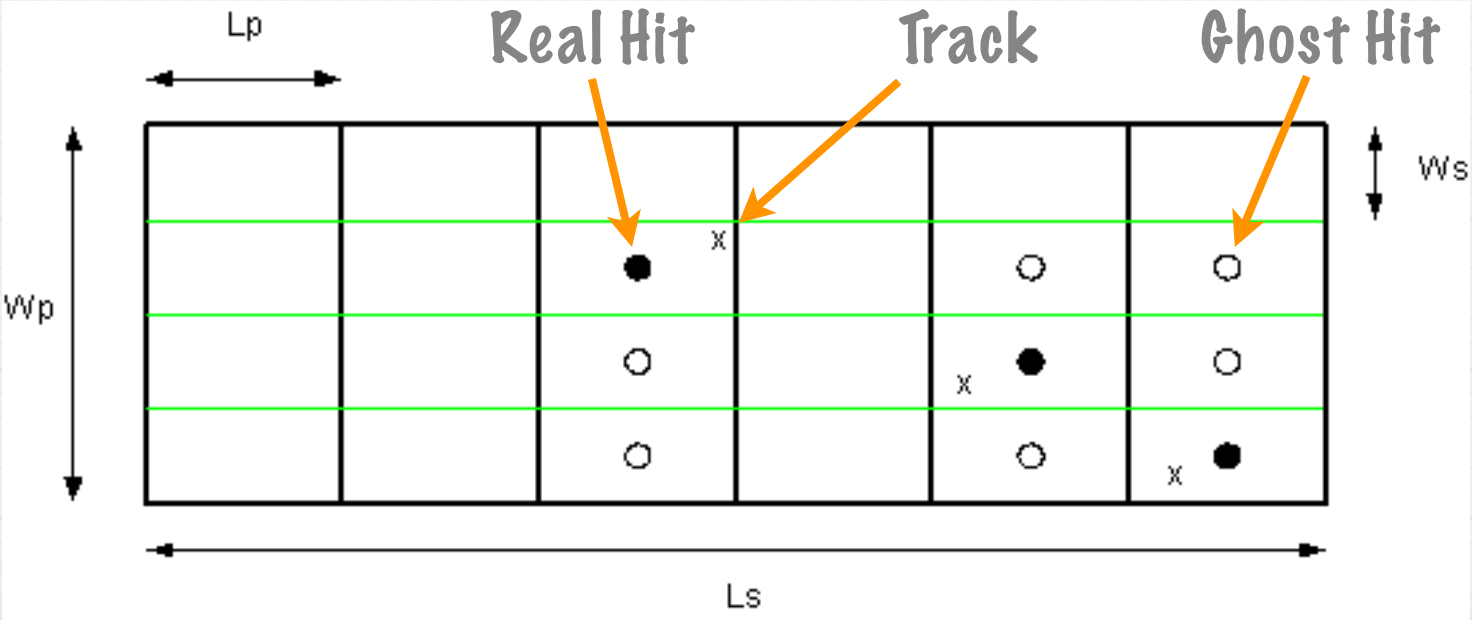
Simple layouts (strips)

- $P_c = 1 / (1 + 2\pi\sigma_x\sigma_y\rho)$
- Howard's MC confirms performance
- All plots have assumed tracking $\sigma_{x,y}$ = 0.3mm



Strips + Pads

- Complications from ghost hits in units (unit = area of 1 strip length * 1 pad width)
  - n tracks in unit produce as much as n^2 hits
  - n tracks in unit produce ~n hits in each pad



Strips + Pads

- Ideal math for ∈:
  - Find track-weighted expectation value of P_c^n
    $P_c^n = 1/N_{hits}$ $P_c = \langle n * P_c^n \rangle / \langle n \rangle$

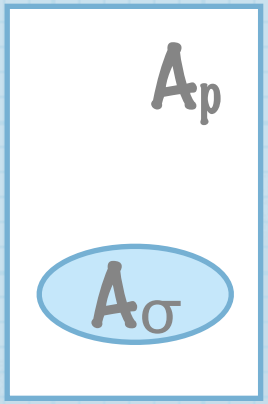
(arbitrary ellipse drawn to suit demonstration)

- Poisson: $P_c = \frac{1}{A_\sigma \rho + 1}$ (n-1) bgnd hits in A_p
- Binomial:

$$N_{hits} = B + 1 = \langle N \rangle + 1 = (n-1)p + 1 = (n-1)\frac{A_\sigma}{A_p} + 1$$

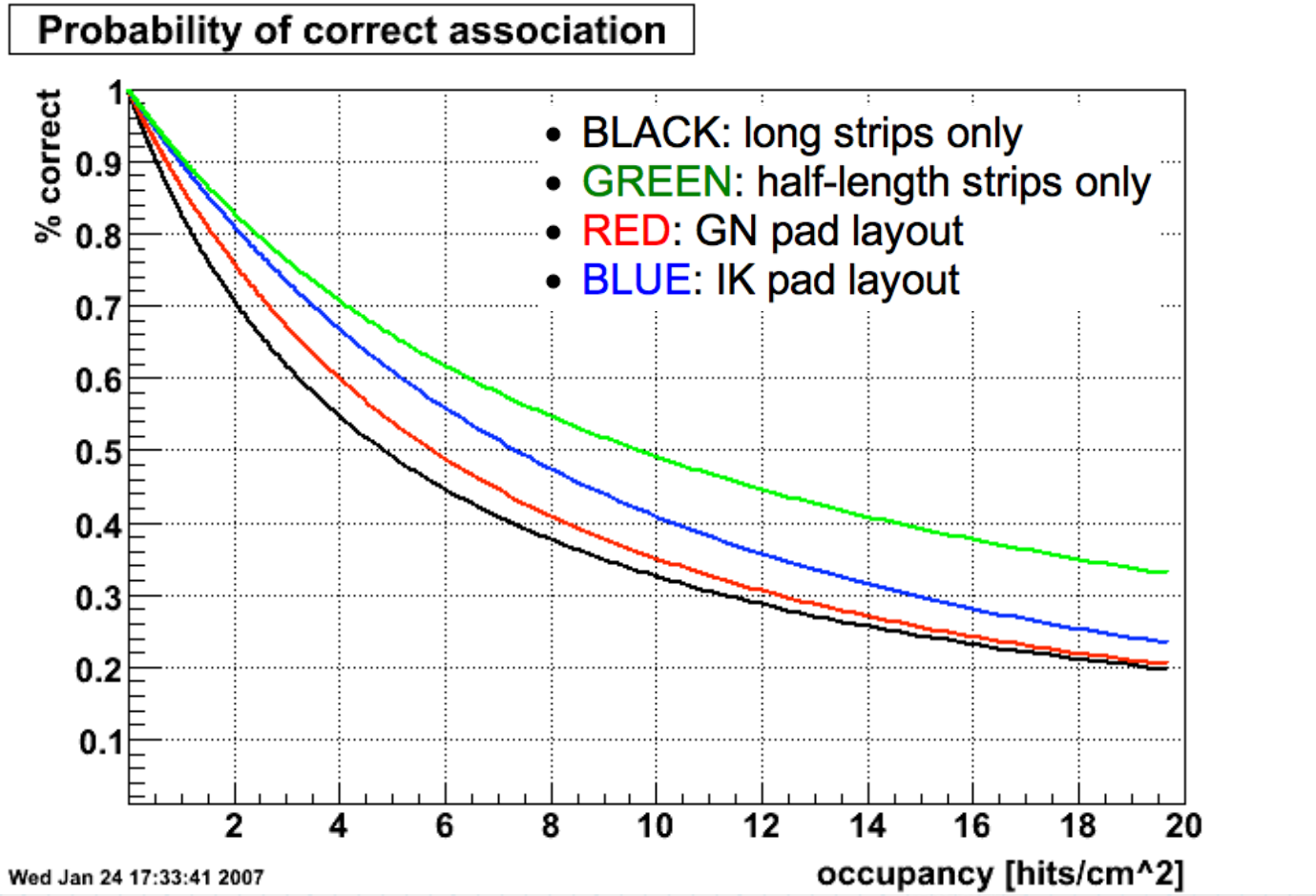
$$P_c^n = \frac{1}{A_\sigma \frac{n-1}{A_p} + 1}$$

$$P_c = \frac{\sum_{n=1}^{100} n \frac{P(n, A_u\rho)}{A_\sigma \frac{n-1}{A_p}+1}}{\sum_{n=1}^{100} nP(n, A_u\rho)} = \frac{\sum_{n=1}^{100} n \frac{P(n, A_u\rho)}{A_\sigma \frac{n-1}{A_p}+1}}{A_u\rho}$$



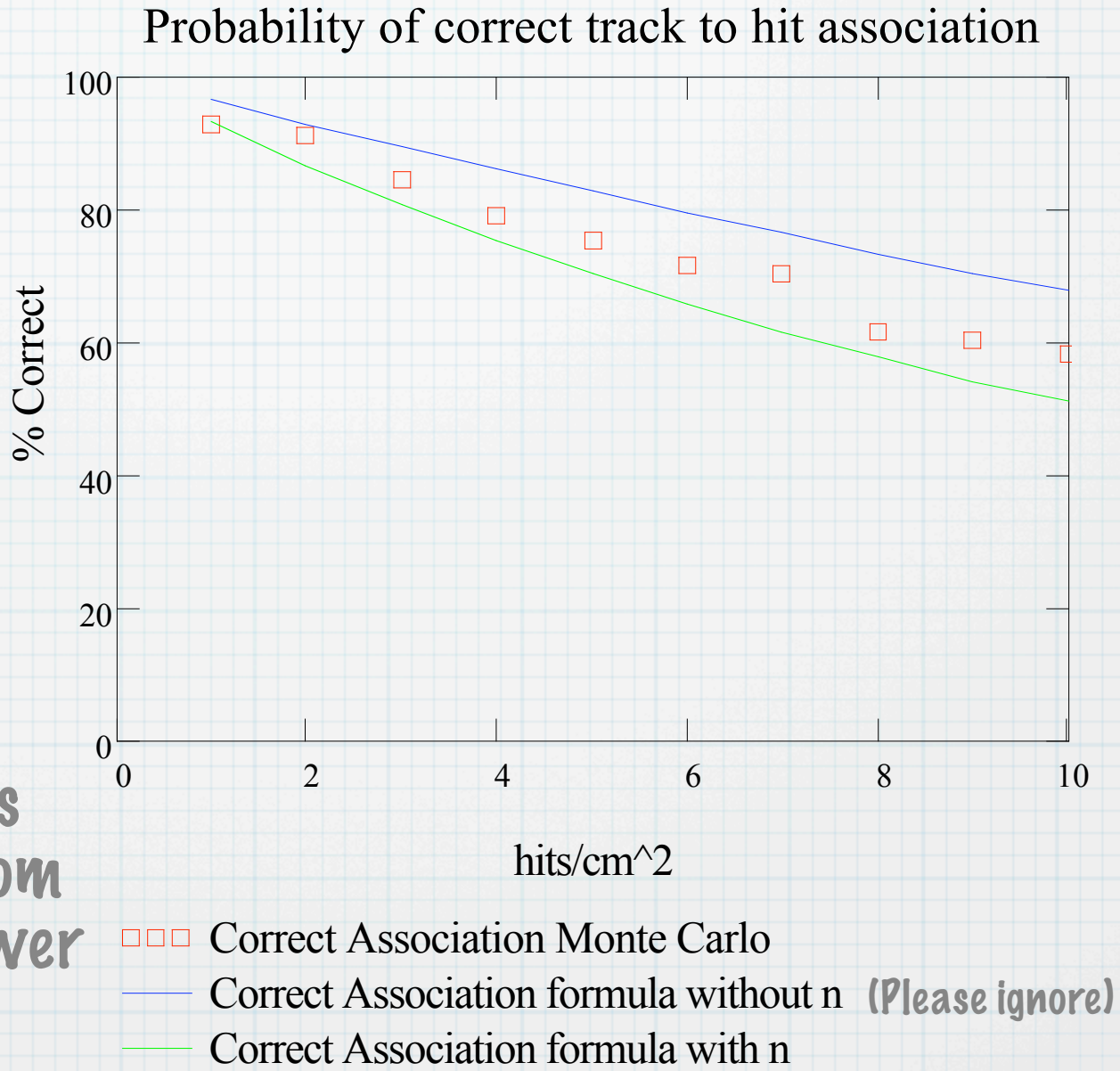
Pad performance

* Long strips: 38.4 x 0.06 [all sizes mm]
* Half length: 19.2 x 0.06
* GN pads: 1.9 x 1.2
* IK pads: 3.8 x 0.6



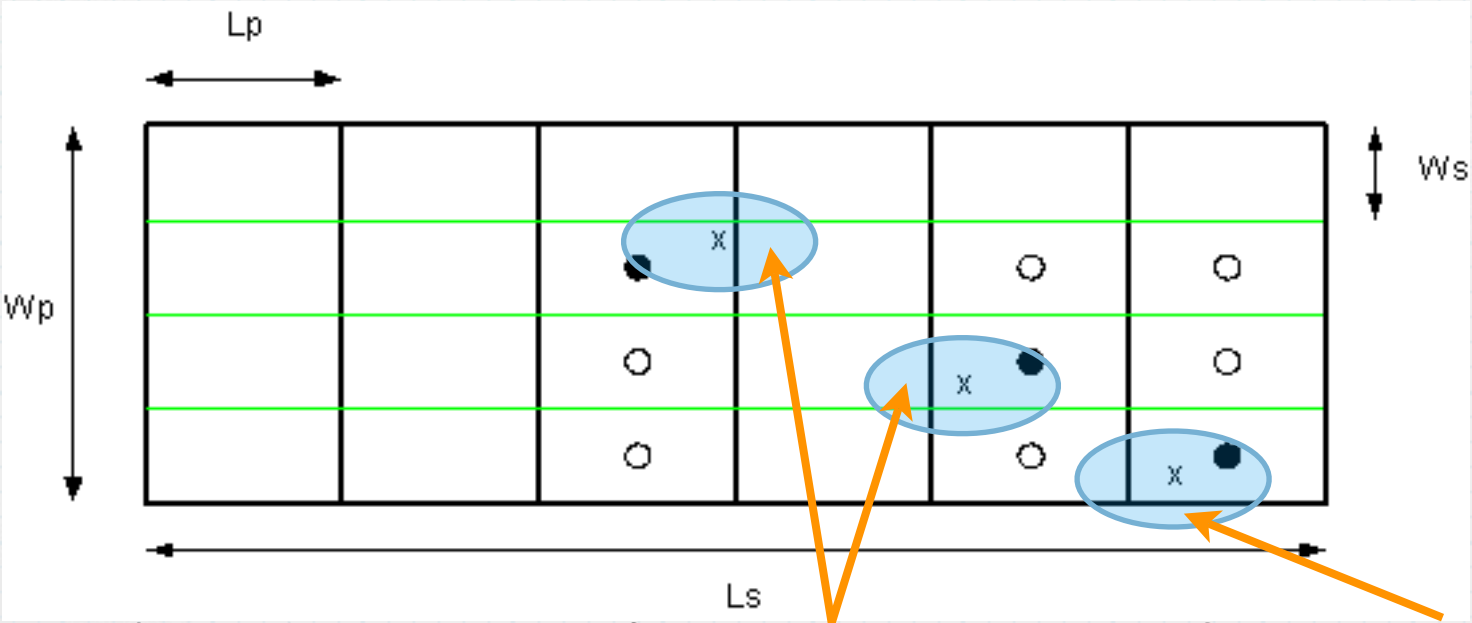
Pad performance

- HW pads: 7.6 x 0.3
- MC exceeds calculations
- Formula is invalid because A_σ extends beyond the unit!
- But neighboring units don't have the hit from the track, so N_{hits} lower there, increasing P_c



Edge effects

- Edge effects at unit boundaries (and even at pad boundaries) benefit the probabilities
  - Effective areas cover regions of (probabilistically) lesser/no backgrounds
  - The math is tough! Leave it to the MC!



(arbitrary ellipses drawn to suit demonstration)

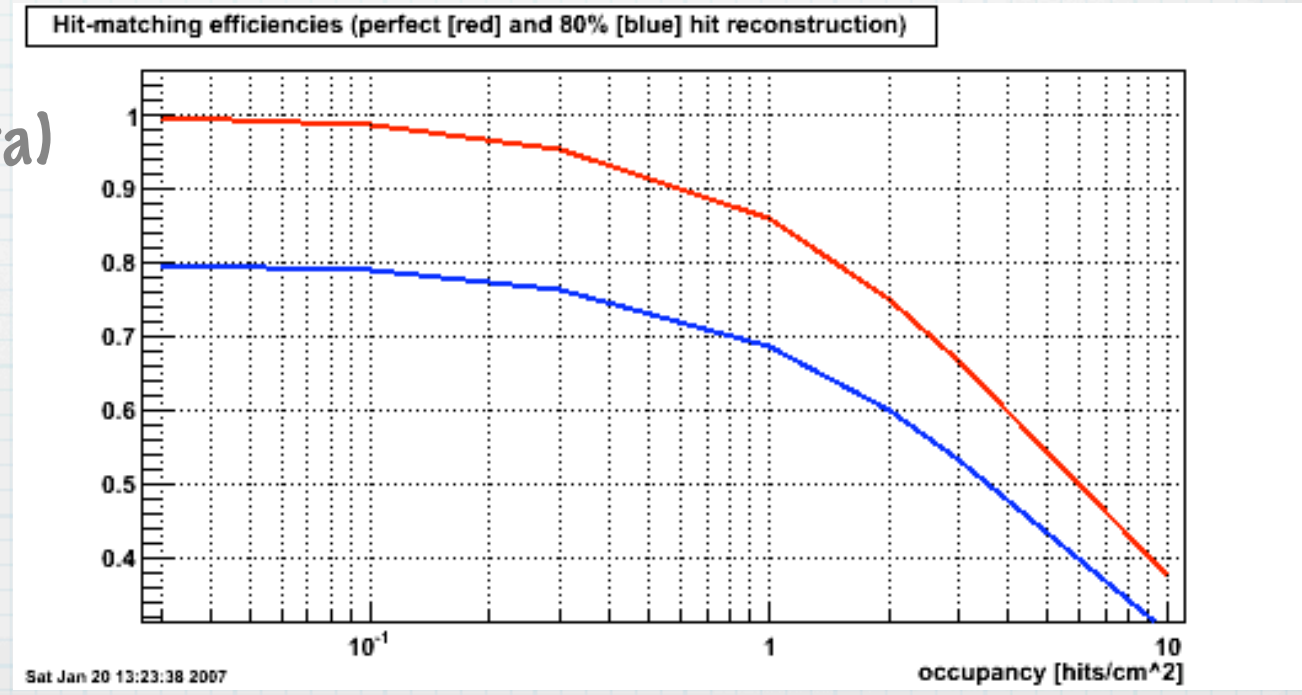
Examples: No backgrounds Lesser backgrounds

Review I

- Caveat: formulas don't include discreteness of reconstructed hit locations
  - Beneficial ONLY if hits can be re-used
    (wrong hit as good as right hit)
- Formulas valid for strips, pretty good for GN pads
  - GN pads likely not as good as half-length strips
- MC shows that narrower pads do even better
  - HW pads likely even exceed half-length strips
  - There's a maximum somewhere because:
    $\lim_{\text{pads}\to\text{strips}} P_c = P_c^{(\text{strips alone})}$
- Don't forget: worse tracking errors have a negative impact!

The real world: hit reco

* Hit reconstruction (in)efficiency ($\epsilon < 1$)
  * Bgnd is purely event tracks: no change
    $P_c = \epsilon / N_{hits} = \epsilon / (\epsilon + \epsilon\,Bgnd) = 1 / (1 + Bgnd)$
  * Bgnd is unknown: worsens
    $P_c = \epsilon / N_{hits} = \epsilon / (\epsilon + Bgnd) = 1 / (1 + (Bgnd/\epsilon))$
* SVT: $\epsilon = 0.7$
  (to match Yuri's real data)
* IST: perhaps
  ϵ -= 0.05 / year
  (Ivan's estimate,
  remember the x40
  integrated luminosity)

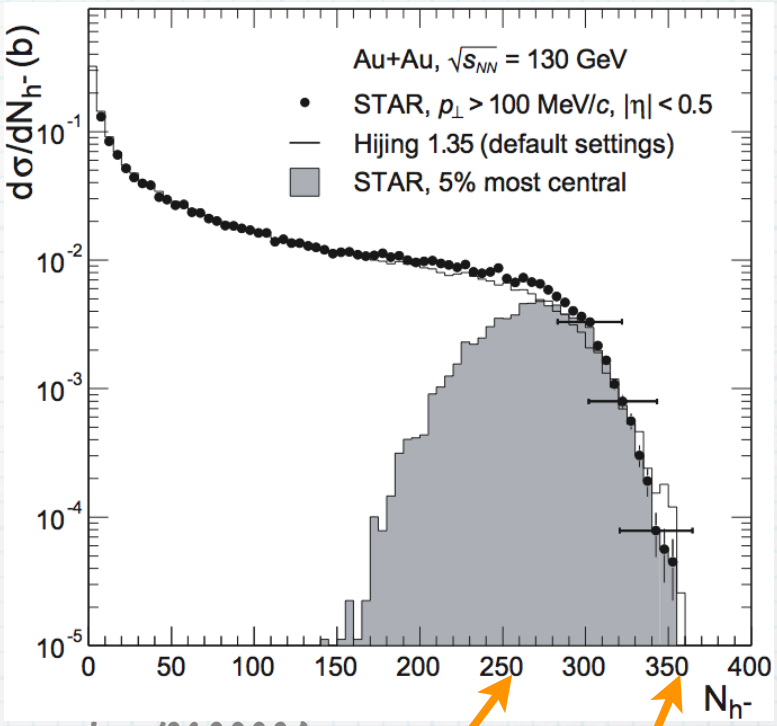


The real world: occupancy

- Must handle the maximum possible occupancy
  - 0-10% Central U+U estimated at 1.2 hits/cm^2 for IST1
    - Not the real maximum (see AuAu130 data shown here)
    - Odd geometry, who really knows what the "right" collision can produce?
- Beam-gas, collider backgrounds
- Detector noise (aging)

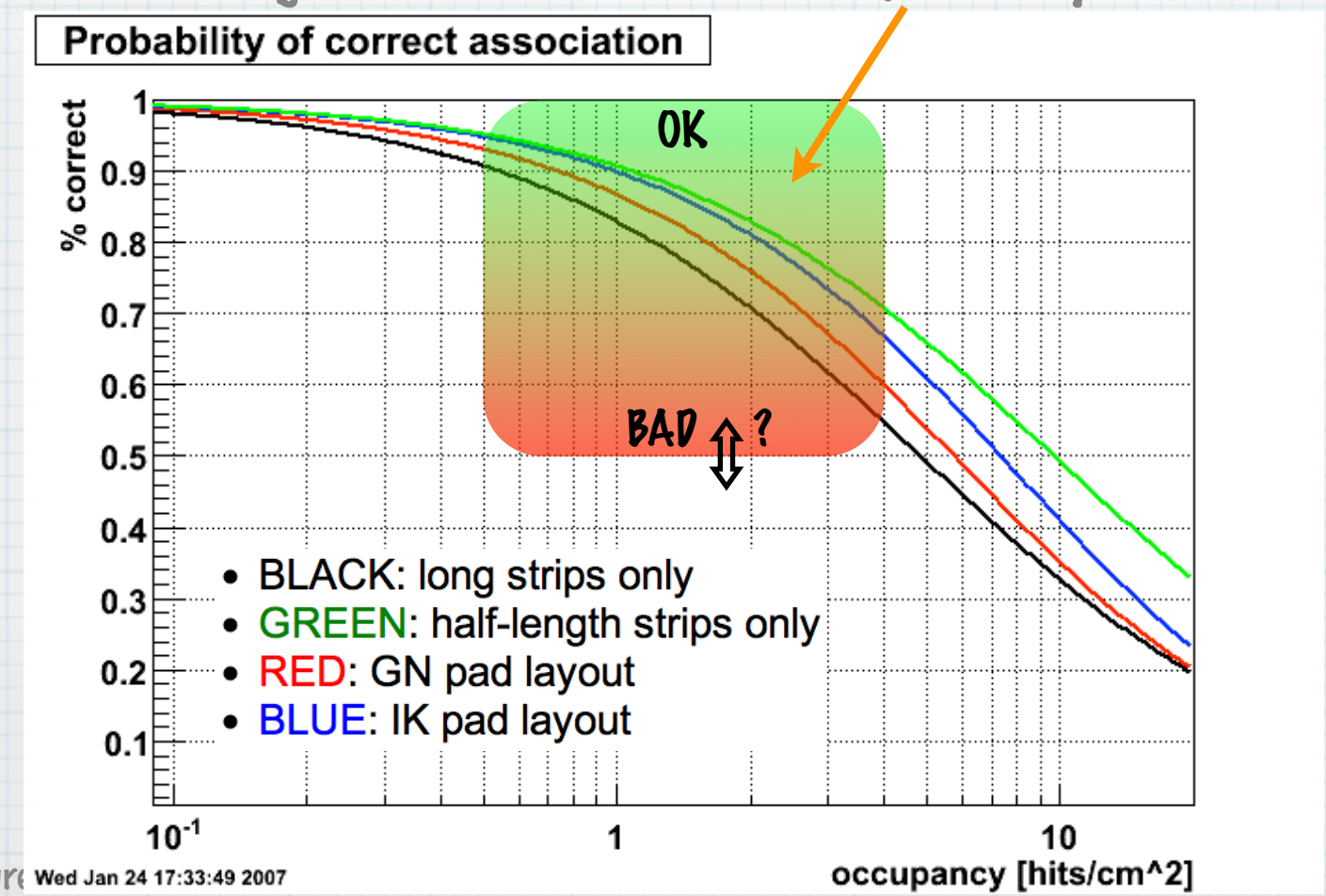
There better be a margin!

Not a factor of 10, but at least 2 or 3



On the knee

* We won't have a margin of x10 for IST1
* What is the minimal acceptable P_c? (D^0 goes as P_c^2)
* Best configurations perhaps at about the minimal margin for a reasonable P_c on day 1



(same as earlier plot, but with log scale for occupancies)

Review II

- Our best P_c configurations are half-length strips or narrow pads from the hand-calculations and MC.
- Real world P_c performance degradation:
  - Inefficiency for reconstructing hits from tracks...
  - ...Combined with other (background) sources of hits
    - Expect aging to contribute.
  - As goes larger track projection errors, so goes worse P_c.
    - You have a stake in tracking performance!
- Unknown occupancies leave us with perhaps the minimum margins at turn on for IST1.
- 5% P_c drop/year would remove margins within a few years.
  (consequence: best to run U+U early in IST life; jives with current BUR for 2010)